Selection and Use of Strategic Air Bases

A. J. Wohlstetter, F. S. Hoffman, R. J. Lutz, and H. S. Rowen

April 1954

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Guam?

(Second Printing June 1962)

A REPORT PREPARED FOR

UNITED STATES AIR FORCE PROJECT RAND

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gives delivery paths + role of Guam SAC in early 50s. ↑ 1955. new B52s. earlier B47s in J→ Korea War.

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Aside from these debts to individuals, the strategic-air-base study owes a great deal to the work of several other RAND systems analyses that had either been made or were being made concurrently with it. In particular, many components of the Missiles–Aircraft Study (R-248) and the two Air Defense Studies (R-227 and R-250) were useful.

ALBERT WOHLSTETTER

SUMMARY

OBJECTIVES

This study of strategic air base systems has two main objectives. First, it is an analysis of how to look at bases—an examination of the critical factors in strategic-base selection. Second, it is an application of this analysis to the basing of the 1956–1961 bombing force.

METHOD OF THE STUDY

The principal factors considered are the distances from bases to targets, to favorable entry points into enemy defenses, to the source of base supply, and to the points from which the enemy can attack these bases (see Fig. 1). The analysis is concerned with the joint effects of these respective factors on the costs of extending bomber radius; on how the enemy may deploy his defenses, and the numbers of our bombers lost to enemy fighters; on logistics costs; and on base vulnerability and our probable loss of bombers on the ground.

Several different air-base systems for the 1956–1961 strategic force have been compared to find the system of bases likely to give maximum striking power. Early in the work on this study, it was decided to take the *then* programmed system for 1956 as a starting point. This system has since been undergoing a

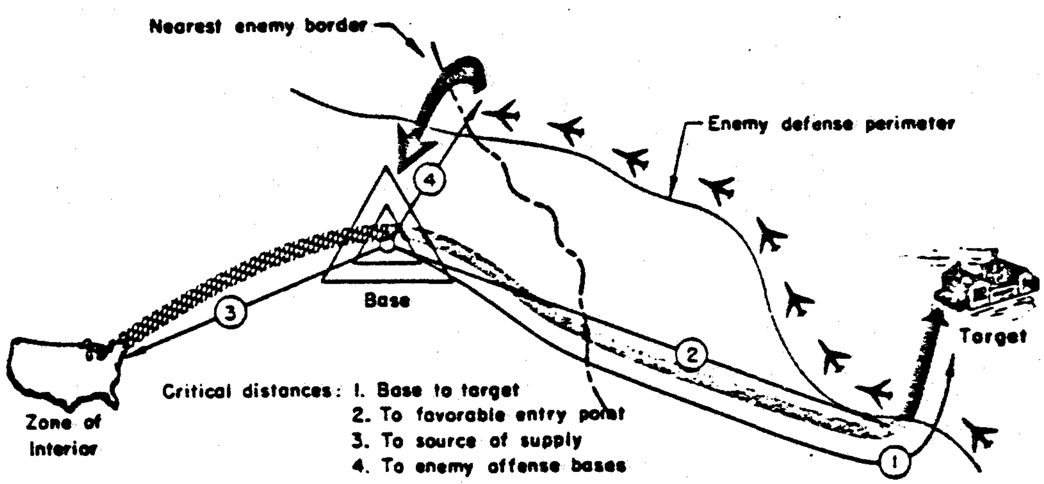

Fig. 1—Critical base relationships

process of modification as a result of the growing stockpile of SU nuclear weapons. Although no drastic changes are evident in force composition, important revisions in the method of basing and employment of the force have been indicated. Because of the changes, the system which serves as a point of departure for this study is no longer identical with the one currently planned for use by the Strategic Air Command (SAC) and will be called the formerly programmed system. The other systems compared fall into four broad groups: (1) bombers based on advanced overseas operating bases in time of war, (2) bombers based on intermediate overseas operating bases in wartime, (3) U.S.-based bombers operating intercontinentally with the aid of air-refueling, and (4) U.S.-based bombers operating intercontinentally with the help of ground-refueling at overseas staging areas (see Fig. 2). Several points should be observed. First, all the 1956–1961 systems analyzed, not just the exclusively air-refueled intercontinental case, involve tankers as a regular part of their operation as well as in contingencies. (In all the cases treated in this summary, the tankers are based in the same location as the bombers. Other variants were studied and are dealt with in the body of the report.) Second, all the systems, not just the intercontinental ones, involve Zone of the Interior (ZI) bases in time of peace. Third, all these systems are mixtures involving many elements. The first system, the advanced overseas operating base case, resembles the main method formerly programmed for operating the medium bombers. The fourth system, the intercontinental ground-refueling case, resembles the method formerly planned for the heavies (and now programmed for a larger part of the strategic force). The formerly programmed system, then, involved elements of most of these types: tankers, staging areas, and operating bases in both the United States and overseas. Increasing Russian capability compels examination of the methods and elements used jointly in the former program in order to detect the vulnerable components and to extend the most effective.* The various systems are therefore evaluated in the context of a two-sided atomic war in which the enemy attacks SAC while it is performing its mission.

THE PREFERRED SYSTEM

It appears, on the basis of this analysis, that systems consisting of U.S. operating bases and overseas refueling bases are markedly superior.

* See *Hearings*, Subcommittee of the U.S. House Committee on Appropriations, *Dept. of the Air Force Appropriations for 1955*, 83d Cong., 2d sess., Washington, D.C., February 11, 1954, p. 77.

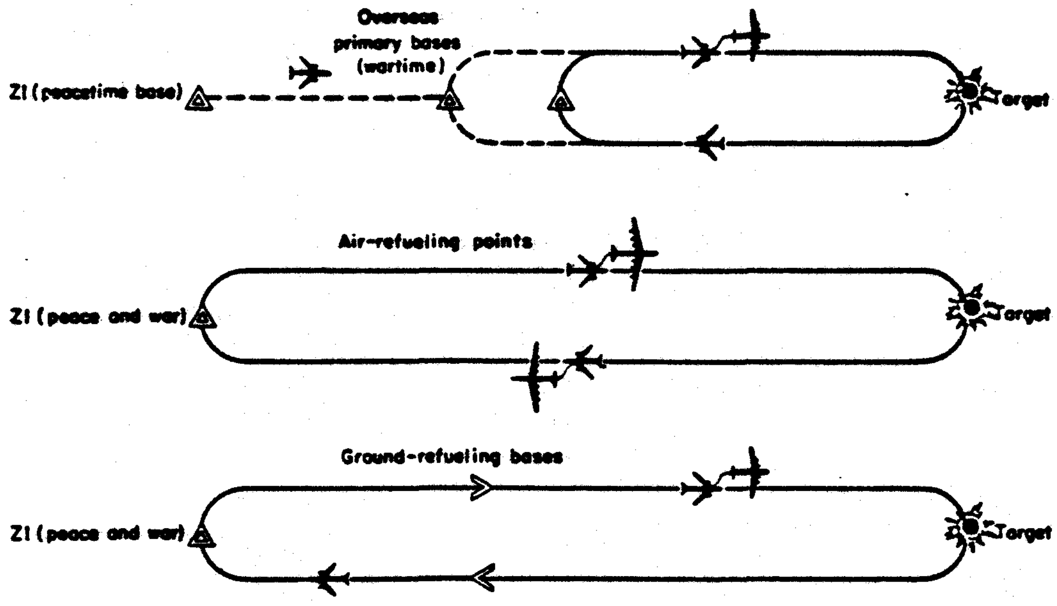

Fig. 2—Types of base systems

In brief, overseas operating base systems are too vulnerable, whereas a U.S.-based air-refueled system would buy lower base vulnerability at so high a cost that total striking power would be drastically reduced. Ground-refueled systems can be designed so that bombers will be present on refueling bases only a small fraction of the time, and the ground-refueled system will be much less vulnerable to enemy attack than systems which rely on overseas operating bases. Such refueling bases can be provided in adequate numbers with only moderate extension and modification of our presently planned overseas base complex. Our strategic force in the United States can be protected primarily by evacuation of bombers, crews, and other essential mobile elements. (This requires, however, both reduction of the evacuation time needed and expansion of the time supplied by early warning radar. As was mentioned, all the systems compared have a ZI peacetime base component and need such an intensification of the evacuation program.) The preferred system has the greatest destruction potential of the systems compared. It is also the most flexible as to the size and rate of strike, proportion of targets attacked, and route of approach and flight profile.

The multiplicity of strategic objectives and the variety of contingencies in which our bombers may operate require, for flexibility and efficiency, a variety of bases, policies of base employment, and methods of extending radius. Some of the alternative objectives and contingencies are indicated briefly in this summary. However, for reasons indicated in what follows, future strategic base systems combining U.S. operating and overseas refueling bases as their principal component will be superior.

This summary of the study will refer principally to the B-47. The analysis and the body of the report also considered heavy bombers, for which results are similar: ground-refueled intercontinental operation is best for them, too. While the study analyzed the use of bases by all the types of bomber programmed for the fifties, it was concerned with problems of *base choice, not bomber choice.*

It is important to emphasize that the programmed base system has many elements of the system preferred in this study and currently is moving even closer to the preferred system. For example, the specific overseas locations programmed cover most of the regions desirable for the recommended refueling-base system. (Coverage should be extended in Northeast Africa and in the Arabian and Indian peninsulas.) In the case of heavy bombers, even the method of overseas base employment resembles (with a few important differences) the method of staging recommended. Recent programs have adopted the refueling-base concept for some medium bomber wings. In fact, taking into consideration the Air Force's previous work of negotiations, construction, etc., it appears more feasible to realize the system recommended than to carry through the one formerly programmed having overseas operating bases for all medium-bomber wings.

THE FORMERLY PROGRAMMED 1956 SYSTEM

A base system like the one formerly programmed will be extremely vulnerable in 1956. A sizeable part of the force based in the ZI, before the deployment overseas, is susceptible to an air attack which is well within enemy capabilities. The forces based overseas are even more vulnerable. We can expect the majority of the force to suffer serious damage on the ground. The destruction potential of the formerly programmed system is, as a result, smaller than that of any of the other systems examined.

forward based bombers to be vulnerable

IMPROVED OVERSEAS OPERATING BASE SYSTEMS

The vulnerability of overseas operating base systems for the bomber force can be reduced by specific defense measures. But even so, such systems are more vulnerable than any U.S. operating base system. Moreover, this comparative vulnerability increases sharply as offensive weapons of higher performance and greater numbers are assumed to be committed by the enemy to these targets.

Consequently, plans for deployment of bombers to overseas operating bases in general would represent a gamble that enemy capabilities, particularly atomic capabilities, would be low and remain so.

UNREFUELED AND AIR-REFUELED SYSTEMS

From the standpoint of cost, it would be exorbitant to abandon overseas bases to solve the overseas-base vulnerability problem. If conventional high-performance unrefueled bombers with the extremely high combat radii required are possible at all, they will almost certainly be large, vulnerable, and expensive. This is likely to be the case for a long time to come, since, to counter improved enemy defenses, the technical improvements anticipated in aircraft will concentrate on speed and other high-performance characteristics rather than on increased unrefueled radius.

In the study, intercontinental air-refueled systems have been assumed to be feasible, but such systems are shown to be undesirable in situations where overseas ground-refueling is possible. It is shown also, for the period of the fifties, that preparation for the contingency of base loss is best accomplished not by assigning the entire strategic force for regular two-way intercontinental air-refueled operation, but by other methods. (Air-refueling, however, plays an essential role in these methods.) It costs considerably more to refuel in the air than it does to refuel on the ground, even when full account is taken of the costs of defense, of expected enemy damage to refueling bases, and of stockpiling and protecting extra fuel to make the overseas refueling base relatively independent of problems of resupply. The more refueling needed to extend bomber radius, and the larger the proportion of refueling accomplished by tankers, the larger the cost difference. Since the short intercontinental air routes approach Russia from the north, a system employing air-refueling exclusively is ill-suited to take advantage of the nighttime penetration routes and to compel dispersion of enemy fighter defenses. The study confirms, however, the desirability of retaining an air-refueling capability as a supplement to ground-refueling—essential even if the base system survives intact, and also as an insurance against loss of overseas bases.

Outline of the Analysis

THE FORMERLY PROGRAMMED OVERSEAS STRATEGIC FORCE

The point of departure and frame of reference for the comparison of strategic base systems is a system like the formerly programmed strategic force and air-base complex. This is chiefly a 1750-n-mi-radius medium-bomber force composed of approximately 1600 B-47's and RB-47's. It has, in addition, some 300 B-36's and RB-36's, and about a wing of B-52's.

Until the outbreak of a war, most of this force would be based in the United States on 30 bases. The farthest forward of these bases would be from 3300 to over 6000 n mi from targets in the Soviet industrial heartland. A part of the strategic force would be deployed on rotation at overseas primary bases.

After war began, substantially all combat-ready medium-bomber wings would move overseas to operate from a base system consisting of about 70 bases. Roughly half of these would be operating bases and half would be staging bases. Defenses of this base system would consist of approximately 30 squadrons of USAF all-weather interceptors, perhaps 40 antiaircraft battalions, and, in some theaters, Royal Air Force and other NATO interceptors. In addition, about 10 wings of USAF escort fighters would be available for base defense. Relatively little emphasis is given to the passive defense of this system.

The medium-bomber force would be supplemented by approximately 720 KC-97 tankers. Medium-bomber attacks would be launched from overseas operating bases with the aid of both air-refueling and some prestrike forward-base refueling and by the use of poststrike staging bases. Heavy bombers, in general, would start from home bases, use overseas bases for staging, and return to home bases.

THE INTERCONTINENTAL MISSION

An intercontinental mission is only one of several means of accomplishing strategic objectives, and whether or not it is preferred must depend on its relative cost and effectiveness rather than merely on its feasibility. In assessing an "intercontinental" operation, some care must be taken in defining the base geography assumed. Some "continental" bases (such as those in Alaska and

Greenland) are more vulnerable to enemy attack and more difficult to support than some non-"continental" bases (such as those located in the Azores or Iceland). The intercontinental bases considered in this study are well within the early-warning perimeter of the United States and have the attendant advantages of logistics economy and reduced vulnerability.

Estimates of cost in this study include sizeable overseas expenses in addition to the direct costs of the strategic force (e.g., the costs of ground forces needed directly for the local defense of some overseas bases). However, many of the extra costs sometimes considered (such as the costs of economic and military aid to our allies, of the Army, the Navy, and the tactical air units) cannot properly be regarded as chargeable to an overseas strategic air-base system.

POLITICAL CONDITIONS AFFECTING OVERSEAS-BASE CHOICE

Political factors in overseas areas restrict the availability of air bases and the conditions of their use. But the choice of location is wide enough to offer considerable insurance against political mishaps. Choice between overseas and domestic systems can be made on the basis of comparative costs and effectiveness.

Political considerations reinforce certain technical and economic factors. Uncertainties of political alignment may make it necessary to distribute the bases among many distinct political entities. This dispersal, however, may have the advantage of reducing vulnerability to enemy attack. Limitations on the use of certain bases to air defense and tactical missions may be relaxed in wartime, suggesting that such facilities might well be designed for conversion to strategic uses. Finally, the existence of limits on the manning of bases favors the strategy of considering such bases for advanced ground-refueling of intercontinental systems.

BASE CHOICE AND SYSTEMS ANALYSES

Because the choice of weapons, the method of their employment, and base selection are interdependent, an exploration of the base problem may be expected to increase the dependability of weapons systems analyses undertaken to assist the Air Staff in its development program. For example, the radius from base to target may be the dominant factor affecting the choice of bomber design, including type of powerplant, etc.

Radius-extension costs and overseas operating costs, varying with the base system chosen, are incurred for the sortied force and not for a force held in reserve to replace bomber losses. For some base-aircraft combinations these costs are so high, in comparison with the costs of a bomber inventory held in reserve to replace combat losses, that a policy of restricting the size of the sortied force and maintaining a large reserve appears best. For a differently based system, it may be most efficient to sortie all bombers available. Therefore, base choice affects the strategy of employing bombers.

LOCALITY AND LOCATION COSTS AND EFFECTS

The bombing-system costs traceable to base decisions are of two kinds. Those influenced by such particular site characteristics as weather, terrain, availability of construction industry, existing defense, etc., may be called *locality* costs. Those which pertain to such critical general base relationships as the routes from the United States to base and from base to target (including the path through enemy defenses) and to risks of enemy attack may be termed *location* costs.

The consequence of basing aircraft in the Arctic illustrates the importance of *locality* cost differences. For example, construction costs may exceed by five times or more the costs for a similar base in a different area. An Arctic operation involves *extra* costs not only in construction, but also in supply, equipment, clothing, number and training of personnel, and maintenance, lower rates of aircraft utilization, greater base vulnerability, and decreased recuperability after damage. Although such a base offers certain advantages for penetrating to North Russian targets, it appears that these advantages are not enough to offset the extra costs of operating in the Arctic. If, as the study indicates, operating bases overseas are in general inferior to "refueling" bases, this conclusion is particularly true of Arctic operating bases. Although existing bases *can* play a useful role in refueling systems, other regions are better than the Arctic for future *expansion* of such a base system.

While many locality effects were taken into account by the study, attention was mainly focused on the variations in system costs occasioned by base *location*.

LOCATION COSTS AND EFFECTS

Since base location must compromise some or all of the advantages of (1) proximity to targets, (2) favorable angle of approach to targets, (3) logistics economy, and (4) remoteness and comparative invulnerability to enemy attack,

factors in base choice.

the effects of system cost and effectiveness of each of these factors have been examined.

Effects of Increased Radius to Target

Distances from farthest forward overseas bases to Russian targets range from 300 to 1500 n mi. From the major overseas bases programmed, the targets are anywhere from 800 to 2600 mi away. From the ZI, if we follow routes calculated to reduce losses to enemy defenses, distances to targets are from 3300 to well over 6000 mi.

As our radius of operation increases, the cost to buy and operate our bombing force rises, and its effectiveness declines. The extent and rate of this variation depends on the bomb carrier and on the method of radius extension chosen.

The cost to operate bombers big enough to reach targets *without refueling* increases at an accelerating rate with distances from base to target. Moreover, the cost increments due directly to growth in aircraft weight with increase in system radius are compounded by the probability of interception of the larger and heavier airplanes. The exact rate of increase, in any given state of the art of aircraft design, depends on such factors as powerplant type, payload, cruise and over-target speed, altitude, etc. It is greater for turbojets than for turboprops; and greater at higher speeds and extreme (low or high) altitudes. To have built an intercontinental radius capability into a bomber of the B-47 type would have made it enormous in size, costly, and vulnerable. In fact, the heavy bombers roughly contemporary with the B-47, for example, display larger differences in cost than they do in radius capability. None will be able to reach the whole of a Russian target system at intercontinental radius. In Fig. 3, which illustrates this point, the system cost and radius of bomber types of approximately similar performance and design date as the B-47 are represented by points in the shaded region.

An examination of the next generation of bombing systems shows that the strong influence of combat radius on system cost is not merely temporary. Supersonic and low-altitude capabilities may be sought to meet expected improvement in enemy defense. The normal advances in the state of the art will permit improvement in performance characteristics for any given weight and cost; but these, in turn, will tend to be offset by the performance demands imposed by improved defense capabilities open to a rational enemy. The resulting cost-versus-radius curves will therefore show no substantial improvement. (The curve for supersonic bombers in Fig. 3 illustrates this point.) If anything,

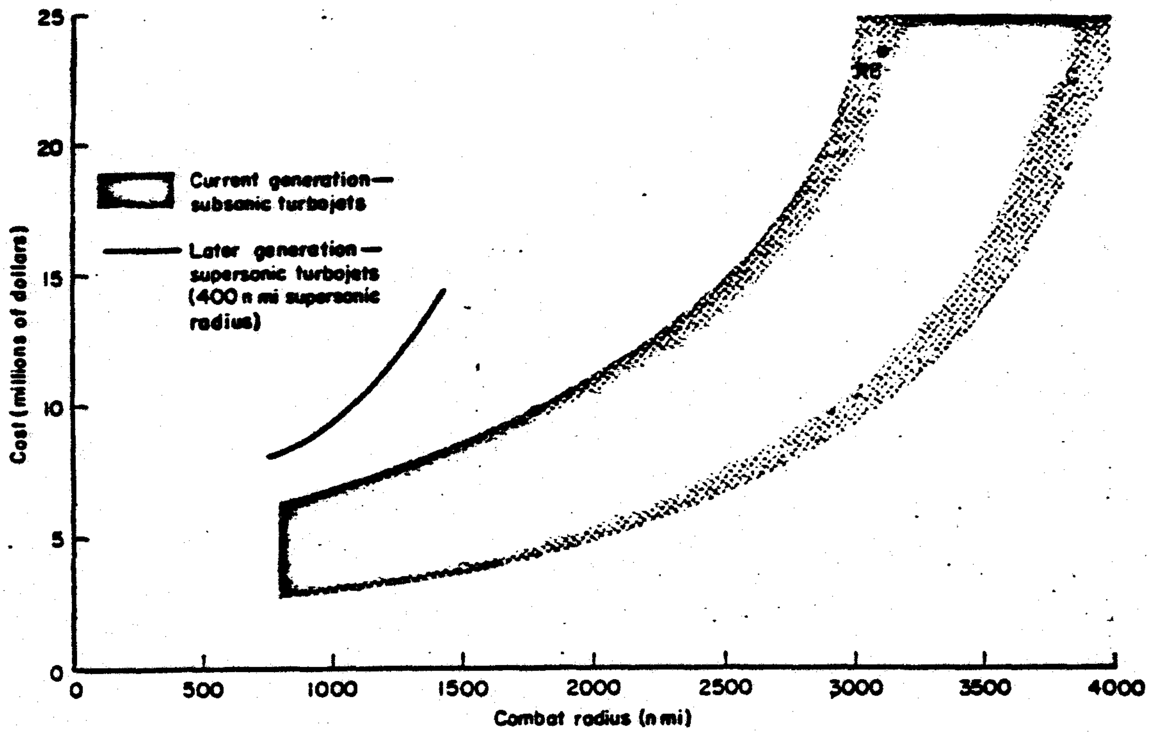

Fig. 3—Cost vs combat radius

the situation appears to be getting worse: combat radius will be *more* rather than *less* critical for some time to come.

Examination of nuclear-powered bombers and surface-to-surface missiles indicated that expected developments in these fields are not likely to alter this conclusion for the next decade.

In air-refueled multistage bombing systems, a bomber of fixed unrefueled radius is assisted to the target by tankers. This avoids the need for bigger, more easily intercepted, and more costly bombers. But the effects of radius on *system* weight or cost (including the weight or cost of the tanker as well as that of the bomber) are nonetheless very marked. Costs increase in steps (see Fig. 4), corresponding to points at which additional tankers are required. As combat radius is extended, the increments obtained by the use of additional tankers become smaller and, allowing for insurance against the uncertainties of multiple refueling, the increases in cost for a given increment of radius become steeper. For a tanker-refueled B-47 system, at 3600, 4200, and 5200 n mi, costs are respectively three, five, and ten times the cost at an unrefueled radius of 1750 mi. (These specific figures neglect the *extra* costs of bomber attrition and bomber aborts likely to be associated with the rendezvous problems in multiple refuelings. Such costs may well be so high as to make extreme multi-refueled systems unfeasible.)

One way to keep operating bases (and so, parked bombers—the most vulnerable and valuable system element) away from enemy striking power is to extend

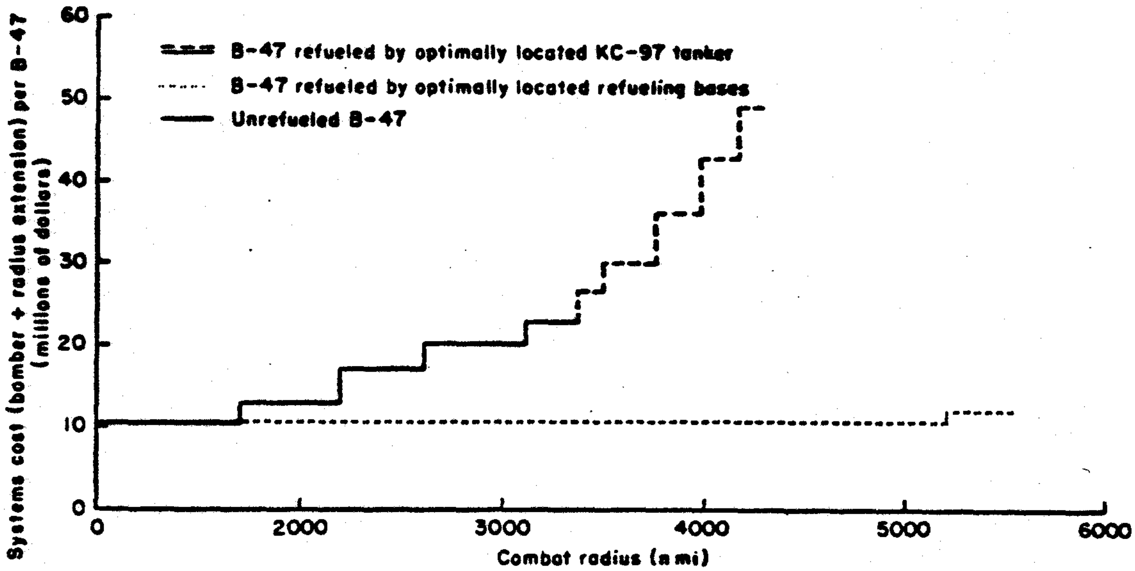

Fig. 4—Multistage B-47 systems vs combat radius

bomber radius by a system of refueling bases. The radius extension such a system provides is very moderate in cost in comparison with the costs of a tanker system. Aside from the costs of defense and expected damage, buying, equipping, and supporting a refueling base with modern landing, take-off, and high-speed-fueling facilities adds something like 15 per cent to the 3-year cost of buying and operating a wing of B-47 aircraft in the United States.

Figure 4, which shows the increase in bomber costs with extension of radius, includes support costs incurred for the peak force sortied. When the costs of radius extension are very high (e.g., in the air-refueled U.S.-based B-47 system), the portion of the total system cost devoted to tanker procurement and operation can be reduced by the strategy of sending fewer than the maximum number of available bombers on each strike. The smaller sortied force means slower initial rate of destruction of enemy targets. It also means more aircraft losses to area defenses per target destroyed; but the smaller operating force will, if we consider cost alone, save more than this amount in tankers for a system with high tanker requirements.

The cost of a summer campaign to destroy 80 per cent of a Russian industrial-target complex using an air-refueled system is 320 per cent of that for a ground-refueled system (see Fig. 5). These costs take into account the detailed geography of bases, identifiable air-refueling points, specific staging areas, points of entry into enemy defense, and paths to targets. Russian area defenses are assumed to be distributed evenly over the area of their ground control intercept (GCI) network coverage, and strike paths are relatively direct to minimize the

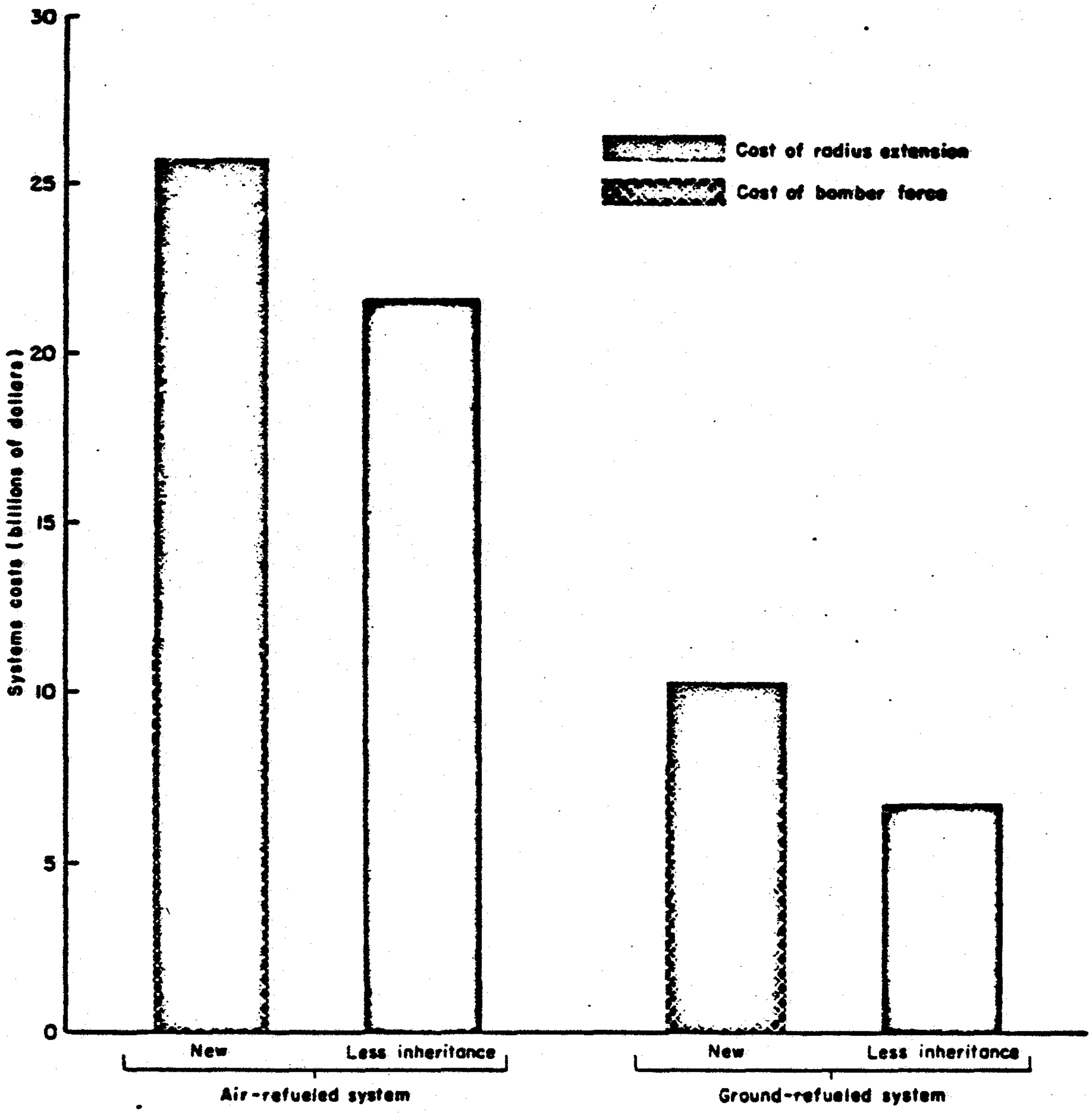

Fig. 5—Costs of intercontinental air- and ground-refueled B-47 campaigns

number of tankers per bomber in the striking force. (As will be shown, both their defense and our offense tactics can be improved decidedly by adaptations to match our base system.) The bombing systems compared use identical airplanes and operating bases in the United States, but aircraft radius is extended in one case by air-refueling and in the other case by ground-refueling. The ground-refueled system uses all available bombers on each strike. The air-refueled system follows the plan of withholding bombers, which, for it, is less expensive (though this plan also imposes some inflexibility as to rate and size of strike and proportion of the target system attacked). No allowance is made for bomber attrition connected with multiple refuelings. The calculations also show that

1. The radius-extension costs for the air-refueled system are about six times those of the ground-refueled system.
2. To limit radius-extension costs even to this high level, the air-refueled system involves a considerable sacrifice in extra bombers lost (about 30 per cent of the value of bombers in the ground-refueled force).

Differences of such large magnitudes occur in spite of the fact that so much of the bombing system is fixed in the comparison (the bomber type and the U.S. primary bases).

Ten wings of penetration fighters are programmed for 1956. Whether they are used as bombers, as escort fighters, or as decoys, their strategic use appears practicable only from an advanced primary-base system or from a more distant primary-base system with overseas ground-refueling facilities. The preference for ground-refueling over air-refueling would be greatly increased by taking these components of the programmed force into account.

Sole consideration of the effects of increasing the flight radius to enemy targets indicates the desirability of operating from bases which are as close as possible to these targets. A decision must also take into account the effects of distance from logistic support in the United States and nearness to the source of enemy striking power. However, if these effects dictate operation at great distances from enemy targets, the analysis so far has suggested that it is especially expensive to store fuel far from targets and to air-transport it for transfer to the bomber.

Effects of Penetration Paths

The study has investigated the effect of base location on the angle of approach to targets, the distance of penetration through enemy defenses, and the hours of daylight and darkness over these penetration paths. Base-location considerations affect our choice of the route to the target and the enemy's choice of defense deployment.

The distance traveled over enemy defenses, and so the number of bombers lost to enemy fighters, can be reduced by doglegging, but this increases combat radius (see Fig. 6). A tanker-refueled system using U.S. operating bases begins far out on the cost-radius curve, and additional radius is very expensive.

We may distinguish three kinds of penetration routes. First, relatively direct routes minimize the number of tankers necessary for each bomber in a strike. Second, there are routes which minimize penetration distances and so reduce

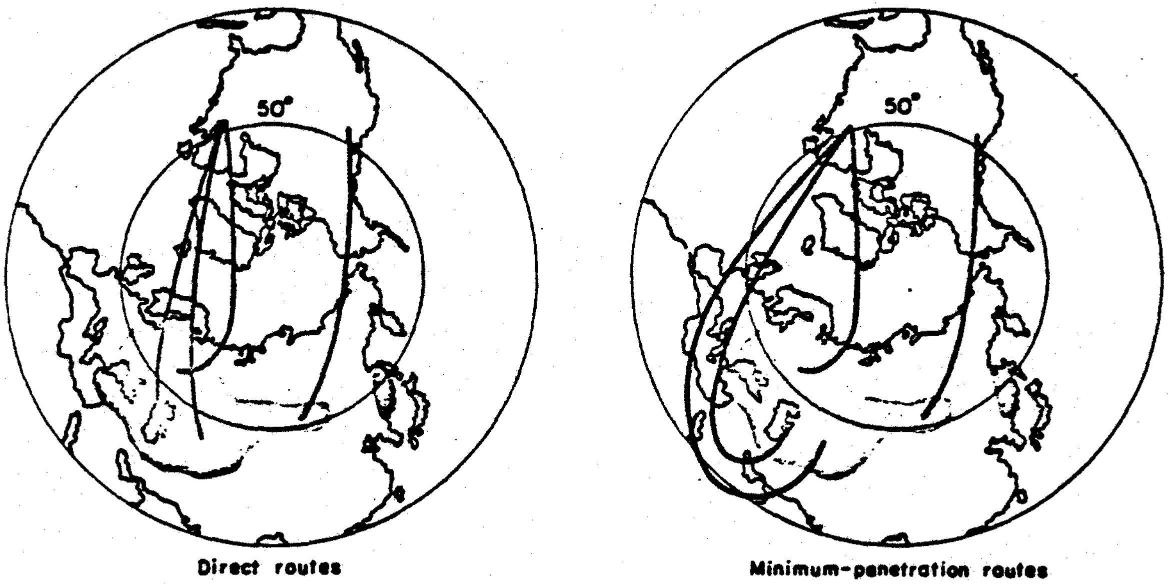

Fig. 6—Routes for intercontinental air-refueled strikes

attrition inflicted by area defenses (fighters). A third set may be chosen in summer to take greatest advantage of darkness to reduce losses to fighters. Darkness has a decided effect, since (1) the USSR is expected to have a larger number of day than night fighters in 1956; (2) few day fighters will be usable at night—e.g., employing the buddy system: day fighters led by night fighters; and (3) the individual effectiveness of Russian night interceptors is expected to be much less than that of their interceptors in daylight.

We have compared systems using routes minimizing distance flown through enemy defenses with systems using direct paths which minimize tankers per bomber sortied. For air-refueled U.S.-based B-47's in a multistrike summer campaign to kill 80 per cent of the Russian industrial-target system selected, this comparison reveals a significant preference for minimum-penetration routes. The system flying minimum-penetration paths loses fewer bombers to enemy fighter defenses, and so reduces the size of the force needed to insure an acceptable crew-survival probability. Finally, although the system has more tankers per bomber, it has fewer tankers in total, reducing even the radius-extension costs for the campaign.

Base systems which permit entry from the south can take advantage of the cover of darkness with little or no extra extension of radius. Since the ground-refueled U.S.-based system has many staging areas to the south, its short-route system is largely protected by darkness and is one that nearly minimizes attrition. Bombers flying direct routes in summer suffer no more attrition than bombers flying minimum-penetration doglegs without the advantage of darkness.

The enemy, in turn, may improve his defense by matching our offense capability. Against systems flying the shortest routes from the U.S. operating bases, he might concentrate fighter defenses in the north (see Fig. 7). Systems using peripheral operating or ground-refueling bases would compel a more even dispersal of enemy defenses, as shown in Fig. 8.

Campaign results presented in Fig. 9 indicate that if the enemy can concentrate day fighters in the north, taking account of the greater density of targets in the west, he can do better than when he distributes fighter defenses uniformly.

The Russian area defenses so reoriented will exact a higher attrition against all bombing systems, but in particular against "one-sided" base systems: the exclusively air-refueled intercontinental systems or a Western Hemisphere system. Russian defenses further improved by specific tailoring to meet each of our base systems could do still better, especially against a one-sided system with relatively concentrated avenues of approach to the targets. Limitation in the number of night fighters available makes it difficult for the Russians to improve their fighter deployment very much against attack from peripheral overseas bases (operating or refueling).

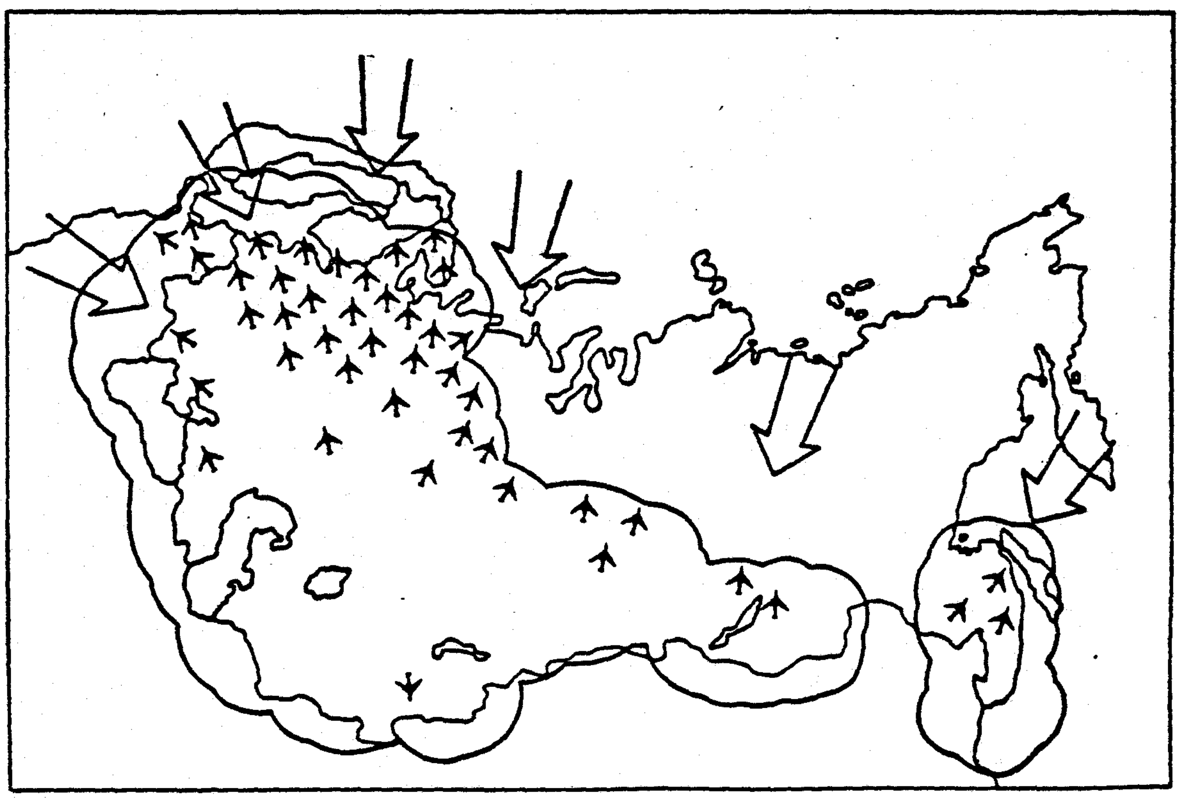

Fig. 7—Russian fighter deployment against direct intercontinental air strikes

Fig. 8—Russian fighter deployment against strikes from overseas bases

The use of optimal routes and profiles requires increases in radius-extension capabilities, giving additional advantages to systems which can achieve them cheaply. Furthermore, peripheral base systems, unlike one-sided systems, permit, in the short run, the exploitation of the enemy's soft spots; in the long run, they force a dilution of his defenses.

Effects of Supply Distance

The peacetime cost of buying and maintaining a wing of bombers in the United States must be increased by over 50 per cent to cover the additional cost of operation from primary bases overseas. This extra cost is incurred for additional bases, theater support, and airlift. However, the differences among overseas base systems do not increase substantially with supply distances in peacetime. Transportation, travel, and stock-level costs are only moderately affected by increasing distance, even when these distances vary up to 10,000 surface miles. (*Locality* considerations, on the other hand, as distinct from location considerations, do entail substantial extra costs for peacetime resupply in the

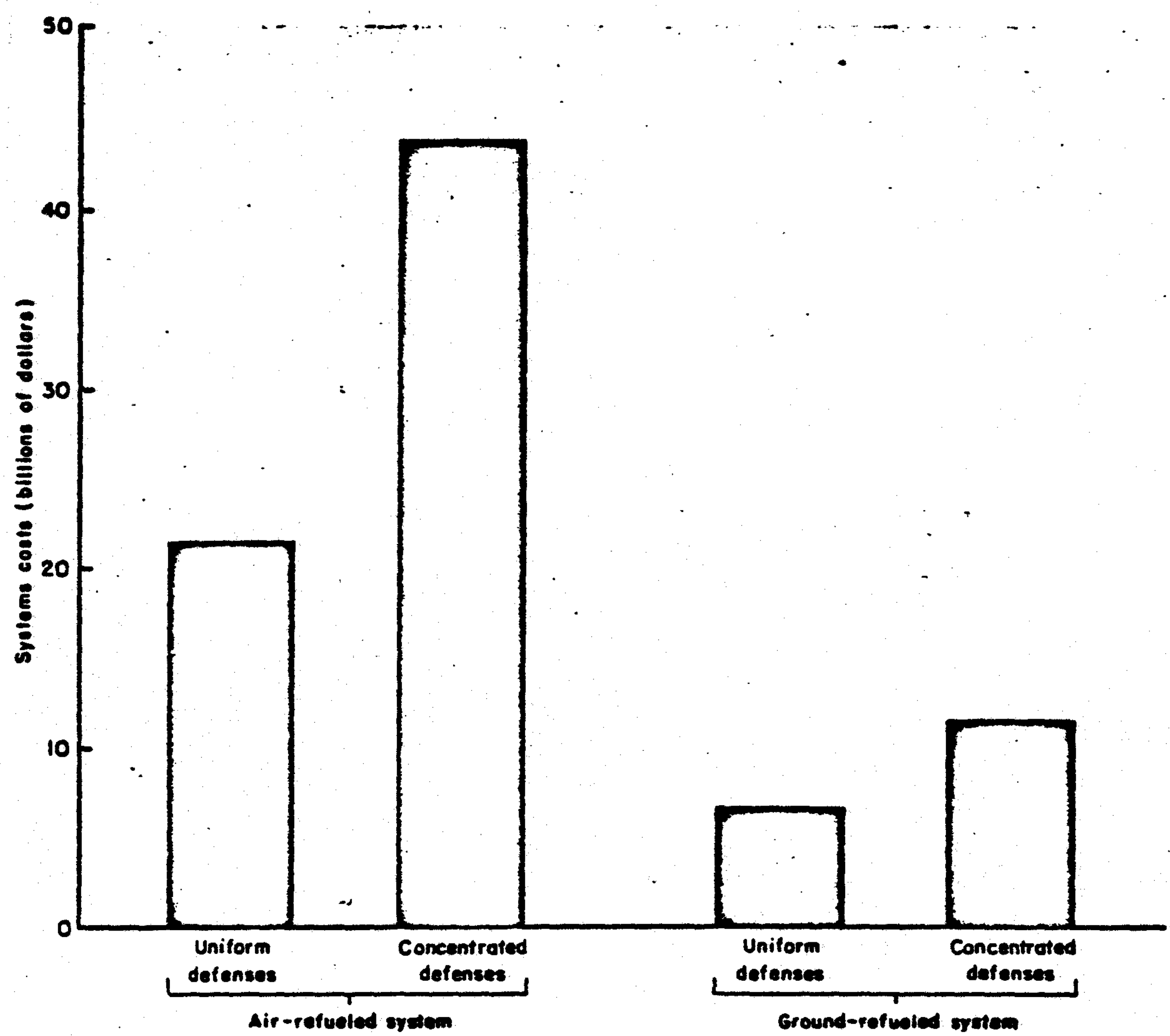

Fig. 9—Cost of B-47 campaigns against a uniform and concentrated area defense

Arctic.) Except for the case of a system using refueling bases, the extra costs involved in wartime resupply and pipeline attrition have not been investigated in detail. For a refueling base, the prestocking of fuel at moderate cost frees the base from the problem of losses in surface transport during the early months of a war. To free an operating base overseas from such problems, a considerable quantity of air transport would have to be purchased.

While, in any case, there are extra costs for operating facilities, airlift, stocks of matériel, etc., involved in adding an overseas component to a bombing system, it is much cheaper to add refueling facilities than operating facilities, even if we neglect vulnerability considerations.

So Guam is an exception.

Effect of Proximity to Enemy Striking Power

Consideration of the first two critical factors (target radius and penetration routes) stressed the advantages of being close to the target and close to favorable points to enter enemy defenses. Unfortunately, when we are close, not only is our power to attack the enemy very great, but so also is his power to attack us. (The rings in Fig. 10 indicate the steps in which the enemy's striking power diminishes with distance from his border.) The most obvious disadvantage of an overseas base system is its increased vulnerability (see Fig. 10).

The analysis of base vulnerability covers (1) the size and type of air attack that the enemy can launch against various base systems; (2) the likelihood that attackers will penetrate our base defense to bomb, and their capacity to re-attack; (3) the elements at risk on the base at the time of bombing; (4) the

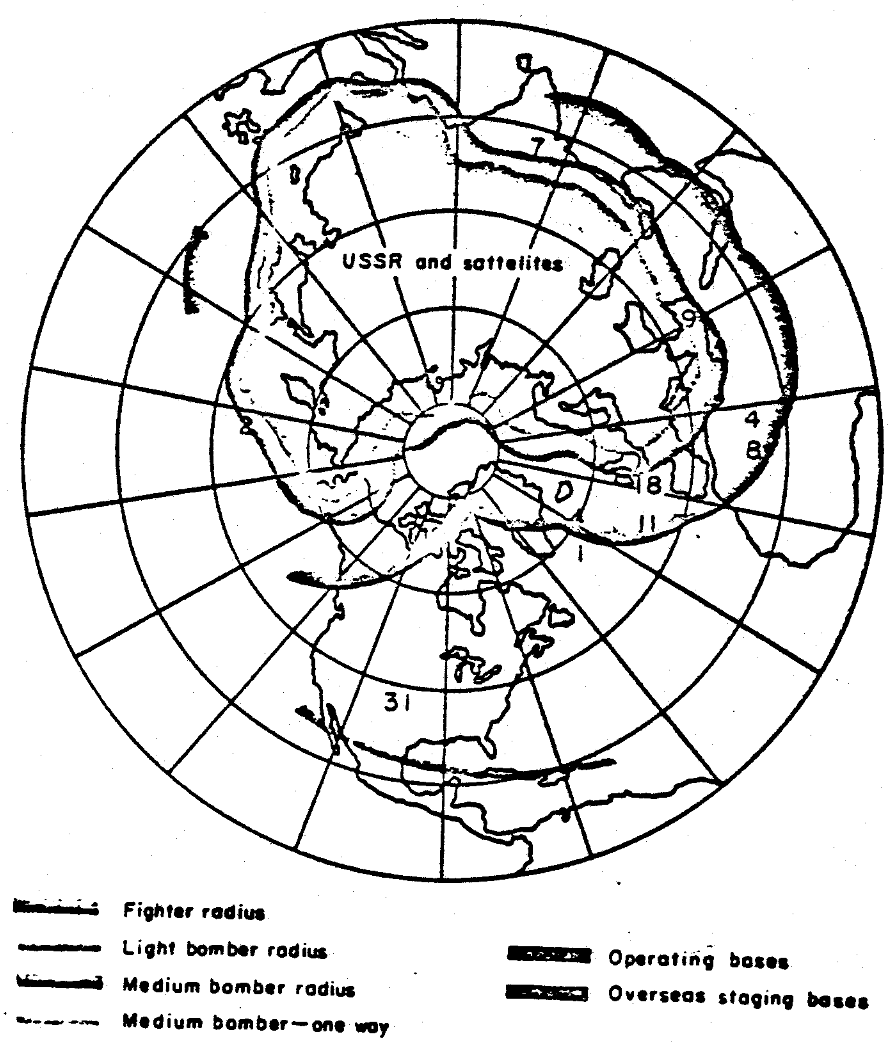

Fig. 10—Base locations relative to USSR striking power

physical vulnerability of these elements and the damage resulting from bombing; and (5) the consequences of damage in terms of base operations. These factors correspond to the successive phases of attack.

United States Operating Bases. The most vital and easily damaged elements of a strategic force based in the U.S. ZI will not be very vulnerable *if* the aircraft, personnel, and essential matériel evacuation plan of SAC is carried out. *However, a large number of U.S. bases are too close to the perimeter of our projected 1956 radar net to have even marginally adequate warning against air attack.*

Moreover, in the event of Russian use of a short-range submarine-launched A-bomb carrier, no future extension of the radar network is likely to provide adequate warning for coastal bases. A single, high-altitude mass Russian strike against U.S. targets, including SAC, with 1956 defenses could result in attrition of 75 per cent to 85 per cent of the medium-bomber force. With adequate warning this could be reduced to an attrition level of less than 20 per cent. These estimates are based on a Russian commitment of 120 bombs to the destruction of SAC. Considerably smaller bomb commitments by the Russians could also result in high levels of destruction in the absence of adequate warning. In addition to bomb commitment, the analysis also considered varying estimates of Russian bomber stockpiles, expected operational aborts, and attrition inflicted by U.S. defenses. Figure 11 illustrates expected ground attrition of strategic aircraft on U.S. bases in 1956 for a range of A-bombs allocated by the Soviets to the task of neutralizing this force, and for a range of probabilities of their delivering the bombs allocated. The delivery probability depends on the number of bombers assigned to the task and the effectiveness of our fighters—which, in turn, depends on the likelihood of Russian countermeasures, etc. The lower limit of the shaded areas in Fig. 11 (and also in Fig. 12) represents probable values of enemy bomber assignment and effectiveness of our fighters. The upper limit indicates the result of assuming a higher enemy offense capability and lower effectiveness of our own defenses.

The great reduction in U.S. bomber losses when adequate warning is received shows the benefits of evacuation. In addition, fly-away kits and operating personnel would be protected by the execution of the SAC evacuation plan. Dispersed operation can be considered an alternative or an additional defense to evacuation. However, as a substitute for evacuation it is unacceptably sensitive to the number of enemy bombs directed against SAC. As a supplement to evacua-

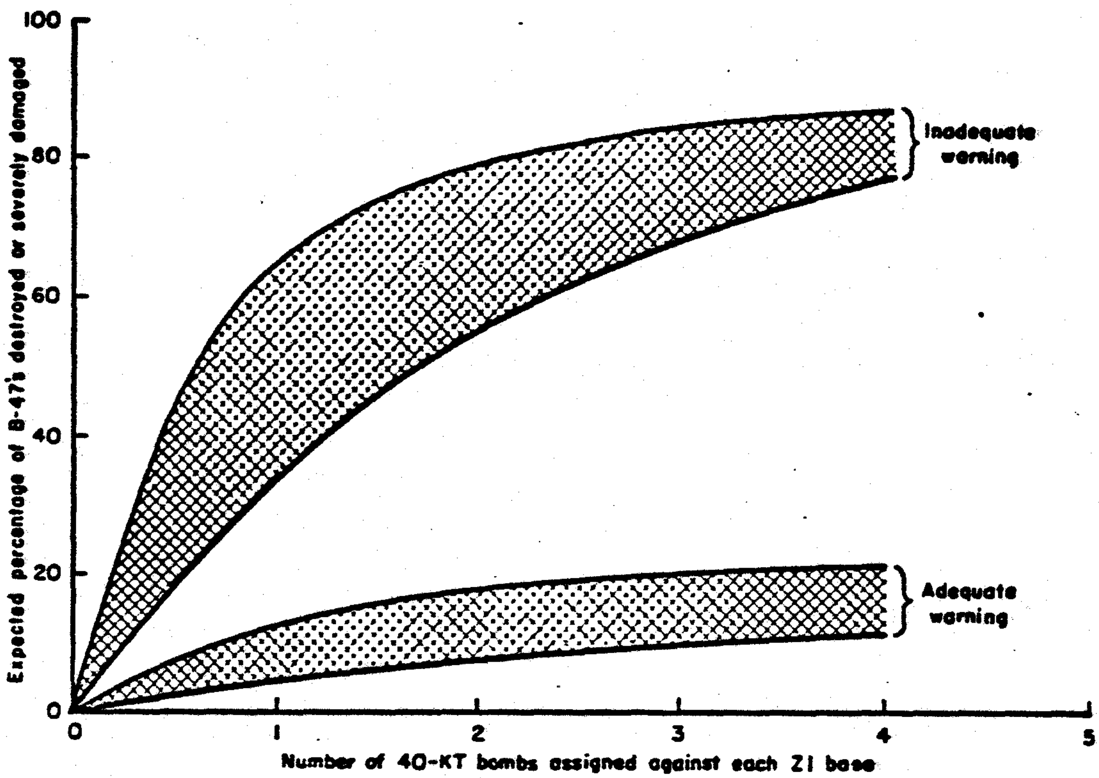

Fig. 11—Attrition on programmed ZI strategic bases vs enemy bomb allocation

tion, dispersed operation tends to cost more than it saves in unattrited bombers (see Fig. 13, page xxvii).

Wherever possible, measures (e.g., addition of radar, reduction of time required for evacuation, and transfer of wings from the periphery to the interior) to provide adequate warning and to facilitate evacuation of critical elements of the striking force appear to be more effective and less costly than initially dispersed operations as a means of defending operating bases.

In particular, it appears important to modify the SAC evacuation plan by—

1. Hastening the decision to evacuate by allowing SAC evacuation to be triggered automatically by a warning derived from the continuous statistical evaluation of unknown aircraft within our radar network. (The triggering level to flush SAC can and should be lower than the level the Air Defense Command [ADC] requires for its full Red alert, affecting as it will many civilian activities. It might be set so as to exercise SAC in the evacuation plan two or three times a year.)
2. Separating the plan for evacuation from the plan for deploying bombers for attack, and giving higher priority to the essential job of saving the striking force.

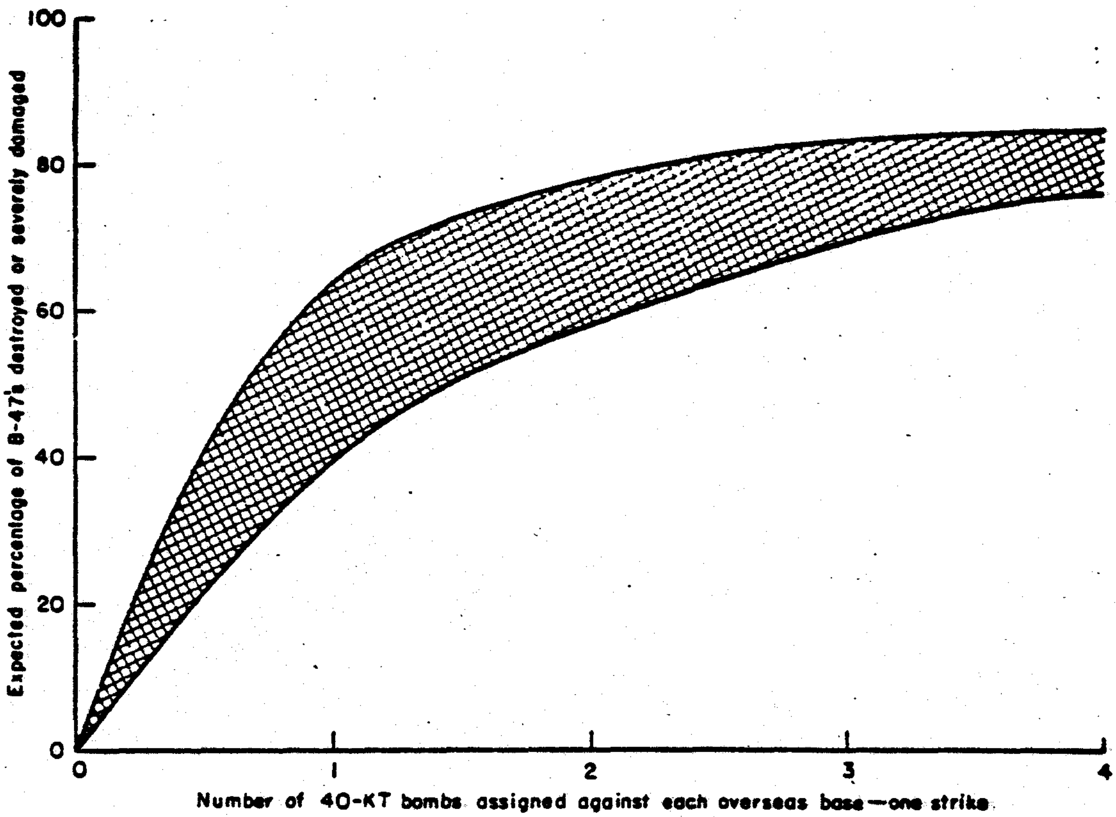

Fig. 12—Attrition on programmed overseas operating bases vs enemy bomb allocation (no aircraft evacuation)

3. For at least the interim, keeping minimum evacuation crews on hand at all times at bases which have insufficient reliable radar warning to permit crew assembly.
4. Providing egress taxiways, wherever possible, to permit the taxiing or towing of nonflyable aircraft off base.

Other critical defense measures for bases in the ZI, besides evacuation, are discussed below. (With these modifications, the probability of evacuation is high enough to make the extra insurance of operating bombers in many units of less than wing size excessively costly. However, forms of dispersal other than dispersed operation may be of considerable importance. An example is preparation of alternative U.S. sites for emergency use and local dispersal.)

Overseas Operating Bases. Evacuation does not appear feasible for most overseas bases (advanced or intermediate) because of the very short warning times and a high enemy capability for frequent air attacks and feints. (The inadequacy of warning time is emphasized by the threat of submarine-launched attacks.) Five-sixths of these projected overseas bases are within 100 mi of the sea. The vulnerability of units deployed to such overseas bases would be high.

Analysis of the consequences of a Russian A-bomb air attack on the whole of the projected 1956 overseas primary-based system with the projected defenses clearly shows that only small numbers of A-bombs are needed to eliminate the majority of the force surviving attack in the United States (see Fig. 12). (Although expected destruction of aircraft is used as a measure of vulnerability in Fig. 12, the combat effectiveness of the force would be further reduced by loss of personnel, bombs, base facilities, fuel, supplies, etc.) The extensive destruction indicated by rather moderate investments of Russian bombs results from (1) the concentration of our strategic forces on relatively few bases (a reasonable allocation of expected enemy forces provides very large attacking cells per base), (2) inadequate radar coverage and defense weapons effectiveness, especially at low altitudes (bomb carriers in attacking cells have a very high probability of reaching the bomb-release line), and (3) the high physical vulnerability of system components likely to be on the ground on overseas bases at the time of attack (the probability of destruction, given bomb release, is very high).

After the outbreak of a war, the initial vulnerability of wings deployed overseas will be critically dependent on the period of exposure before the mounting of the first U.S. strike. Measures can be taken to reduce the period of exposure before our first strike, but after that our B-47's scheduled to operate from overseas bases will be exposed to repeated attacks by enemy aircraft carrying high-explosive and atomic bombs. Units on rotation overseas at the outbreak of hostilities can expect to suffer great damage immediately.

Guam could expect such an attack immediately.

The vulnerability of the formerly projected overseas operating base system to even a quite low level of enemy attack can be reduced. By allocating more of our strategic budget to the purchase of active and passive defense, rather than bombers, we can increase the total number of our bombers likely to survive all but fairly high levels of enemy bombing attack.

In our final comparison an improved overseas operating base system is considered. Under the next three headings, three classes of passive defense measures are treated. They involve multiplication of bases, relocation of bases, and changes within bases (separation and toughening facilities). The first two involve large-scale changes in the base system as a whole. Of these, one, base relocation, might affect the warning available and the probable size of the enemy attacking force. The other increases the number of enemy bombs required; the third—local changes—forces an increase in the size if not the number of bombs.

Passive Defense: Multiplying Operating Bases. Since evacuation is generally not feasible overseas, multiple separated bases should be considered. Protecting the *bombers* by this means requires multiple *operating* bases. The cost (in extra base facilities, equipment, and personnel) compared with the reduction in aircraft ground attrition from a single enemy strike for three degrees of operating-base dispersal, is shown in Fig. 13. Over a considerable range of pos-

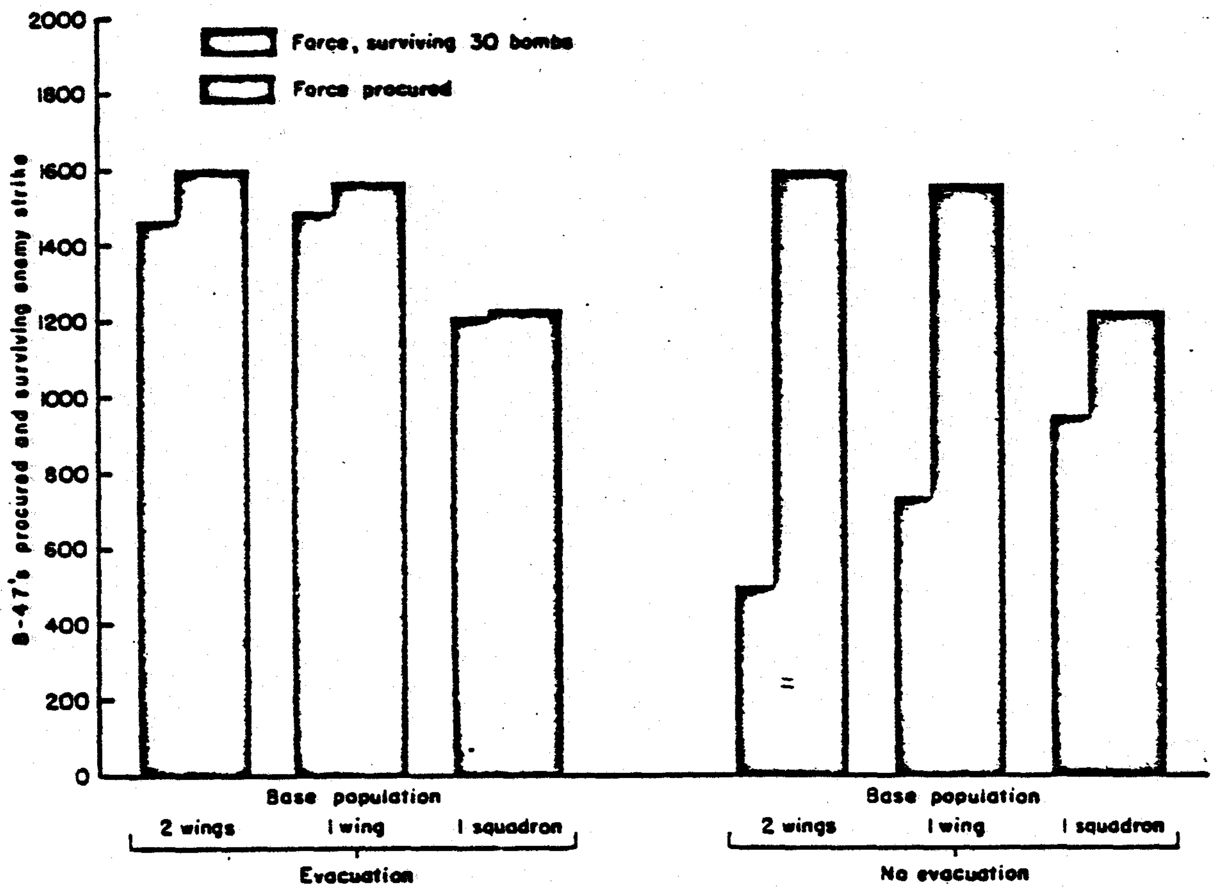

Fig. 13—Evacuation and dispersal

sible Russian bomb commitments against our strategic force in 1956, there would be a net gain in the number of aircraft surviving after combat, even if the extra cost of separated bases resulted in fewer aircraft being procured. However, we have no reliable knowledge of what Russian capabilities will be in 1956. It must be noted that if the number of bombs available and allocated to this task is higher than estimated, dispersed operation will buy very little defense (see Fig. 14). Since we can expect the Russian capability to increase rapidly as time goes by, we cannot rely on this method of defense.

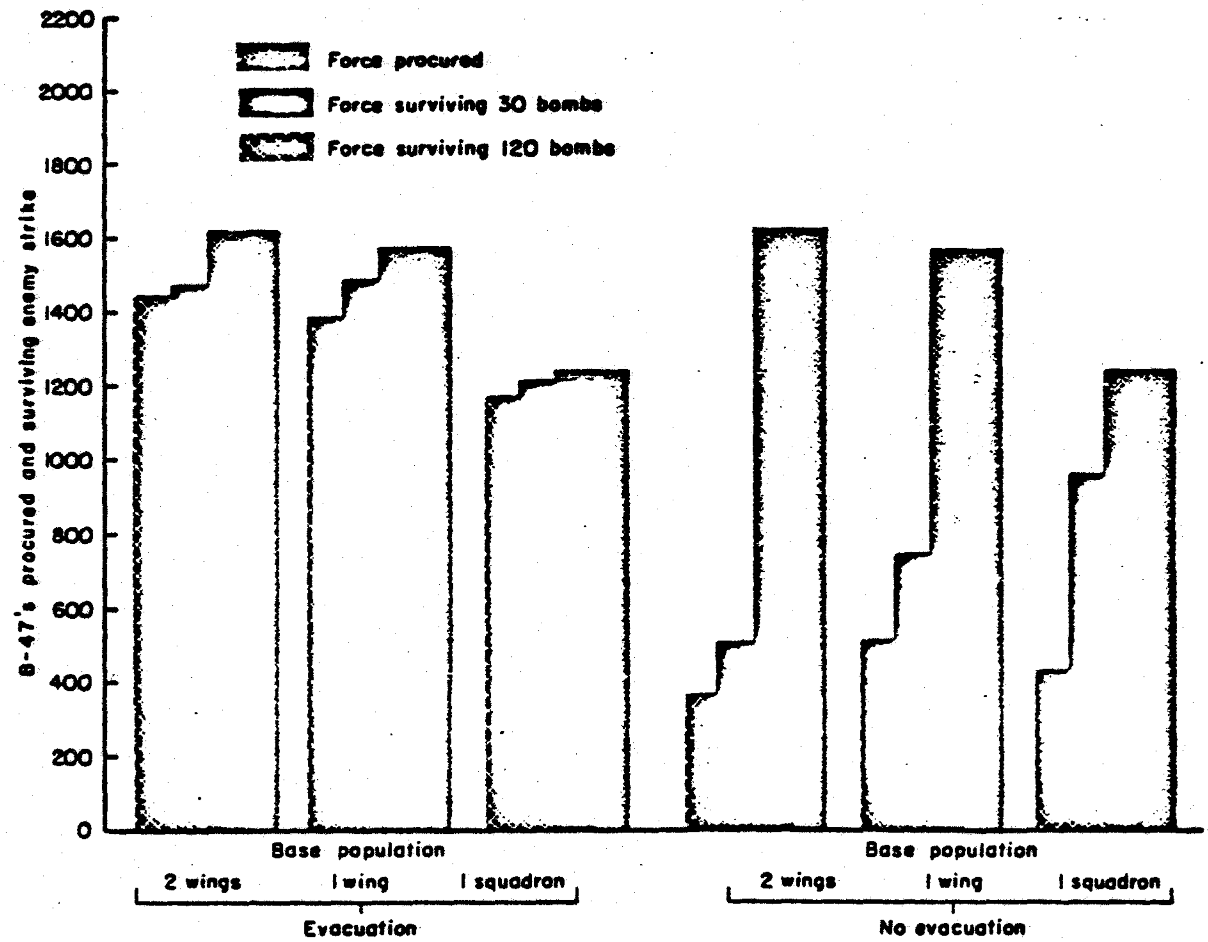

Fig. 14—Evacuation and dispersal: sensitivity

Passive Defense: Relocation of Operating Bases. This has been indicated as a measure which might be necessary in order to counteract some threats against ZI operating bases. If applied to overseas bases, this measure yields the intermediate overseas operating base systems which have been mentioned. It does, indeed, reduce the number of sorties which the enemy can mount with a fixed force. This is a great asset against a high-explosive attack; but it is, as the analysis shows, of little value against atomic attack. Repeated atomic sorties are not required to destroy soft targets such as bombers caught on the ground. Since intermediate base systems are not within the deep fighter-backed U.S. radar network, evacuation is denied them as a defense. Therefore they are little less, or no less, vulnerable to atomic attack than advanced overseas operating base systems.

Passive Defense: Changes within a Base. No existing strategic base was specifically designed to reduce damage from atomic attack. A medium-sized (40 KT) bomb dropped with a 4000-ft CEP is expected to result in destruction and serious damage ranging from 80 per cent to almost all the aircraft, structures, supplies, and personnel exposed on ZI bases and most overseas bases. Damage to many base elements can be reduced by local dispersal and blast-protective shelters. Parking aircraft on the perimeter of our large French Moroccan bases rather than the use of *area* dispersal (now employed overseas for protection against high-explosive attack) would reduce expected aircraft destruction and serious damage by about one-half in the case of an attack with a 100-KT bomb. Several of these defense measures are relatively inexpensive and at least insure against the use of medium-sized bombs. However, their effectiveness depends on the limits to the size of the bomb used. The study found such methods inadequate for assuring protection of our bombers against the delivery of large-yield bombs with normal accuracies. On the other hand, they have an important role to play in protecting the critical fixed facilities and the base defense weapons. *The hardening of critical facilities against the possibility of attacks aimed at base denial is useful, according to the results of the campaign analyses, even given sizeable enemy stockpiles of thermonuclear weapons.*

Active Defense. The effectiveness of scheduled active defenses can be improved somewhat by added radar coverage, especially at low altitude. Over-ocean coverage is inadequate and, as has been stressed, most of the projected forward operating bases are within 100 mi of the sea. Area defenses are particularly ineffective in such circumstances. Achieving a *high level* of defense by adding more defense weapons of the type presently scheduled would cost about as much as it would save.

Ground attrition *would* be significantly reduced by the use of weapons not likely to be available for the defense of overseas bases in 1956 (Nike and Loki local-defense weapons, etc.). However, in all cases, the effectiveness of the active defense of the overseas bases is critically dependent on the performance and number of carriers, tactics, and countermeasures employed by the enemy. In view of the uncertainties as to the effectiveness of various active defense measures, it appears very risky to defend bases primarily by active means. This is particularly true of bases that can be reached by high-performance jet aircraft (IL-28, EF-150) which the Russians may have in large numbers.

Recuperation Plans. Recuperation plans can drastically reduce the impact of physical damage on base operational effectiveness. In the case of an A-bomb attack on a base, a large number of the aircraft may require replacement of those parts likely to be damaged by blast (e.g., control surfaces, bomb-bay doors, external plastic surfaces). These are not parts normally requiring replacement in quantity, and so are not stocked in quantity at bases. However, such stocks would not be expensive, and failure to stock them could mean weeks and possibly months of inactivity.

Aside from decontamination, the essential measures to meet the radioactive fall-out problem on home bases include (1) evacuation to emergency alternate bases and delay in using the contaminated bases (because of the rapid decay, such delay times can be short—provided the period of exposure is short), and (2) shortening the period of occupancy and exposure by staging through the contaminated home bases from the emergency alternates.

Other measures examined and found useful include duplication of vital base facilities, the training of damage-repair teams, and provision for emergency construction to replace facilities destroyed.

Combinations of active and passive defenses are better than any single defense measure for the defense of an overseas operating base system. At present, manning and real-estate constraints act to restrict the range of choice available. A comparison of the formerly programmed system with an overseas operating base system modified to reduce vulnerability shows an increase in the number of bombers available for combat when extra funds (out of a fixed budget) are spent for additional active and passive defense measures, including local dispersal and blast protection, augmented interceptor and local defenses, and ground and airborne early warning (AEW) radar coverage (see Fig. 15). Although the cost per bomber procured is increased by 30 per cent, the cost per bomber *surviving for combat* (along with supporting elements) is decreased by 35 per cent. It should be noted that this combination of defense measures is not regarded as optimal, and that there are wide variations in preferred measures for different overseas-base areas.

Preferred Defense Measures. It appears that the vulnerability of SAC before deployment to overseas primary bases is moderate for units stationed on bases likely to receive adequate warning of attacks. While many units are not

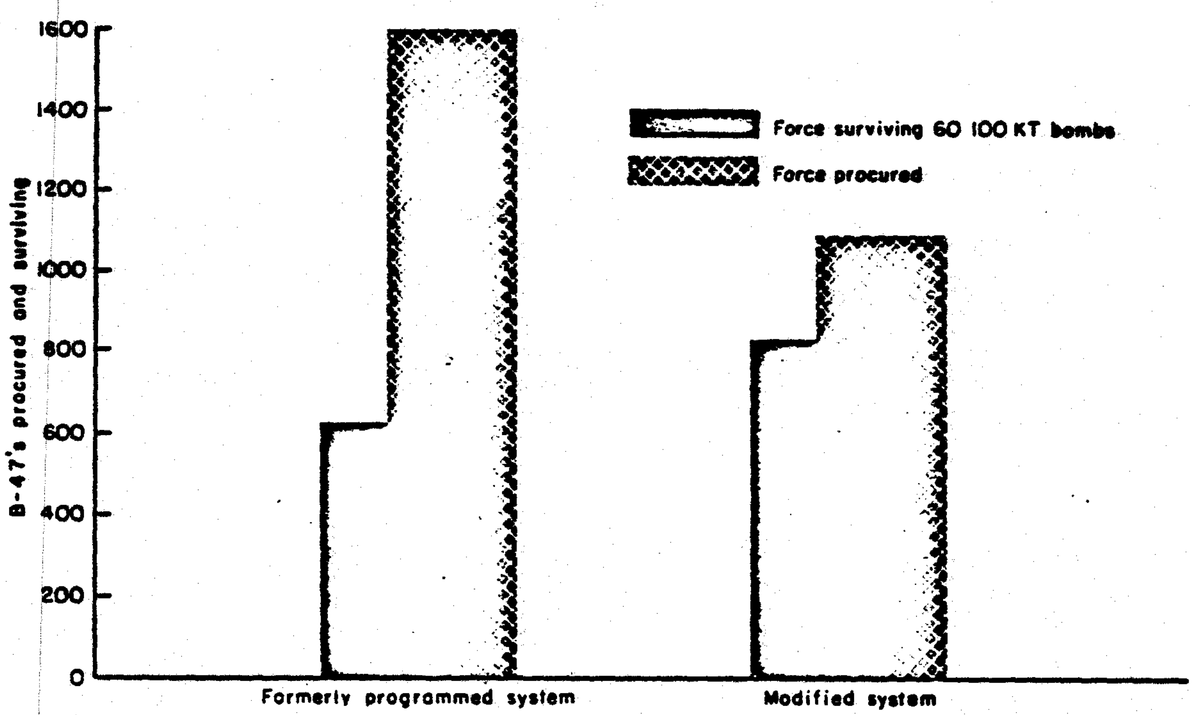

Fig. 15—Effect of augmented overseas-base defenses: overseas primary systems

now scheduled to have such warning, it may be provided by the means suggested. The cost of this measure is small in comparison with the damage that it would avoid.

By 1956 the vulnerability of overseas operating bases is likely to be unacceptably high. It is possible to reduce this vulnerability by applying the measures described above, but the success of such defense measures depends critically on enemy capabilities. It is also possible to reduce vulnerability by an essentially different strategic base system: one using operating bases in the United States in conjunction with overseas refueling bases. Like evacuation measures in the United States, this ground-refueling system overseas makes it improbable that our bombers will be caught on the ground. The probability of success of such measures, which reduce the chances of our being on base when enemy bombers reach the bomb-release line, is comparatively unaffected by a wide range of possible increments in enemy capabilities.

Defense of Overseas Refueling Bases. The study examined a strategic system with refueling bases as the sole overseas element. For the purposes of this study, the refueling system has been assumed to include all the bases now scheduled for use as either refueling or operating bases.

Detailed study of overseas refueling bases showed that defense may be achieved economically by (1) having many more bases than are demanded by traffic requirements; (2) reducing the period of exposure of aircraft on bases (2 to 3 hr for a base near enemy territory; for more remote bases, safe periods are more extended) and employing a base-use pattern that would make it improbable that the enemy would find the bases occupied; (3) dispersal, multiplication, and blast-protection of minimal facilities to reduce physical vulnerability; (4) active defense even when bases are unoccupied (10 wings of interceptors, 35 battalions of Loki weapons), and, when some of the bases are occupied, concentration of fighters (and addition of 10 wings of fighter escorts) at the points of occupancy; and (5) establishing a damage repair and recuperation capability. The multiplicity of these bases, the physical toughness of the few fixed installations, and their considerable active defense would make them unprofitable targets (even assuming quite large Russian stockpiles of A-bombs and long-range bombers) so long as the bases were unoccupied by bombers.

Figure 16 (which shows, for one attack strategy, the percentage of the total bombing force at risk in the refueling-base system at various times during the first month after D-day) illustrates one of the most important features underlying refueling-base defense. Even if attacked at precisely the hour of maximum concentration, only a quite small percentage of our force is risked (for some attack strategies, a percentage comparable with the unevacuable part of our force on interior U.S. bases having adequate warning). Moreover, even allowing for extensive intelligence information on the part of the enemy, we can, by using feinting tactics, random strategy, and the like, make his expectation of finding us considerably less than that indicated at the hour of maximum concentration. The feints, supplemented by such devices as B-47 dummies on the refueling bases and by the active defenses assumed, could mean a very substantial waste of enemy bombs and bombers.

A U.S.-based bomber force operating through an overseas refueling-base system so defended would suffer extremely low ground attrition compared with an overseas-based force. The projected 1956 system of operating and refueling bases would require only moderate extension and modification to adapt it to such use. A strong overseas refueling-base system would be tactically as well as politically feasible. Moreover, refueling bases (like U.S. operating bases, but

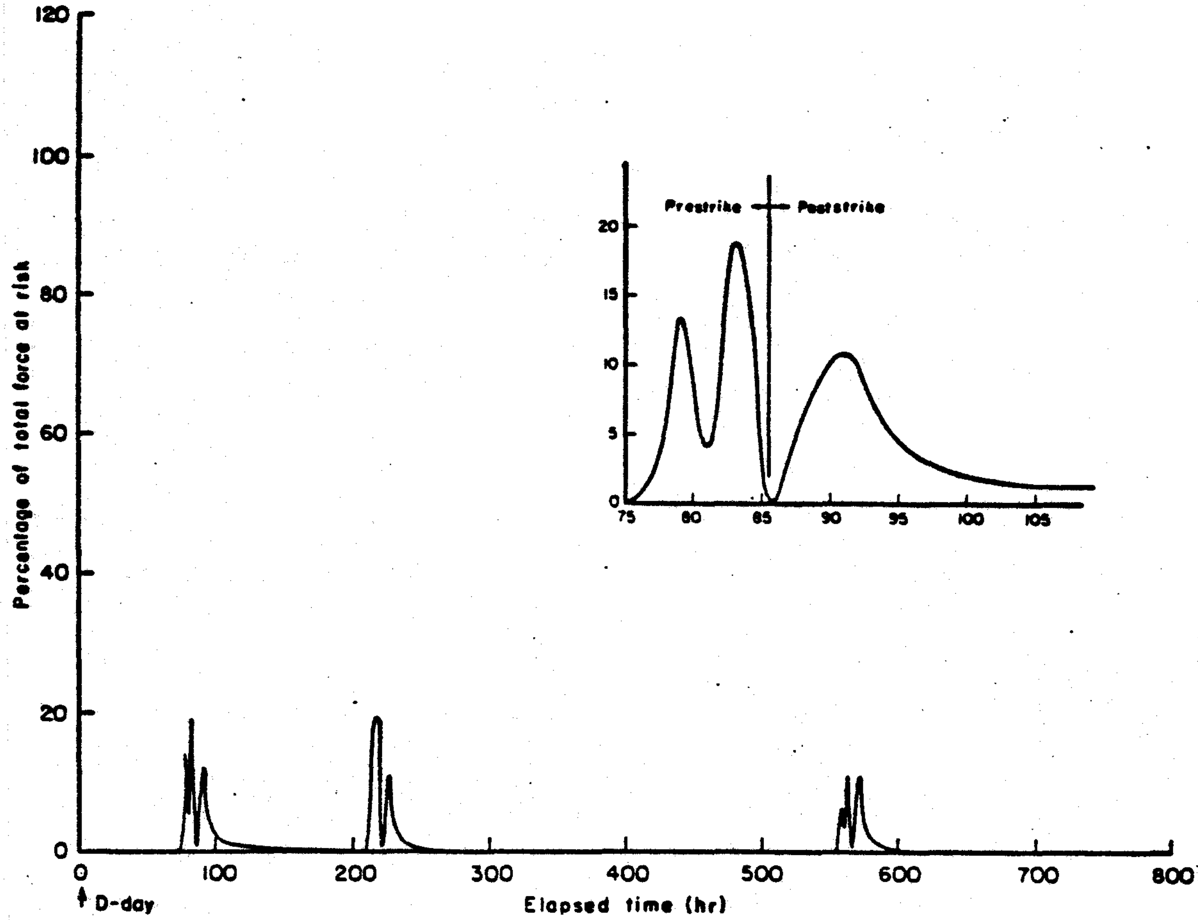

Fig. 16—Refueling-base occupancy

unlike those operating overseas) would not increase sharply in vulnerability with even rather large changes in the number of bombs and carriers the Soviets might commit to an attack on the U.S. strategic force.

Summary of Base Defense and Expected Damage

1. The unmodified overseas operating base system will be extremely vulnerable in 1956.

2. While SAC cannot be made invulnerable, its vulnerability can be reduced by a variety of measures which save more than they cost. No one measure suffices for the defense of the strategic force; many are required in combination.

3. The best of these combinations of measures involves as a major component the absence of the critical vulnerable elements when bombs are released over the base. This means measures enabling evacuation in the United States, and measures reducing and making irregular the time spent on bases overseas.

4. With such measures it is feasible to preserve the majority of our strategic bombers from enemy bombing attacks, even assuming very high enemy offensive capabilities and commitment to the task of destroying SAC.

5. Defense methods which leave our bombers on base at the time of attack depend very much for their success on limitations in the enemy capability. This is true of the augmented defenses examined for overseas primary bases. Multiplication of operating bases can be matched by a proportional multiplication in the enemy bomb stockpile. Dispersal within a base can be matched by the increasing yield of enemy bombs and active defenses by enemy countermeasures and by the increased apparent size of enemy attacks.

6. In comparing the destructive power of the four broadly different alternative systems for basing the B-47, it is important to include both the costs of appropriate base-defense measures and also the specific effects of enemy bomb damage on each system.

There are some measures necessary to reduce vulnerability that are common to all the systems we are comparing. These are the measures for the hardening of critical facilities both in the ZI and overseas, and (since all the systems involve a ZI component) for protecting aircraft on the ground in the ZI by intensifying the evacuation program. These measures are effective and essential. But the most critical problem is the protection of bombers overseas. The analysis makes it clear that edging back, as in an intermediate base system, does not significantly reduce vulnerability to an atomic attack. It is clear that from the standpoint of vulnerability, it is important to be as far back as possible. However, leaving the refueling function forward involves much smaller risks of damage than advanced operation.

COMPARISON OF BASE SYSTEMS

The effects of the operational distances (base to target, base to enemy border, etc.) have been discussed separately. In reality, they interact. The joint effect of these operational-distance variables has been studied in a comparison of several widely different strategic base and aircraft combinations. The systems compared are those described earlier: (1) an exclusively air-refueled intercontinental B-47 system, (2) a ground-refueled intercontinental B-47 system with a tanker supplement, (3) a B-47 advanced operating overseas base system (with local dispersal, more radar and active defense), and (4) an intermediate overseas operating base system (with an appropriate level of active and passive defense). In these final comparisons, a considerable number of plans with alternative force requirements were tried for each of the competing U.S. offensive systems. Each system was matched against an enemy defense and offense and deployed to take some advantage of its characteristic weaknesses. On the other hand, tanker-bomber combinations, routes of deployment and penetration, and active defenses were chosen so as to exploit advantages of each system and to reduce its force requirements and cost. Appropriate additional defenses for the overseas operating base and refueling-base systems have already been described. In all systems the U.S. bases are well within the early-warning network. The costs, both of these defenses and of the ground damage to be expected for various Soviet bombing force and bomb assignments, have been included in the total cost required by each system to destroy various Russian target systems.

Although the bombers and the U.S. operating-base locations are the same in all the systems compared, and although their methods of defense are in all respects identical except for those aspects associated with the concepts of operations, the differences in campaign costs are striking. The intercontinental exclusively air-refueled system is decidedly inferior to the intercontinental ground-refueled system. The advanced overseas operating base system studied is, assuming a low enemy commitment against SAC (30 100-KT bombs and 200 TU-4's), intermediate in effectiveness between the two intercontinental systems. However, its cost and effectiveness are very sensitive to the assumption regarding the number and size of enemy bombs committed. Given a higher enemy commitment (120 100-KT bombs and 400 TU-4's), its cost reaches that of the intercontinental air-refueled system. The intermediate overseas operating base system, which combines the high radius-extension costs of the intercontinental air-refueled system and the vulnerability of the advanced overseas operating base system, makes the worst showing of all. It is expensive for a low level of enemy offensive commitment and sensitive to increases in the level of commitment. (Both the relative standing of the overseas operating base systems and their sensitivity to differences in enemy offense would be shown to be worse if Fig. 17 included the indirect effects of ground attack as well as the direct damage to bombers.) These results apply to a campaign in which the air-refueled and overseas operating base systems withhold bombers to cut support and ground-loss costs, etc. If, in accordance with Air Force doctrine, nearly all combat-ready bombers were used, the inferiority of both systems would be even more marked.

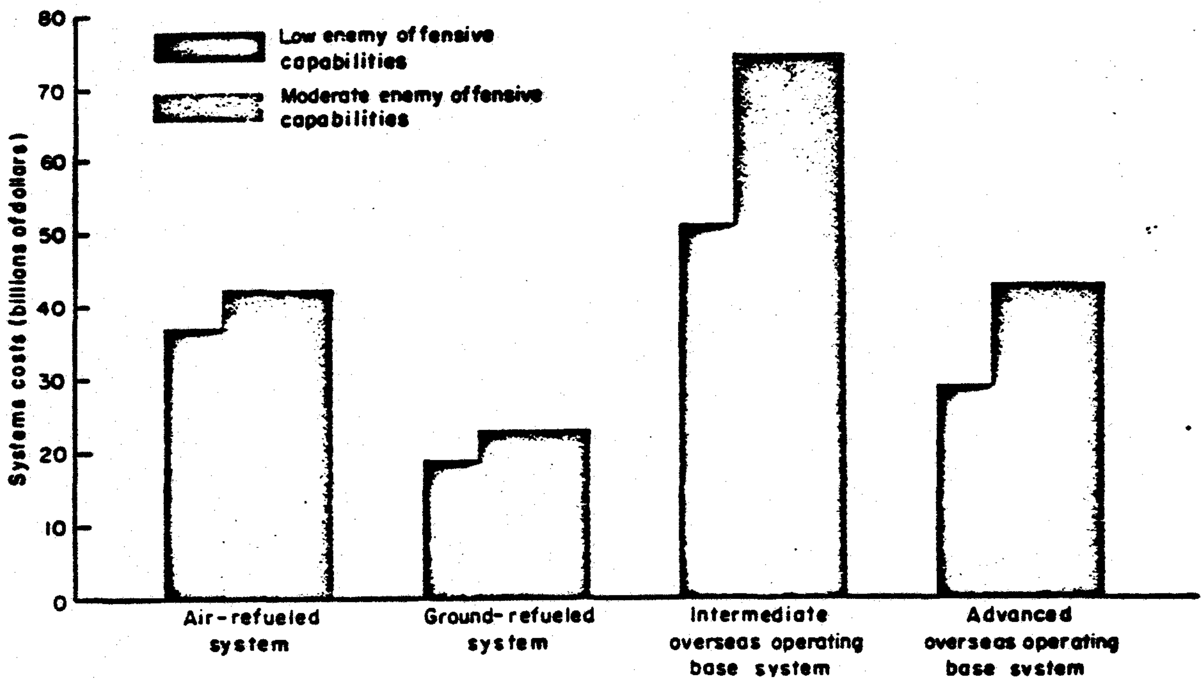

Fig. 17—Intercontinental and overseas operating base systems: cost to destroy an industrial-target system in the face of enemy A-bomb attack

UNCERTAINTIES IN ENEMY DEFENSE AND OFFENSE CAPABILITY

Since all systems use the same bombing aircraft, the results are unaffected by wide alterations in the *total* enemy defense capability. The results are affected somewhat by the allocation of enemy defenses between area and local defense. The assumed local defense may be high relative to the assumed area defense, but a downward adjustment would worsen the relative position of the air-refueled system still further and so would not change the results. It has already been demonstrated that the effectiveness of an overseas operating base system is likely to vary markedly with the magnitude of enemy offense capability (e.g., A-bomb commitments to attacks on our bases), whereas that of a ground-refueled system is relatively unaffected.

In studying campaigns conducted with reserves against both air and ground losses, it was assumed, as is the custom, that the losses to be exacted by the enemy were known in advance. Even in the tests summarized above, where a range of enemy capabilities and resulting attrition was tried, correct anticipation of our losses is assumed in each case. Adjustment for the realistic uncertainties of preparing for a campaign against an enemy about whom we have imperfect intelligence would worsen further the situation of all systems which show a large difference between reserve and operating costs, for it could no longer be assumed that precisely the correct reserves could be stocked (see Fig. 18). It should be stressed that this would be an adjustment for the gaps in our intelligence about future attrition rather than for differences in attrition itself. Figure 18 illustrates the differing degradations in the percentage of targets destroyed by each of the systems if they all prepare for a specific enemy offensive capability (the same as the one assumed in the right half of Fig. 17); but the enemy capability turns out in fact to exceed somewhat our expectations.

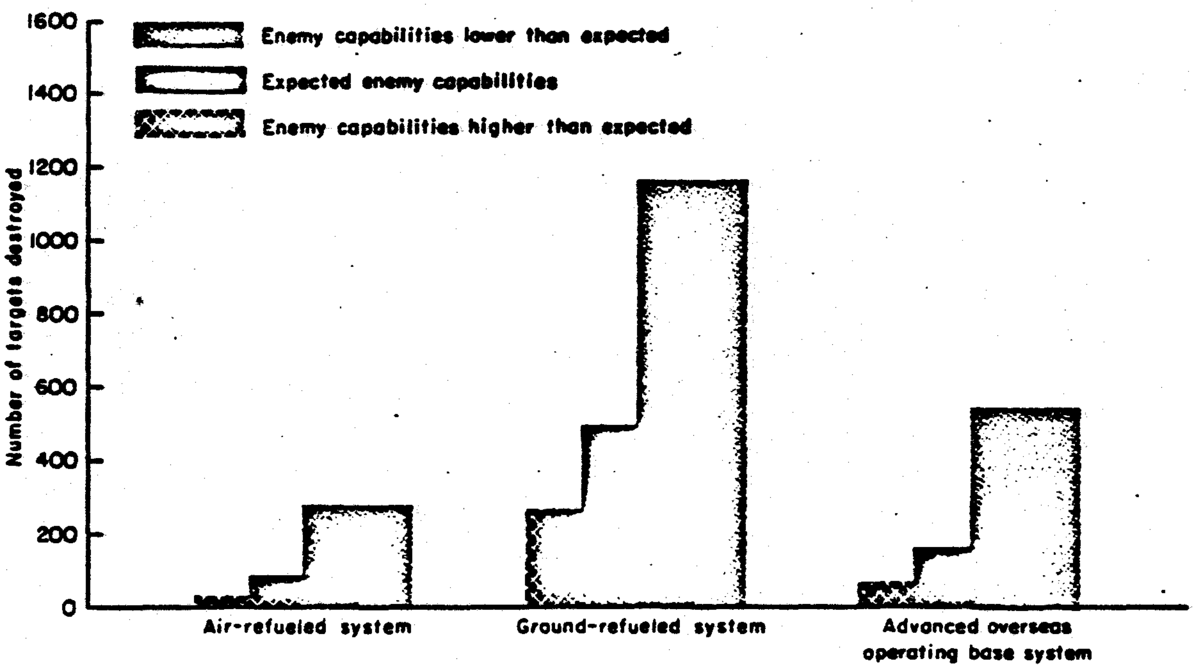

Fig. 18—Target destruction potential and uncertainty in enemy capability ($40 billion budget)

FEASIBILITY

The preferred system is more feasible than the air-refueled system, which, to destroy the same target system, would involve more bombers, many more tankers (as high as 1700 KB-36 type), more U.S. bases, and more construction money than is programmed. The preferred system requires roughly the number of bombers programmed and somewhat fewer tankers. The overseas refueling bases assumed use the sites programmed; and these are easier to obtain and to keep exclusively for refueling use than for their programmed use. The improved overseas operating base system requires operating bases in many areas not scheduled for this purpose. It also involves a great many more bombers than the ground-refueled system.

FIXED BUDGET CAMPAIGNS

The comparisons shown so far in this summary are made in terms of the relative cost for alternative systems to do the same fixed job of target destruction. If we were to use the reverse criterion and compare systems, having identical budgets, with respect to the relative number of targets they could destroy, the differences shown would be drastically increased. This is due to the effect of saturation on enemy defenses: Systems which can allocate a large proportion of their budget to buying bombers in excess of the minimum needed for saturation obtain more than the proportional benefits in increased targets killed. The intercontinental air-refueled system must spend most of its budget to procure noncombat elements, namely the tankers. The overseas operating base system must spend much of its money on logistic support, active and passive defense, and purchase of bombers which are killed on the ground. The intermediate system spends money on all of these.

The characteristic differences in allocation of funds between combat and noncombat elements are responsible for some of the rather surprising differences in the time developments of the campaigns.

FLEXIBILITY AND CAMPAIGN TIME

Bombing aircraft operated at intercontinental distances are expected to have lower sortie rates than those operated from advanced bases. In the case of a ground-refueled system this does not mean a longer campaign than for an overseas-based system. In both the overseas operating base and air-refueled systems, the strike rate, using a tactic of holding bombers in reserve, is limited by the operating support force (available tankers in one case, and overseas operating bases, logistic support, and active defense in the other). To increase the support force to the point where all the available bombers could be sortied in one strike would be extremely expensive. For the ground-refueled system the extra cost of providing support for the entire force would be moderate. Inexpensive extra support would increase the potential strike rate of the ground-refueled system and permit it to finish a campaign not only at lower cost, but also in at least as short a time as any other system. In short, a ground-refueled system has a marked advantage in flexibility of strike size, rate of strike, and proportion of the target system attacked. (It also has greater flexibility in choice of route and in choice of flight profile.)

The overseas operating base systems have an advantage in shorter mission time, which, it seems, would permit more frequent sorties per bomber. Several points should be observed. First, the importance of high sortie rates for a World War III atomic campaign against Delta targets is much less than for campaigns with high explosive, of the World War II type, in which damage had to be administered cumulatively, a little at a time, and from which recuperation was relatively rapid. (This diminished significance is implicit in the Air Force's desire for an intercontinental mission capability.) Second, the proportional increase in sortie rate with decreasing mission distance is qualified by a number of difficulties, most important of which is the effect on our sortie capabilities of enemy attack. This in fact can reverse the apparent advantage. Finally, however, even if we assume the sortie rates of individual bombers on overseas operating bases to be twice those of similar bombers based in the ZI, the campaigns show that the ZI-based ground-refueled system can achieve a higher rate of destruction for a fixed budget. The essential reason for this has been indicated: An overseas operating base system cannot spend enough of its budget to buy bombers with the hypothetically high sortie rates. It must allocate its budget to logistic support, defenses, and bombers, many of which are killed on the ground before sortieing at all.

OPERATING OVERSEAS AFTER THE "BRAVO" CAMPAIGN

The analysis indicates clearly how increasing Russian atomic capability makes overseas operation of the strategic force unacceptably risky. What of the possibility of strategic operation after the destruction of the enemy air force? The likely difficulties in conducting a successful Bravo campaign against the Russian strategic force are suggested by the feasibility of a successful defense of our own SAC. Russian bombers may be home-based deep within their radar network, with plenty of warning to permit evacuation. Northern peripheral bases may be used for staging only, and critical facilities may be hardened to make a base denial campaign difficult. The enemy may use a large number of alternate bases in an emergency. Furthermore, the Bravo campaign required to make continuous occupancy of the overseas bases safe is much more extensive than that which is generally understood by the designation "Bravo," i.e., a mission to blunt the Russian attack against the ZI. Since a large fraction of these bases are within IL-28 radius and even one-way MiG range, nothing far short of the destruction of the entire Russian air force is required. Finally, we have a disadvantage not suffered by the Russians in that we have incomplete (and increasingly incomplete) information as to the location and function of their various airports. For such reasons, by the time the destruction of Russian atomic-delivery capability has advanced to any substantial degree, the major Delta targets, which are much softer, will have been destroyed. (This is indicated by the results of several joint Bravo-Delta campaigns which have been tried.) The part of our force that is unattrited at that point can be expected to be substantially less than the total force, and, most important, our principal atomic strategic job will have been done by the time it is safe to move overseas to operate.

LIMITATIONS AND FLEXIBILITY

The results presented here have been derived from campaign comparisons in which many elements were varied and some were fixed. The study analyzed, in the context of campaign, only the programmed bombers. In most of the campaign analyses, only one target system was used—a Russian industrial-target complex. It is natural to ask whether the demonstrated superiority of a ground-refueled home-based system would be confirmed by additional analyses in which these other fixed elements were also varied realistically. The composition of our potential bombing force is increasingly variable when later time periods are considered. And although Russian industry is the most familiar target postulated for our strategic force, it is not the only objective: long-range interdiction and the destruction of the Russian long-range air force are other prominent objectives.

Against long-range interdiction targets, the overseas operating base systems have an advantage in coordinating the bombing schedule with rapidly changing requirements for retardation. And, even for industry bombing, there are circumstances in which they would appear in a more favorable light. Some of the difficulties in achieving our counter-air objectives have been suggested. Nonetheless, if the Soviet atomic-delivery capability could be destroyed (although it seems doubtful that this could be done before the completion of the major part of the Delta mission), or if it should turn out to be much smaller than is expected, then, once this was known with confidence, overseas operating bases could be more favorably regarded for industry bombing.

However, one of the merits of the recommended system is its adaptability. Refueling bases could be converted to operating bases if desired and might be combined with a certain number of overseas operating bases used in connection with retardation targets. Similarly, the ground-refueled system could permit the economic use of penetration fighters. This would hardly be feasible for the air-refueled case considered. And for high-performance bombers, the ground-refueled system would provide great flexibility in the choice of routes, speeds, and altitudes of penetration and make possible the large payloads that might be demanded in connection with the advent of H-bombs.

A growing Russian defense forces us to the use of high-performance comparatively short-radius bombers. At the same time, an increasing Russian offensive power will compel us to keep as much as we can of the vulnerable part of our strategic complex a long distance from the enemy's borders. In such a world, a system for basing our bombers at home within the cover of our radar network and extending radius to target by means of dispersed overseas refueling stations appears to be important for a large part of our strategic task; and it is capable of combination with methods suited to accomplish the rest.

CONTENTS

PART I: THE CONTEXT

A. The Base Systems Evaluated

THE FORMERLY PROGRAMMED SYSTEM FOR 1956

With its ingenious Mobility Plan as an essential feature, the Air Force had developed a strategy for the basing and use of its 1956 bombing force in a period of low SU atomic capabilities. The programmed use took into account both the restricted unrefueled radius of the projected bomber force and the vulnerability of the base areas. This strategy is the necessary point of departure and standard of reference for a study of alternative base systems. Accordingly, its major and more or less stable elements are described below. The strategy was never hard and fast. It is now in the process of rapid change, particularly in the matter of base defense. The following outline indicates the major planned features of the base system as of a year ago.

The bombers programmed for operation in 1956 included approximately (1) 1600 B-47's and RB-47's, (2) a wing of B-52's, and (3) 300 B-36's and RB-36's. The combat radii of these aircraft with A-bombs, according to the usual national military establishment rules, are, respectively, 1750, 3060, and 2950 n mi. The actual radii these planes will attain on a bombing mission will be smaller than the figures shown, depending among other things on the condition of the plane, pilot technique, and the necessities of mass formation flights. A tanker force consisting mainly of 720 KC-97's is also projected. As the B-52's come into the force, the B-36's are expected to be phased out—perhaps to be used as tankers, as carriers of small reconnaissance planes, etc., in varying proportions in the next years. In any case it is clear that for some time to come our bomber force will be composed primarily of medium bombers with a radius of 1750 n mi.

Up to the outbreak of war, roughly three-fourths of the medium-bomber portion of this force would be based on some 30 fields in the United States (see Fig. 19). The force would be supported by several Zone of the Interior (ZI) depots, two of which would contain most of the spare parts for the B-47, with five depots supporting types of strategic bombers. The other one-fourth of the force would be deployed on rotation on perhaps 14 of the 30 foreign

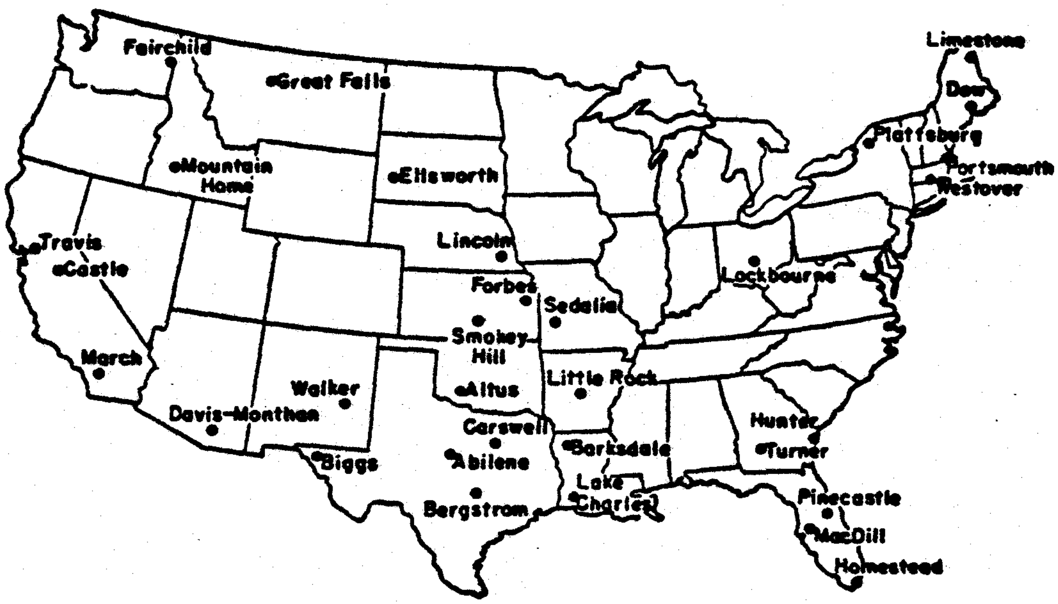

Fig. 19—ZI SAC bases

operating bases in accordance with the SAC overseas rotation program. The U.S. bases closest to Russia—Limestone, Maine, and Fairchild, Washington—are anywhere from 3300 to some 6700 n mi from major Russian industrial targets, if distances are measured along flight paths which minimize the distance traveled through enemy defenses and which take into account some of the realistic requirements affecting the choice of refueling points. These distances of course exceed in length the great-circle measurements.

After the outbreak of war, the Mobility Plan called for the moving of substantially all combat-ready medium-bomber wings overseas to operate from an extensive system of foreign bases.* The movement of wings under this plan was to be accomplished with the aid of transient airlift consisting of about 40 trips by aircraft of a capacity equivalent to the C-54 for every medium-bomber wing. The combat aircraft would carry a large part of the personnel and equipment needed for 100 flying hours. They would remain at the overseas bases for several days en route to the targets for their first strike. The

*Since early in 1954, however, revisions in Air Force plans have moved away from sole reliance on this method of operation for medium bombers. As of the date of publication of this report, the Air Force appears to contemplate operation of some medium-bomber wings from the ZI, staging them through overseas bases in a manner similar to that discussed below. Therefore, when reference is made to a base system which utilizes overseas operating bases for all medium bombers, it will be called the formerly programmed system.

supporting elements of the wing would follow the combat aircraft overseas, with almost all the air echelons of the wings expected to be transferred in about 2 weeks.

The heavy bombers are expected to operate in a way essentially different from that projected for the medium bombers. After the outbreak of hostilities, the heavy bombers would continue to maintain their base of operation in the United States, using the overseas bases largely for staging purposes only. They would, however, be on these overseas bases for considerable lengths of time to permit crew rest, etc.

The overseas base system will consist of some 82 bases. As of 1952, some 32 of these were expected to be operating bases, and the remainder, staging bases only. The 143-wing program called for 24 overseas operating bases for medium bombers, and for 58 other bases, consisting of strategic fighter operating bases, heavy-bomber, medium-bomber, and strategic-fighter staging bases, and emergency bases. Some six major depots were projected to support this strategic base system.

overseas SAC —
82 bases
32 - operating
50 - staging

Figure 20 indicates the approximate position of these bases. Formerly it had been anticipated that about two-fifths of the overseas bases would be in two areas, the United Kingdom and French Morocco, the remainder being rather widely distributed. The bulk of the staging bases, but none of the operating bases, were expected to be in the Middle East. Some of the areas in the Middle East are now regarded as also being possible operating base sites. The radii to nearest Russian industrial targets from appropriate parts of this base system are anywhere from 350 to 3000 n mi if distances are measured along flight paths which minimize distances flown through enemy defenses.

The preceding description roughly characterizes the programmed base system with respect to its employment in attacks against targets in Russia. A description follows of some of the characteristics of this base system as itself a target—a possible object of attack from Soviet or satellite countries.

It is clear that all the U.S. ZI bases are beyond the unrefueled two-way radius of the TU-4 bombers which are anticipated to be the principal components of the enemy's long-range air force in 1956. They are, however, within one-way range, and, with the aid of refueling techniques, the enemy could approach all our bases from a variety of angles. Eighteen of these bases are situated near the Atlantic or Pacific coasts or along the Canadian border. These bases are close enough to the edge of early-warning network to have less than 2 hours'

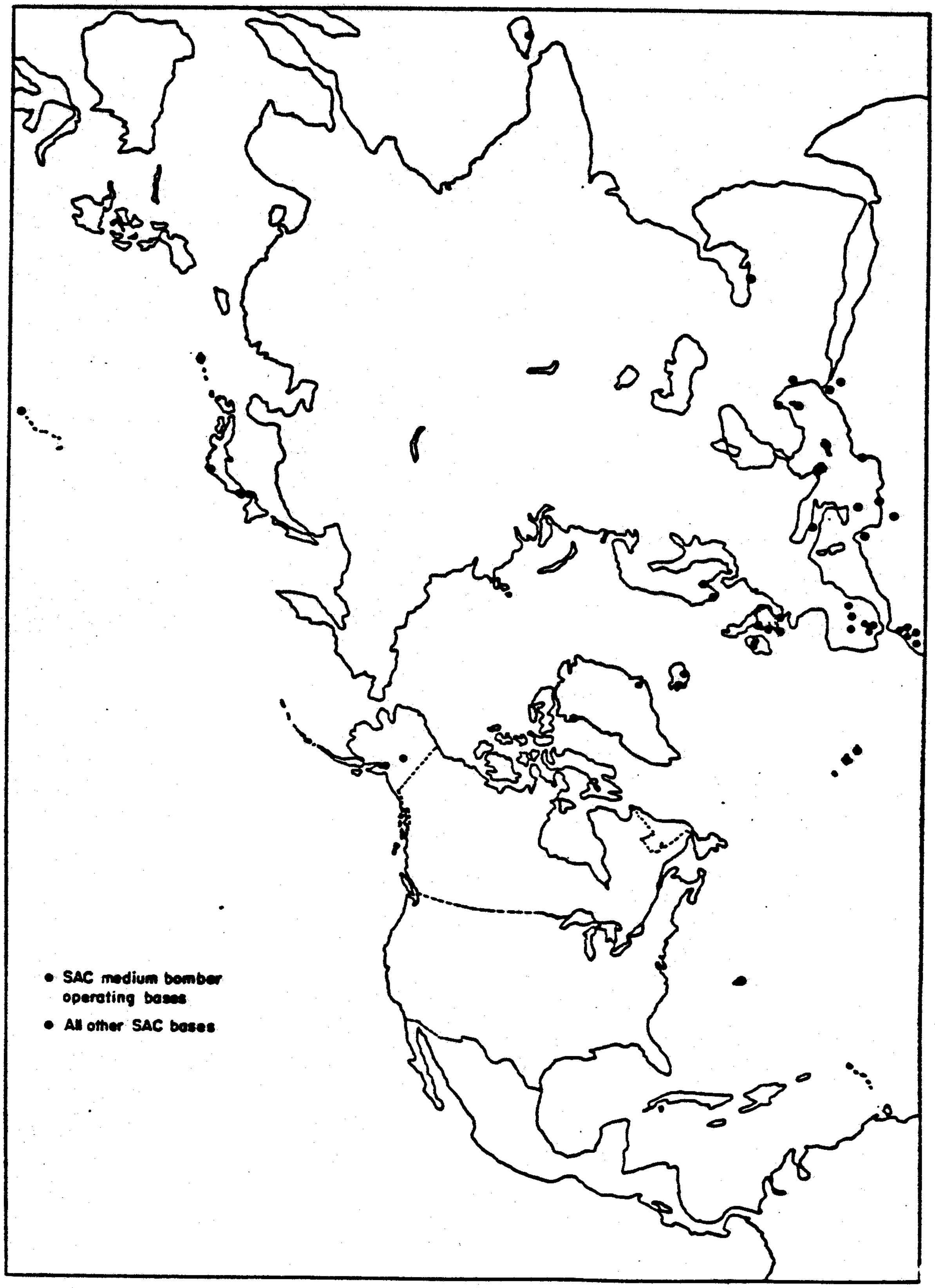

Fig. 20—Overseas SAC bases

warning and some will have under 1 hour's warning. Interior bases will have over 2 hours' warning as will those in the south, unless the Russians can follow minimum-penetration routes around the periphery of the ZI.

The position of the overseas bases with respect to the Russian air attack is quite different. As those bases were planned until recently, one-third of all the operating bases would be within light-bomber radius of enemy forces, and none would be beyond medium-bomber unrefueled radius. Over half the projected staging bases were to be within reach of enemy light bombers; and most of the rest, within enemy medium-bomber radius. For reasons connected with logistics, about five-sixths of these overseas bases were within 100 mi of the sea.

A considerable active defense has been planned for the protection of this base system. In the ZI, defense will be provided by the Air Defense Command. In addition, over $3 billion will be spent for some 30 squadrons of all-weather interceptors and about 40 battalions of antiaircraft to be used primarily for the defense of overseas bases. These will be stationed overseas in peacetime as well as wartime for the defense of both operating and staging areas. In addition, some 10 wings of strategic escort fighters, deployed in accordance with the Mobility Plan, will be available for base defense at the critical times when the bombers are on base. Varying amounts of protection will also be provided by active defense forces intended primarily for other purposes—the Navy, NATO, etc.

For the passive defense of the system, in contrast, rather moderate amounts are to be expended. Viewed in the large, it is apparent from the description above that there is to be a considerable concentration of the vital elements of the strategic force in relatively few bases and depots. Analogous comments apply to local concentration of functions within specific bases and depots. In the ZI, aircraft are parked on hardstands and grouped closely to economize on construction costs.* The buildings are, in general, located near the optimal bomb aiming point for the aircraft and have been constructed in accordance with regulations calling for economies in construction and operation through concentrations of structures within the limits of the standard fire safety clear-

*The criterion suggested in MCAIZD-2: ML: mgr, January 31, 1950, is "the minimum clearance necessary to reduce the detrimental effects to engine blasts on equipment and/or personnel employed on or near aircraft parked to the rear."

ances.* Bulk storage of petroleum is generally accomplished in a single tank farm, frequently above ground. Operating storage of fuel is usually below ground. Aircraft supplies, it appears from AFR 86-4, are generally situated as close as can be managed to the maintenance and repair shops. No systematic attempt is made to disperse the storage of a given item. Overseas, passive defense measures have been used somewhat more than in the ZI. There is a trend toward the use of a larger number of operating bases, and the individual bases are on the whole larger and more dispersed than in the ZI. However, the forms of dispersal are designed for protection against high-explosive attack and would be comparatively ineffective against atomic weapons.

As one important measure for the protection of its force based in the ZI, the Air Force has developed an evacuation plan. If warning of an enemy attack is received in sufficient time, the crews of all combat-ready planes will assemble; the necessary equipment needed for 1 month's operation overseas as specified in the Mobility Plan will be loaded on the planes; and bombers will be immediately deployed overseas. If there is not sufficient time to complete preparations for deployment, all flyable aircraft for which skeleton crews are available will be flown to predesignated orbiting areas until the danger has passed. These planes will return to home base if possible; otherwise, to predesignated alternative emergency fields.

While some of the specific numbers were altered from time to time—the proportion of operating to staging bases, of medium bombers to heavy bombers, and so on—the general outlines of the formerly programmed system are clear. It was a system made up mostly of medium bombers, based in the United States in time of peace and moving overseas in time of war, with some heavy bombers based in the United States using the overseas areas for staging only.

THE REVISED OVERSEAS OPERATING BASE SYSTEM

We shall refer frequently to the destructive potential and vulnerability of a second base system, closely related to the formerly programmed system for

*AFR-86-4, *Master Planning*, March 23, 1951, reads, in part: "a. Building Area. The building area should be planned to minimize the distance traveled by personnel in performance of their duties. Housing area for school troops should be located as conveniently as practicable to the school structures and technical area, and base personnel should be housed close to industrial, utility, and administrative areas.... Consideration will be given to the maintenance of required fire breaks and building separations in all planning. b. Warehouse Area. Warehouse and storage areas should be located to minimize the amount of construction required for railroad spurs and access roads.... In many instances, it is advisable to locate the warehousing area adjacent to, or as an integral part of aircraft maintenance and repair shops and within the prescribed distance from main crash and fire station to avoid the need for additional fire stations."

basing medium bombers. Like the formerly programmed system, it involves the location outside the country of operating bases—i.e., bases to which bombers return after each strike in the war and where, in general, they remain during the intervals between strikes. What is more, the specific locations of these bases are assumed to be chosen from among the 82 overseas locations now programmed. For some of the campaigns studied, something less than the total 82 locations is required. For other campaigns, used for testing the value of squadron dispersal, more than 82 bases are assumed. (In the latter campaigns, the extra bases are assumed to be distributed geographically in the same way as the other 82 bases.) As in the programmed system, a moderate number of tankers is required as a supplement to the programmed overseas bases. These are needed especially for penetrations to the North Russian targets by the B-47. However, this revised overseas operating base system differs from the formerly programmed system in that the overseas bases are more strongly defended: (1) The individual bases are altered to reduce the physical vulnerability of the elements on the base, petroleum storage is dispersed and, where possible, placed underground, aircraft parking is spread around the periphery of the base, and underground or other blast-protective shelter for personnel and essential supplies and equipment is provided; (2) the operating force is defended by very much more local defense (Loki- and Nike-equipped antiaircraft battalions) and by approximately the same interceptor force as that programmed; and (3) it has more radar cover, especially at low altitude.

These points of difference from the formerly programmed system distinguish the revised overseas operating base system. Other points of difference it shares with the two alternative systems to be described next. Like them, it differs from the programmed system in that it has a more elaborate passive defense for its ZI bases. The main aim of this extra passive defense is an increase in the probability of evacuation. This means more radar, the transfer of bases to the interior, and modification of the Air Force's evacuation plan to increase the number of planes evacuable at a given time. The major modifications, which are described in detail later, include (1) separation of the problem of evacuation from the problem of deployment, (2) the holding on base at all times of a minimum evacuation crew for a substantial proportion of the aircraft, and (3) provision of egress taxiways, wherever feasible, to permit the taxiing or towing of nonflyable aircraft off the field.

INTERCONTINENTAL AIR-REFUELED SYSTEM

This system employs operating bases in the ZI only and relies exclusively on air-refueling to extend the radius of our 1956 bomber force to targets. For protection of the aircraft in this system, it is assumed, as has been indicated in the preceding description, that both tankers and bombers operate from bases well within the cover of the early-warning network in war as well as in peace. To facilitate measurement of the tanker requirements, it was assumed that the bombers and tankers both stage through bases in the Limestone or Spokane regions. Bombers and tankers are assumed to be based jointly. Because of the large number of tankers required per bomber in the force, this results in considerable multiplicity of bases and dispersal of bomber operations.

Where, as is invariably the case with the medium bombers, the assistance of more than one tanker is needed to extend the radius to Russian industry targets, it is generally assumed that there will be no more than one meeting point for fuel transfer on the target-bound leg of the mission, and no more than one on the home-bound leg. This is assumed in order to reduce the difficulties of rendezvous. And while it diminishes somewhat the uncertainties of multiple refueling, there remains considerable question as to the operational feasibility of this system. The analysis proceeds, on the assumption of feasibility, to trace the costs involved.

INTERCONTINENTAL GROUND-REFUELED SYSTEM

This system, like the preceding one, keeps primary bases for operation against Russian industry well within the cover of the U.S. radar net in wartime as well as in peacetime. Bombers start from the ZI and refuel overseas poststrike and in some cases prestrike and return to their home bases in the United States after each strike. In the interval between strikes, they remain in the ZI. The time spent on overseas bases is shortened by limiting the function of these bases essentially to refueling only. No crew rest is provided on these bases; crew exchange is used instead. The overseas bases, while minimal in function in the sense that they are confined essentially to the purpose of refueling, are not minimal in the equipment provided to fulfill this function. A high-speed hydrant refueling system is assumed, having a larger number of hydrants than is presently programmed for overseas bases. The runways and taxiways meet the full requirements for a permanent bomber base according to the standard Air Force criteria. They have in fact been designed to provide greater passive defense through dispersal in parking and the availability of taxiways or emergency runways. All petroleum storage, both the bulk storage as well as the operating storage, is underground and dispersed. Shelter, in some cases underground, is provided for the small number of elements of the base requiring protection against blast, such as the hydrants themselves and the few people on the base.

The overseas base locations used for refueling in this system, except where noted, are assumed to be those now programmed for either operating or staging bases. As in the case of both the programmed and the revised overseas operating system, a comparatively small force of tankers—mostly KC-97's—is used as a supplement to extend the radius of the medium bombers to those targets, particularly in North Central Russia, which are more than 1750 n mi from the overseas base locations assumed. In addition to this, as insurance against the loss of advance bases, a portion of the bombers is assumed to be convertible to tankers in the event of such loss.

MIXED OR INTERMEDIATE SYSTEMS

Not only the programmed system, but the three additional base systems described are in a sense "mixed." They all involve a multiplicity of elements: bases, tankers, several types of bomber, etc. All but the exclusively air-refueled intercontinental system involve overseas bases. However, they do represent certain extremes. The revised overseas primary system, by accepting the overseas base locations as formerly programmed, permits focus on certain problems essential to overseas primary basing. In the analysis of this system we explore the feasibility and cost of defending against atomic attack a system in which bombers are kept overseas in the intervals between strikes. The air-refueled case uses air-refueling only for all radius extension outside the boundaries of the United States.

It is clear that we might multiply these cases without limit. And between the various extremes studied there are several interesting intermediate cases.

Mixtures of the Overseas Operating Base and Exclusively Air-refueled Cases

The exclusively air-refueled system we have described has its operating bases in the United States. Since air-refueling costs rise at an increasing rate with increasing distance from targets,* it is natural to ask about the comparative

*See Figs. 27 and 28, p. 76.

merits of an exclusively air-refueled system with its bases of operation somewhat nearer the targets. This would mean in effect combining the elements of two systems: the revised overseas operating base system and the intercontinental air-refueled system—i.e., an overseas operating base system more remote from enemy striking power (and the targets) than the revised overseas operating base system described on pages 8 and 9, and an exclusively air-refueled system closer to targets (and to enemy striking power) than the intercontinental system described on page 10. Intermediate systems of this type are dealt with in Part III. We may anticipate the results of that analysis. There is a sharp discontinuity in the vulnerability and in the costs of base defense between operating bases outside and operating bases well within the deep interceptor-backed U.S. early-warning network. This jump in the cost of defense and expected damage to elements on base, coupled with the added logistics cost of operating outside the country, must be set off against the reduction in expenditures needed for tankers obtained by moving closer to the target. This intermediate case combines some of the weaknesses of both systems—much of the vulnerability of the advanced overseas operating base system and some of the high radius-extension cost of the exclusively air-refueled system.*

Mixtures with the Ground-refueled System

Another type of intermediate system that might be studied would combine elements of either of these two major alternatives with the ground-refueled alternative; e.g., a system involving intercontinental operation with prestrike air refueling and poststrike ground refueling, or an overseas operating base system beyond unrefueled TU-4 radius from Russian borders supplemented by refueling bases closer to targets. Such systems are also dealt with briefly in Part III. They are intermediate in effectiveness, and their cost lies between that of the intercontinental ground-refueled operation and the other major alternative studied.

*Where reference is made below to an overseas operating base system, it will be the advanced overseas operating base system that is meant. The intermediate overseas operating base systems will always be so labeled.

B. Criteria for Base Evaluation: Objectives, Obstacles, Uncertainties

Figure 21 shows a RAND industry system which is taken as the object of destruction in some of the campaign analyses presented in this report. This is an extensive system of aiming points covering a very wide range of Russian industry. In the majority of the campaign analyses presented in this study, however, a narrower target system is used, which consists of 100 RGZ. The specific aiming points (RGZ) selected in this narrower system account for a large proportion of USSR capacity in steel, petroleum, nitrogen compounds, aircraft engines, and motor vehicles. (And given the lethal radii of bombs used in the campaigns presented, the destruction of these aiming points carries with it as a bonus a rather high probability that a good many plants—roughly, an equal number—in other industries will be destroyed at the same time.) It is clear that a successful campaign against this target system would seriously reduce Russian capability to wage war. However, for our purposes the essential traits of this target system concern its geometry. This is more or less typical of other Russian industrial-target systems, with some deep-penetration targets, a scattering of targets in the Far East and Central Russia, and much the heaviest concentration in Western Russia; a considerable number of targets are below the summer darkness line and a large number are in the summer daylight region.

The geographic distribution of the 100-RGZ system, the aiming points of which are all included in the larger target system, is very similar to the one shown in Fig. 21.

We shall use, as a criterion for choosing among the various base systems compared, the least cost to destroy, in the first two months of the war, the major part of these fixed Russian industry-target systems. And we shall also compare systems in terms of the reverse criterion: the number of industry targets they can destroy on the basis of various budget expenditures. Such a procedure for comparing base systems in terms of their ability and cost to achieve this well-known objective of our strategic force appears straightforward enough. In fact, it is not. The objectives of our strategic force are considerably more complex than their usual representation as a "phase 1"

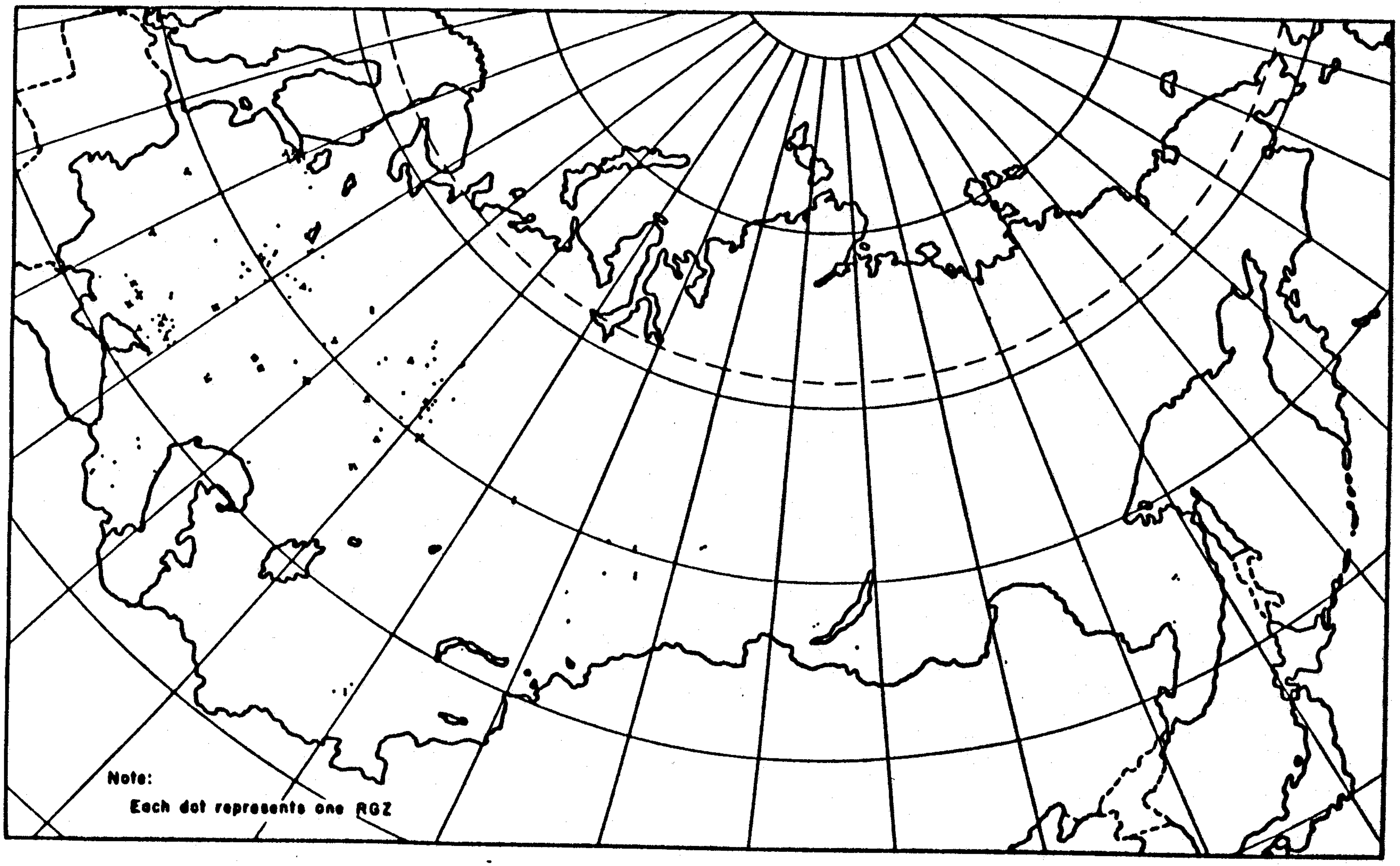

Fig. 21—250-RGZ target system

A- or H-bomb destruction of Russian heartland industrial targets. They are multiple, more complicated in time pattern, themselves affected by base choice, and in large measure contingent and uncertain.

OBJECTIVES OF THE STRATEGIC FORCE

Targets

First, consider the targets. The Joint Chiefs of Staff (JCS) have made it explicit that our strategic force has targets of the highest priority besides Russian industry—the air bases of the Soviet long-range air force, and long-range retardation targets. The first of these appears to be of vital importance in the defense of the United States; the second, in the defense of Western Europe. The strategic force may, moreover, be called on to attack satellite targets with nuclear weapons; to deliver high explosives against friendly and neutral areas overrun by the enemy; or, in later phases of a long war, which might exhaust our stock of nuclear weapons, to deliver high explosives against Russian targets. It might be required to attack urban areas rather than specific "point" targets, such as industrial plants. If the war develops along lines requiring reoccupation by NATO forces of all or most of Europe, it may have an important role to play, with or without A- or H-bombs, in preparing for such reoccupation. And as Korea demonstrates, it may be called on to play a quite different role, involving high explosives only, in peripheral "warm" wars. Aside from these hot and warm wartime objectives, our strategic force is also supposed to serve a peacetime purpose which is related to but distinct from its capabilities in the event of war—namely, deterrence. In fact, the purpose of our bombing force has been stressed* as being primarily deterrent and only secondarily contributing to the winning of a war, once started. Preparing a deterrent force is not necessarily identical with preparing a force capable of the maximum contribution to victory once the war has begun.

Timing

Second, consider the question of the timing or phasing of the strategic bombing attacks. Time figures in both the popular and the official versions of the purpose of the strategic force. Its importance is generally expressed in the description of our goal in terms of an immediate response to attack, start-

*See, for example, Secretary Finletter's speech before the Patent Law Association of New York, February 26, 1952, in *USAF Research and Development Quarterly Review*, 2d Quarter, 1952.

ing with the destruction of Russian targets as soon as practicable after the outbreak and maintaining a maximum intensity in the rate of destruction from that point on. The phrase "instantaneous retaliation" has been familiar at least since the report of the President's Commission on Air Policy* and since the findings of the Congressional Aviation Policy Board.

It now appears in fact that timing considerations in bombing are essential, but that in general the urgent targets are not the deep industrial targets with which retaliation has been popularly associated. The timing requirements differ for various types of targets and under varying conditions of vulnerability of the strategic force. For counter-air and retardation targets, at any rate, it is apparent that a high early rate of destruction is critical. The object of attacking the Soviet long-range air force is to forestall or reduce the damage they inflict on us. And the earlier that is done, the better. Similarly, it makes a difference to the defense of Western Europe whether the Soviet advance is "retarded" in the first weeks of the war or considerably later.

If industry targets were the only objective, the motivation for a high, early concentration would not be immediately apparent. So far as the effect on the fighting front and on the ultimate outcome of the war was concerned, a lag in the destruction of steel rolling-mill capacity by, say, 1 month might not be substantial. Rolling-mill production is in any case many months in time removed from the consumption of finished munitions. An early concentration of attack does not have the clear urgency that is so apparent in the case of the destruction of the Soviet long-range air force. This is not the same as saying that a *high rate* of destruction *later* is not called for. The rate of destruction is obviously connected with the vulnerability and recuperability of industry targets. However, there are some industry targets which are clearly rather like retardation targets, so far as the time requirements of their destruction are concerned. Petroleum is perhaps one of the best examples. The destruction of Russian petrolum might have a rather quick effect on Soviet capacity to wage war.†

The timing of our bombing strikes in preparation for a reoccupation of overrun territory would have to be phased in accordance with still another criterion, one which would take into account both the recuperation period of

Survival in the Air Age, Jan. 1, 1948.

†One important argument for flexibility in the timing of bombing attacks, which concerns the cost of reaching targets rather than the effects of their destruction, stresses the use of such flexibility in deceptive tactics. An irregular pattern involving high strike concentrations may lower attrition to enemy fighter defense.

the targets and the schedule of reoccupation. The object then would be to maximize the effect of destruction at the time of reoccupation.

Persuasive arguments have been advanced for a different time order of attack and a different time frequency of attack for city as distinct from industry targets. It has been argued by some that the optimal psychological and political effects would be achieved by beginning with a comparatively slow spacing of attacks and, perhaps, increasing their frequency with time. (The latter version of this argument presupposes the capacity to concentrate attacks in the later period.)

Capacity for instantaneous retaliation is stressed in particular in connection with deterrence. Such a capacity is intended to make clear to the Russians that, whether or not they accomplished the objective of overrunning Europe, the cost to them would be certain, immediate, and more terrible than such a victory would be worth. How essential is the instantaneity as distinct from the *certainty* and *effectiveness* of the retaliation for deterrence? Instantaneity of destruction (that is, a very high early rate of destruction) is of dubious worth for winning the war. It might have some psychological force for deterrence. But it might just as well be argued that an inexorable, slower advance has its own terror. And there would be very little basis for choice among these horrors.

But the value of speed here is not easily separated from the question of certainty and effectiveness. If we get in our strikes fast, we may get in more of them. This is especially so in the case of the counter-air targets. If we strike fast and frequently, we can get in more strikes against their long-range air force bases (provided we can find them and find bombers on them) and we may also get in more strikes against their industry.

However, the certainty of our strikes depends on other factors as well. Specifically, it is related to base vulnerability and the position of our bases with respect to the level of attack the Russians can muster. Putting all our bomber force forward in peace as well as in war, so that it is at all times poised to spring, would not insure our quick retaliation. As the Air Force recognizes in its Mobility Plan, it would invite extinction of our power to retaliate for a long time to come. Increasing the strike-rate capacity beyond a certain point may be more expensive than microscopic and macroscopic active and passive defense measures as a device for insuring the ability of the force to perform its tasks. Base decisions may affect the deterrent power through their effect on the capacity of the force to retaliate—either by affecting our strike rate, enemy attack aside, or, taking enemy attack into account, by affecting the vulnerability of our attacking power. The disposition of our forces in Pearl Harbor invited rather than deterred the attack and destruction of our force.

TARGET SELECTION AND BASE SELECTION

The difference in deterrent power of alternative base systems illustrates the fact that the comparative advantage of various base systems must be measured in terms of their contribution to the multiple and complex objectives we have listed. And these advantages vary with changes in the objective. Retardation targets might favor smaller aircraft with higher sortie capability and comparatively short combat radius, and base systems that would permit such aircraft to operate economically. Some of the secondary objectives mentioned above also favor base systems which facilitate the use of smaller aircraft. On the other hand, a deep industry-target system might call for quite another base-aircraft combination. Base systems are unequally adapted to the quick launching of the first strike or the maintenance of a high rate of attack. For these reasons a change in the list of targets or in the desired schedule for their attack affects base choice.

But there is an interplay here. The target set we select is affected by our choice of bases. Alternative targets must be viewed from the standpoint of the differences in our cost to destroy them as well as from the standpoint of what their destruction yields in the balance of military power. And base weapons complexes differ in their cost to hit specific target areas. For certain base-aircraft combinations, a variety of remote targets may be more trouble than they are worth. An overseas B-47 system has a particular advantage for South Russian targets; and, because of the paucity of bases in the north, it has a much smaller advantage there. An air-refueled U.S.-based B-47 system is better in the north than elsewhere and is totally unsuited to hit several important South Russian targets. Again, in selecting targets we might consider those involving relatively shallow penetrations and those involving comparatively short total radii. But such groupings would mean different things for differing aircraft and base combinations.

In this study, we have been concerned more with the interdependence of base and aircraft systems than with the interdependence of base and target systems. We have not attacked the difficult problem of valuing targets in terms of what their destruction might accomplish in various sorts of war. As our point of departure we have taken an industrial-target system used in several of the current RAND weapons systems analysis.* However, it has been our purpose to treat this target system in a way that preserves geographic diversity, brings out the differences in cost to reach targets in different regions, and so forms a partial basis for future selection among these industrial targets and for the substitution of new targets.†

UNCERTAINTY AND EVALUATION

Our account of the multiple and complex objectives of the strategic air force and their interdependence with the problem of base selection suggests some of the uncertainties of an evaluation of strategic air base systems. Some of the objectives described, e.g., those generated by the defense of Europe or, perhaps at a later and closing phase of the war, by the preparation for reoccupying Europe, involve a good deal of uncertainty precisely because they are closely connected with the actual course the war might take. But they are not less important for this reason, and the appropriateness of our base systems in these circumstances has a bearing on our decision.

Such uncertainties in the very objectives of the strategic force must be coupled with large and necessary doubts concerning the major factors related to the accomplishment of our objectives. We cannot be entirely sure about the level and composition of Soviet capability for long-range attacks against our air bases. Similarly, we have no exact knowledge of the level, the composition, and the effectiveness of Russian defenses against our air attacks. The same status obtains for the costs and performance characteristics of our own future weapons systems, the accuracy and lethal radius of our bombing, and the recuperability of Russian targets. Some of these uncertainties are large, and any one of them may affect a close comparison among alternative systems. For example, the

*See, among others, G. H. Clement and C. P. Bahrman, *Missiles System for Strategic Bombardment*, The RAND Corporation, R-248, November 20, 1953 (Secret—Restricted Data); and L. B. Rumph, *Low Altitude Strategic Bombing Systems*, The RAND Corporation, Research Memorandum RM-1007, December 1, 1952 (Secret). This target system, which has no official Air Force status, was prepared originally for the purposes of the RAND Missiles-Aircraft Study (R-248 and related documents).

†Our analysis of alternative base systems has another sort of relevance for target selection; namely, in connection with evaluating a counter-air target system. On the basis of our analysis of the vulnerability of our own strategic air bases and of methods available for reducing this vulnerability, it is possible to make some inference as to the likelihood of destroying the Russian long-range air force on the ground. This is one component of the decision as to the advisability of taking the long-range Soviet air force as a primary target. The problems of destroying the Russian strategic force are discussed on pp. 365*ff*.

amount of effort that the Russians devote to air defense, the way they divide this effort between area and local defense, the geographical distribution of area defense, and the effectiveness of such defenses as against our own deceptive tactics and countermeasures may very well affect judgments concerning attrition rates by a factor of at least 10. In fact, competent analysts differ in their anticipation as to the probable rate of attrition by this amount. Some of the attrition models used in systems analyses have involved enormous cell sizes in order to insure 50 per cent probability of survival on any given strike. On the other hand, 90 per cent probabilities of survival in connection with strikes involving much smaller cell sizes are anticipated by analysts having a lower estimate of Russian defense capabilities. These assumptions exhibit gross differences in their implication for the size and number of strikes required to accomplish a fixed task of destruction, the prospective number of re-uses of a bomber, and a host of other system elements.

OBJECTIVES AND UNCERTAINTIES

It is plain that, given any combination of types of bases and weapons, the level of costs to destroy a fixed number of targets or, having a fixed budget, the absolute number of targets that may be killed will vary widely, depending on how these uncertainties are resolved. This means that no simple, straightforward answer is possible to the question of the destruction potential of a given strategic force or the cost of a fixed job of destruction. A proviso is implicit regarding the level of enemy defense and offense capabilities. Even more critical for purposes of comparison and choice among systems, the *relative* costs and effectiveness of the systems compared depend, in general, on the level of enemy capabilities.

It is even plainer that the absolute and comparative performance of systems depends on how we specify our campaign objectives, and these, we have seen, are rather fluid.

Such uncertainties are responsible for some of the principal characteristics of our method of investigation: (1) Throughout our inquiry we have looked for *gross* differences in the relative cost and effectiveness of alternative base systems, and specifically for differences of the sort that have a chance of surviving any likely resolution of these uncertainties. (2) In analyzing relative differences, we have addressed ourselves to the question as to which systems have a clear advantage rather than to the question as to precisely *how much* better one system is than another. (And where we have not been fortunate enough to have found such clear alternatives, we have much less confidence in the distinctness of the advantages shown.) (3) The comparisons have been made with the following gross uncertainties in mind. (*a*) We have tested the systems for a very wide range of enemy offensive and defensive capabilities. (*b*) We have taken as one test the determination of which systems are least dependent on certain knowledge of the level of enemy capability. (This is different from the preceding point, which refers to tests in which our losses on the ground and in the air range from low to high figures, but it is assumed that these losses are correctly anticipated. This second variety of test investigates the consequences for different strategic systems of having assumed one level of loss when in fact another is experienced.) (*c*) While the criterion used for evaluation is the destruction of a specific industrial-target system in a 2-month campaign, with no other time restrictions imposed, we have kept in mind some of the other objectives and have examined the various systems for their relative flexibility in industry campaigns with other time patterns and a larger number of industrial targets, in atomic campaigns with other objectives than industry, and in other types of war. (*d*) We have tested the systems for their performances under a variety of political circumstances involving the loss of bases.

The number of targets destroyed with a given force is affected (1) by the difference in attrition suffered on the ground by varying systems; (2) by the differences between the cost of holding a bomber and crew in reserve to replace attrited aircraft, as distinct from keeping it in the force sortied, with the attendant costs of tanker support or other means of radius extension; and (3) by the differential cost of flying alternative flight routes and alternative flight profiles to target and the associated differences suffered in attrition at the hands of enemy air defense, etc. These latter factors exhibit certain broad differences according to the base system assumed. We have investigated in considerable detail such gross base factors affecting systems cost and effectiveness.

C. Bases and the Total Weapon System

Base determinations depend closely on the predicted characteristics of the weapon that will be using the base. Among aircraft, for example, turbojets fare worse than turboprops with increasing distance from the target. The cost-increasing effects of extending combat radius are more drastic at very low and very high altitudes and at very high speeds. For this reason base systems which reduce combat radius show to better advantage in the context of turbojet systems, and increase in preferability with increasing extremity in altitude and speed of the planes we choose. To take another example, bombing systems with a short supersonic capability fare best when their short capability covers a large part of the total distance penetrated over enemy defenses—or when their short capability covers much of whatever part of the penetration path is more heavily defended than the rest (perhaps because it is in daylight). Then their brief supersonic dash may enable them to elude most of the area defense. Bases chosen so as to reduce such penetration paths may appear in a particularly favorable light if we assume that the Air Force has a considerable proportion of such bombers.

For such reasons base selection depends on weapons choice. It is also clear that, for converse reasons, weapons choice is not independent of base selection, and that, where both choices are open to us, they should be made jointly.

However, for some time in the future the choice is not open. The types of bomb carrier that will make up the major part of our strategic force in combat units are more or less fixed for the rest of this decade. And in this report the principal application of the analysis is to a decision among broad alternatives for basing this programmed force. For this purpose we do not face the difficulties of joint decision on the bombers as well as the bases. We can avoid or defer not only the choice of type of bomber, but also the question facing procurement as to the optimal mixture of the programmed medium- and heavy-bomber types. This is possible because our findings indicate that the same fundamental method of basing is best for both the medium- and the heavy-bomber components of the force.* The problem of base choice in the context of

*Such a procurement decision, however, it appears from our analysis, will be strongly influenced by the base system assumed.

the programmed bomber force is made easier also by the systematic analyses, made both at RAND and by the Air Force, of the probable performance characteristics of each of the programmed carriers and of their behavior in penetrations through Russian defenses. With changes appropriate to the large variations treated in methods of basing, we have made extensive use of this material.

While this study has been confined in application largely to the programmed 1956 bomber force, the importance of the role of base decisions in connection with both future procurement and future research and development appears clear. Base choice affects the total weapons system—the hardware and the manner of its employment.

EXAMPLE OF CHOICE OF POWERPLANT AND TARGET RADIUS

Fixing the radius performance conditions for an aircraft- or missile-design competition, and the method of evaluating the competition's results, like choosing the setting for a systems analysis, demands considerable care. The mere specification of a "mission distance," say 2000, 3000, or 5000 n mi, covers a multitude of assumptions concerning the actual physical distribution and relative importance of alternative base and target complexes. And it has a potent influence on our evaluation. In particular, the so-called intercontinental mission distance requires re-examination and clarification. A comparison of turboprops and turbojets at a combat radius between 3000 and 4000 n mi will be strongly influenced by the fact that, in the present state of the art, the combat radius of unrefueled turbojets has an upper bound in that interval. Near such a boundary, even at lower speeds, every small increment in radius means a huge increase in cost for the turbojet as distinct from the turboprop.

TANKER CHOICE AND THE LIKELIHOOD OF EXCLUSIVELY INTERCONTINENTAL OPERATION

Another instance of the interaction of base and weapon choice involves the relative merits of using bombers convertible to tankers to refuel similar bombers (say, a B-52 refueled by another B-52), as compared with using for this purpose aircraft designed specifically as tankers (e.g., a KC-97 tanker refueling a B-52 bomber). This comparison is sharply affected by our view as to the availability of an overseas base system and the possible necessity of operating at a very long range.

One way of looking at it is merely to assume intercontinental operation, or, at any rate, to take as being by far the most probable eventuality the fact that there will be no feasible overseas alternative. Then we can compute the comparative costs and effectiveness of various tanker-bomber combinations, neglecting their use at any but very remote distances from targets.

Another way of looking at it would be to take account of the extensive overseas base system already in existence which the Air Force plans to use. Then the total loss of the overseas bases and the necessity of operating at great distances appears not as an assured or most probable event, but rather as an unlikely contingency against which we want, nonetheless, to insure ourselves. Looking at it in this way, we have to compare the operations of various tanker-bomber forces both in the most likely circumstances and in the unlikely event, and roughly weight their relative performances in these two circumstances according to the probability of each.

The first way of looking at the necessity for remote operation favors using, for air-refueling purposes, aircraft designed specifically as tankers. This is true particularly where we are considering the very-high-performance, high-cost bombers of the future. The second way of regarding the matter, in which very-long-range operation is only a matter of insurance, suggests attractive features of a refueling device which is usable for bombing. In the unlikely contingency of remote operation it may prove successful; but in the most probable event—namely, overseas operation from fairly close by—these potential tankers will operate as bombers and so increase the effectiveness of our force.

The aircraft designed specifically for tanker use, on the other hand, ninety-five chances out of a hundred, may have very little use. Inasmuch as the Air Force now plans to operate from an extensive overseas base system that is in large measure already in being, this hypothetical example has quite practical implications.

CHOICE OF BOMBER FORCE UTILIZATION AND BASE SUPPORT AND REFUELING COSTS

Not only the aircraft, but the strategy of their employment depends on the base system. One important example concerns the following question: Should we use all aircraft and crews which are available for each successive strike?

Or, should we follow a deliberate policy of reserve? The results of previous systems analyses suggest that it is more efficient to withhold a large proportion of the aircraft available as a reserve for replacement of losses suffered in succeeding strikes. Which method is the better depends in good part on the relative cost per bomber of the operating and reserve forces, as well as on the expectation of ground loss due to enemy attacks. In analyses that indicate the comparative advantage of the reserve policy, the cost per operating bomber has been very much higher than that of a reserve bomber. Take the following cases. The first is an overseas campaign assuming that all operating bombers and their crews are stationed overseas in time of war, and that reserve bombers and crews are stationed in the United States, two wings to a base, until they are needed to replace attrited aircraft. In this case the cost per operating bomber, including active defenses, is roughly half as much again as that of the reserve bomber, even if we neglect the greater losses the operating bombers would suffer on the ground from Soviet air attack. The second case is an intercontinental campaign in which tankers are used as the exclusive method of extending radius—every operating bomber needs considerable air-refueling, and the cost of the tanker force swells rapidly with increases in the proportion of operating to reserve force. In these examples, the cost differences between operating and reserve bombers and, therefore, the optimal reserve policy are a direct consequence of the base policies and radius-extension devices assumed. These serve to illustrate how the strategy of employing aircraft depends on base selection.

For such reasons as these examples illustrate, the juxtaposition of base problems with the problems of selecting weapons and the strategy for their use should benefit the solution of all of them. In this study, however, the analysis is not applied to the problem of bomber choice. The bombers programmed for 1956 are accepted. Their base systems and strategy of employment are varied.

D. The Intercontinental Mission

The work of our strategic force is conventionally supposed to be the intercontinental mission, but such a "mission" is not a task of the same importance as the strategic objectives discussed earlier. It is one alternative means of accomplishing these ends—in the opinion of some, it is the preferred method; and they can point to clear advantages. There are no problems of getting or keeping base rights in foreign countries; the force is easier to support, and it has a lesser vulnerability to enemy attack. (Our own investigation only reinforces the view that, for strategic operating bases, the programmed deep U.S. radar network with its interceptor backing means a sharp decrease in vulnerability and a critical change in the possibilities and cost of defense.) If the vehicles to be used were single-stage unrefueled bombers with intercontinental radius, an intercontinental strategy would have a further advantage in great simplicity of operation.

The view that intercontinental bombing (single or multistage) is to be preferred over other alternatives has considerable force. The advantages of intercontinental bombing are genuine; but they need to be stated more precisely for evaluation, and they need to be balanced against the quite distinct advantage of using various foreign overseas base systems.

THE MEANING OF INTERCONTINENTAL OPERATION

In evaluating various overseas base systems as against intercontinental systems, we have tried to select as a bench mark an intercontinental system that has the typical advantages of comparative political and military invulnerability and logistic convenience. This has involved some refinements in the precision of these terms; for one part of the difficulty of weighing an intercontinental strategy stems from the vagueness and, even more, the appositeness of the terms employed. The use of such cartographical words as "intercontinental," "Western Hemisphere," and "North American continent" is convenient. These terms introduce in rough form the differences in logistic and in political and military security which are without question a critical factor in base choice. They get us into trouble, however, in discussions of strategy unless such discussions are extremely general, leaving both the enemy and our allies unspecified. They are rough, general-purpose words, and they have been used in orienting our thinking about defense against Japan and Germany and many other enemies in other wars. The geographical dividing lines that define their meaning are not only somewhat ambiguous (is Greenland a continent or part of North America?) but, more important, on any interpretation they bear a wholly accidental relation to the political and tactical separations and groupings that interest us in a possible war with Russia. Politically, some countries outside the Western Hemisphere, such as the United Kingdom, are quite as reliable in defensive alliances against Russia as some of the countries inside these boundaries. In terms of their geometric distance and tactical considerations, the inadequacy of the hemispheric and continental dividing lines is even more clearly visible. Some parts of the North American "continent" are separated from Russia by only a little more than 20 mi. Alaska and Northern Greenland are much more vulnerable to Russian air attack and are very much more difficult to defend and support than such non"continental" areas as Iceland and the Azores. It appears, therefore, that we should be cautious of a certain incontinence in our use of the concepts "continental" and "intercontinental."

In discussions of intercontinental strategy, it has been usual to include the Arctic regions of North America as base areas for intercontinental attack. Up to recently Alaska was popular, and now it appears that Northern Greenland is taking its place. However, these regions do not offer the economies of defense and logistics, or the insurance, which are the principal motivations of the strategy. They appear to be an unlikely choice in a base system which might deliberately exclude such areas as Iceland or French Morocco. For similar reasons they would represent an extremely improbable surviving subgroup of a system of overseas bases that started more inclusively and was reduced by enemy action.

One of the purposes of this study is to develop a method of weighting regions systematically (1) from the standpoint of the advantages they offer in closeness and angle of approach and penetration for attacking Russian strategic targets, and (2) from the standpoint of the disadvantages they present in nearness to Russian attack bases and distance from our means of support. In this analysis we consider the location of a region with reference to the level of attack the enemy could bring to bear against it, the distance of the region from planned early-warning networks, the contributions which forces needed for other purposes might make to strategic operation in the location, the relationship to enemy targets, and the relationship to other U.S. bases. The effects of such location are considered for *each major* base function. Parking and maintenance of bombers on a U.S. base location such as Limestone, Maine, are affected by the fact that Limestone will have less than an hour's warning time, especially of low-altitude attack, until the present ground radar program is augmented by picket ships and airborne early warning and the proposed Canadian extension. Until such a time, it will have a vulnerability for storing aircraft on the ground relating it more closely to Iceland than to Omaha as an operating base. Such simple alternatives as "overseas versus intercontinental," or even "United States versus foreign," then, have a very limited use for our analysis.

There is a major discontinuity in the vulnerability of the aircraft parking function when the location of this function is shifted to a position well within the boundaries of the U.S. defense network. This discontinuity is the joint effect of the extended radius from Russian bomber bases, the comparatively reliable warning provided by the programmed radar to points in the interior, and the interceptor backing of this radar which, together with the remoteness and extent of radar coverage, makes it costly for the enemy to spoof and offers time to filter out false alarms. Because of this discontinuity, we have taken, among the major base alternatives to be considered, two apparently extreme cases: the intercontinental air-refueled and the intercontinental ground-refueled systems. Both of these systems have operating bases well within the ZI. In this respect they both contrast with the overseas operating system. The intercontinental air-refueled system tests the advantages and disadvantages of removing from overseas areas not only operating bases, but also the function of ground transfer of fuel. These intercontinental systems are compared with relatively short-range overseas systems of the type programmed (and also with several intermediate systems).

PREFERENCE AMONG LONG- AND SHORT-RANGE SYSTEMS

It is a most significant fact that, for the present and for some time to come, the Air Force has selected an overseas base system and has developed a force of bomber systems for operation at considerably less than intercontinental range. So far as an unrefueled, single-stage, two-way operation is concerned, we do not now have any bombers capable of starting from the United States, hitting a significant number of Russian targets, and returning home. Moreover, none is programmed. Even considering multistage operation with the aid of tanker planes, the programmed mixture of bombers and tankers would not sustain an extensive campaign against deep Russian industry-target systems without the supplement of overseas bases.* This situation does not fit the conventional notion of Air Force strategy.

One-way intercontinental operation is of course possible. And we might ask whether other mixtures of bombers and tankers could sustain a two-way campaign against Russian industry. Further, assuming that such mixtures are feasible, we might ask more fundamental questions as to their cost and effectiveness as compared with shorter-range alternatives. *One of the most important differences between our situation and that of the Soviet Union is that we have and they do not have a choice between intercontinental and overseas operation. Their operation against our industry must be conducted from remote bases. We have a considerable range of choice among long-range and short-range systems.*

The position that intercontinental bombing is preferable to bombing from overseas base areas that can be obtained in time of peace and which will remain available for use in time of war should be distinguished from the view (1) that intercontinental bombing is preferable to step-by-step seizure and occupation of defended overseas bases in time of war, (2) that an intercontinental capability is a useful form of insurance against the contingency of losing overseas bases once we have them. Both of these latter views have played an important role in the development of a very-long-range mission for our strategic bombers. It was the fall of France and the apparent imminence of the fall of the United Kingdom that stimulated the first serious plans for an intercontinental bomber in the early phases of World War II.† The very-long-range bomber was first conceived as insurance against an emergency that did not come to pass. As a method of delivering high explosives it was not preferred over attack from close-on, e.g., from the United Kingdom. It just appeared good to have in case the United Kingdom should not be available. On the other hand, in the Far East, there were no bases close to Japan until the "stepping-stones" campaign was carried through successfully. Here a long-range bomber was thought of as obviating delay in bombing the heartland of the enemy in

* *Strategic Air Command Mobility Planners Guide*, SAC Manual 400-1, p. 1-A-1: "A casual inspection of the globe indicates, no matter who may be the enemy, almost any possible target lies beyond the radius of medium bombers and fighters operating from the ZI bases. Heavy bombers, too, for most effectiveness, require staging."

† See *Hearings*, U.S. House Committee on Armed Services, *Investigation of the B-36 Bomber Program*, 81st Cong., 1st sess., HR 234, Washington, D.C., October 5, 1949.

such initial phases of the war.* Also, perhaps, though this is not as clear, it was thought of as avoiding the necessity, in future wars, of seizing these bases at all except insofar as this was justified by military objectives other than strategic bombing.†

None of the views described above supports the theory that intercontinental bombing systems are a cheap or more effective substitute for closer attack when close bases are available. In fact, it is apparent that for delivery of high explosives, the purpose for which they were first planned, intercontinental bombing systems are extremely expensive. A very large total tonnage has to be delivered in a restricted period of time. The large tonnage means a great many sorties. The restricted period of time means a great many aircraft and aircrews.

The A-bomb changes this picture in several relevant ways. It appears both to reduce some of the cost of intercontinental bombing and to raise the marginal cost of overseas strategic air operations. It reduces the cost of intercontinental bombing by increasing the destructiveness of bombing—and also, it might appear, by drastically cutting the number of carriers needed and so making the expensiveness of the aircraft themselves less important. And it seems to increase the marginal cost of operating overseas by reducing the need for nonstrategic air operations (tactical air, those of our surface forces, and those of our allies). These would necessarily be overseas in any case, so that, if they were needed on other grounds, they would contribute bases, base defense, etc., free for the strategic force. If they are not needed for any purpose other than the strategic overseas operations, then they are chargeable to it.

There is no doubt about the relevant and even critical changes introduced by the A-bomb, and, perhaps even more, by the H-bomb. Nonetheless, their effect on the comparative cost of overseas versus intercontinental operation is not entirely clear. The strategic air campaign is a critical and effective part of a many-sided effort, not a substitute for the rest. For one thing, the costs of delivering bombs against defended territory would involve not only the costs of the plane successfully making the delivery, but also the number of aircraft wiped out in the process of penetrating enemy defense. In the face of Russian defenses of any of the various levels presently anticipated, attrition would be considerable, large enough to impel consideration of economy in the force requirements for aircraft. These force requirements are *not* negligible.

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* *Ibid.*, p. 46.
† *Ibid.*

Second, the effectiveness of the strategic force cannot be divorced from the conduct of other military operations. The practical effects of the physical damage and the recuperation period entailed by the bombing of enemy industry and other strategic targets depend on the urgency of the enemy needs for the bombed facilities. And this is imposed in part by the activity of other of our military forces. Third, and most important, is the fact that there are other U.S. objectives that are not easily accomplished by the strategic air force, no matter how destructive it is. The costs of other military operations overseas are, in general, referable to these objectives rather than to the cost of overseas strategic bases.

FOREIGN POLICY AND THE COSTS OF OVERSEAS STRATEGIC BASES

It is not easy to extricate the question of costing overseas as against U.S. base areas from questions concerning (1) our foreign policy objectives, (2), the role of a short strategic air campaign in achieving our objectives, and (3), the roles played by other parts of the Air Force, the other services, and our allies.

In our analysis of the cost of overseas base systems, we have taken pains to include all additional U.S. government expenditures which we could directly trace to the use of such a system. This has meant including, besides the direct costs of the Strategic Air Command (SAC), (1) certain other Air Force costs for the use of interceptors, overseas depots, etc., and (2) other U.S. armed forces expenditures for the Military Air Transport Service (MATS), Army antiaircraft artillery, engineer battalions, pipeline and transportation companies, theater medical corps, signal corps, quartermaster corps, etc., and (3) some foreign aid.

On the other hand, we do not believe that all, or even the major part, of our military operations other than SAC or our program of foreign aid can properly be charged to the cost of securing and retaining overseas strategic bases.

United States economic aid programs cannot plausibly be attributed to the cost of obtaining bombing bases. They were explicitly formulated* and carried through (1) not merely for humanitarian reasons, but (2) because of vital American interests in a stably expanding foreign trade relatively unhampered

*See *European Recovery and American Aid*, Report by the President's Committee on Foreign Aid, November 7, 1947, pp. 17*ff*.

by state controls, and (3) because of the even more vital American political interest in preventing our allies from being taken over by their indigenous communist parties in a series of internal political changes fostered by economic dislocation. None of these three objectives would have been accomplished by improving our capacity for strategic bombing. When, at a later date, economic aid to our Allies was directed at "defense support," defense of the NATO area was the main consideration. In this aspect, it was like our direct military assistance program.

Says it all!

Nor can the costs of our military assistance programs and of our own military preparedness, other than for the strategic air force, be properly attributed to the cost of overseas strategic bases. Aside from the defense of Europe and the Far East and the security of communications lines (for U.S. trade as well as for the support of overseas defending forces), some of the objectives of these programs have been as follows: the development of a capacity to occupy enemy territory and to reoccupy territory seized by the enemy; military aid to non-communist countries subject to aggression of the Korean type, which, for one reason or another, called for less than atomic war; and the interdiction of advance bases from which the enemy might operate against the United States.

These are the basic U.S. policies and they are not quickly changed. It is worth noting that in spite of the obvious difference in emphasis, there is very considerable agreement on most of these points among all the major figures most likely to shape our foreign policy. No major political figure limits our over-all foreign policy objectives and our over-all military strategy to hemisphere defense. Almost all of them advocate economic assistance programs and the building up of large tactical air forces, large naval forces, and, to varying extents, considerable land forces. And this military capability is intended to support other objectives than merely the defense of strategic overseas bases.*

The official Air Staff view regards the strategic air offense as the first, but not the only, fundamental wartime requirement. The defense of the North

*The relevant views of Mr. Eisenhower and Mr. Dulles are familiar. One may cite *A Foreign Policy for Americans*, by the late Senator Robert A. Taft (Doubleday & Company, Inc., Garden City, New York, 1951), which voiced many disagreements with recent American foreign policy but also indicated these general points of agreement. The book (on p. 79) calls for large naval as well as air forces and an extensive assistance to such nations as "Japan, Formosa, the Philippines, Indonesia, Australia, and New Zealand; on the Atlantic side, Great Britain, of course." And, on pp. 80 and 81, Taft continues, "the power of great sea and air forces is not necessarily limited to island nations. The policy I suggest certainly does not abandon to Communist conquest the continental nations. In the first place, we give economic assistance to many such nations, providing that they want that

Atlantic Treaty area and of the Far East and the security of sea and air lines of communication are explicit high-priority tasks. This view is consistent with basic U.S. foreign policy commitments. Given such commitments, something less than the entire cost of tactical air and our Army and Navy and of our various programs of foreign aid will be chargeable to the use of strategic bases overseas. No matter where we base the strategic force, we shall be keeping the sea lanes open, we shall have fighter and air transport bases in a good many parts of the world, we shall be contributing to the defense of our allies, and we shall have forces capable of denying the enemy many overseas areas from which he could intensify attack against the U.S. mainland. Various overseas areas to be used for strategic-base location interest the United States vitally, then, for political and military reasons quite independent of their utility for basing our bombers.

On the other hand, our interest in some of these areas may change, however slowly, and, in spite of our interest, some may be denied us through military action in time of war or political action in time of peace. A comparison of base systems must take these contingencies into account. In determining the minimum cost alternative of a variety of strategic base systems, it is important to charge overseas systems with the considerable cost to be incurred specifically to further the ends of the overseas strategic force. And it is important to test base alternatives for their sensitivity to political as well as military changes. Political expectations, however uncertain, have strongly influenced the desire for a full intercontinental mission capability for SAC. In dealing with political vulnerabilities, as in the case of military vulnerabilities, it is important to discriminate the distinct problems and susceptibilities of each of the major base functions. Here again it is fruitful to consider the separate landing, take-off, and fuel-transfer functions on the one hand, and the functions that are distinctive of operating bases on the other.

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assistance and use it effectively against Communism. We give arms, as we are bound to do under the Atlantic Pact and as we are now doing in Indo-China, in Greece, in Turkey, in Formosa. An adequate modern air force should be able to bomb the communications of any aggressor, its army and air bases, and its manufacturing plants and thus not only deter aggression but seriously interfere with its success. Probably strategic air power cannot prevent a land advance, but it can certainly play a powerful part in the defense against such an advance and in the ultimate outcome of the war.... There are other examples in the world where it may even be wise or expedient to commit some land troops with a reasonable chance of success. The entire continent of Africa is connected with Asia, and certainly we might have to assist in defending the Suez Canal, as a means of maintaining our connections by sea and of defending Africa, where there are many strategic materials, valuable air bases, and a threat to South America. It may be possible to assist Spain...."

E. Political Conditions of Overseas Base Choice*

The problem of selecting points in space so as to minimize system costs depending on various critical distances—distance to target, distance to sources of base supply, distance of penetration over enemy defenses, distance from enemy striking power to the base— is, of course, by no means merely a problem in geometry. Political considerations are frequently dominating factors, since they affect—

1. Whether or not a given country will make land available to the United States for air base development;
2. Where it will make a base available—i.e., the exact location within the country with reference to transportation and population centers—which, in turn, will affect the logistics cost, operational suitability, and possibilities of defense;
3. How long it will take to make the land available, including the lead time required to obtain the base;
4. The method of financing and carrying through base construction, and even the types of structures used;
5. The level of operating or manning which the country will permit;
6. The possibility of interference with base operations, by activities of sabotage or the like, once a base is developed;
7. The likelihood of sudden withdrawal of base rights by the government of the country granting them;
8. The mission of the base; and
9. Our contribution to the land and sea defense of the country granting base rights.

Any realistic consideration of the base problem has to conjure with these political facts. They restrict the solutions possible and they also put a premium on having a clear-cut program for base expansion, with alternates in case of

*Most of the material concerning the critical points of negotiation in obtaining base rights and on the political problems raised by the actual operation of bases was obtained from members of the then Office of the Assistant for Air Bases: in particular, General Maddux, Colonel Crystal, Colonel Clinkscales, Colonel Coddington, Colonel Temple, Colonel Stanley, and from various members of the State Department.

failure anywhere along the line from negotiation to final use.

Consider the first five points mentioned, which are closely connected. Take the question of base availability. The problems here concern both the countries which are securely allied with us and those whose alliance is quite uncertain. It does not solve the problem, therefore, merely to sort countries into probable allies on the one hand—and probable neutrals, probable enemies, and doubtful cases on the other—and to stick to probable allies. Even our major allies, such as France and the United Kingdom, have great difficulty in granting suitable bases. The problems connected with the precariously aligned countries are even more evident. Though it is possible to exaggerate the uncertainty of international alignments (in sorting countries, the relatively certain cases do outnumber the doubtful ones), there is no question as to the importance of the precarious areas. The mobility and uncertainty of political alignments in such important base areas as the Middle East are only too evident. Here and elsewhere the problem is complicated by complexities in the relationships between our major allies and the colonial and semicolonial countries, which are in various stages of the process of detaching themselves from colonial dependency.

In the metropolitan countries the land problem is especially difficult. The well-drained, fairly level land—best adapted to air base construction—is also, in general, the best adapted to any other variety of construction: housing, schools, commercial and industrial building, roads, power stations, reservoirs, and military depots. And it is also, for the most part, the best land for food production. In a country like the United Kingdom, the competition among these uses is most intense. To indicate how tight an island the United Kingdom is, some figures from a recent progress report of the Minister of Local Government and Planning may be cited.* England and Wales have some 37 million acres of land, 24 millions of which are devoted to farming, and a population of 44 million. If Scotland is added in, the totals are 68 million acres of land, of which 28 million are improved farm land, and a population of 49 million, as of last year. This means just about half an acre of food-producing land per person. One part of the United Kingdom's program for solving its serious dollar problem (and a part to which members of the government have assigned considerable importance) is the expansion of domestic food production. When this competition is joined to the urgent housing demand, it is apparent that an increase in the number of air bases is sharply limited, and that the island is

*_Town and Country Planning_, 1943–1951, Command 8204, April, 1951, pp. 81–98.

tight enough to turn local dispersal on any given base into what is very likely to be a real problem. This is confirmed by the account of operations officers who have been concerned with air base defense and location in England.

It is not only a question of making a large claim for restricted resources in land. The actual base construction is a vast project which makes a claim on other resources of the country. And so, subsequently, does the continuous presence of American soldiers. Depending on how the construction is carried out, the extent to which local industry is used in production, or the extent to which American labor is imported and appears in the economy largely as spending units, the base construction may be an important form of economic aid or it may be a very disturbing, even if transient, inflationary element. The dislocations in the ~~wage structure~~, especially in dependent overseas territories, form the subject for a considerable number of State Department cables.

The continuous presence of American troops affords similar possibilities of inflationary disturbance. It involves a host of problems stemming from invidious comparisons of the standard of living of our troops with that of the local population, plus the usual problems of illegitimacy and racial and cultural conflict. The level of manning at the bases is a principal point of negotiation. It is difficult to get military rights for an installation in which we intend putting a large complement of men. And most of the treaties negotiated have placed ceilings on the number of troops we are allowed to bring in.

The negotiation of these treaties is a long-drawn-out, trying matter, seeming to average a period of some 2 or 3 years, and far exceeding the base construction time. Of the various elements present in the usual base mixture in the past—landing, take-off facilities, refueling facilities, maintenance, storage of aircraft, and personnel— the last is the most disturbing as far as native populations are concerned. Storage of personnel involves a more volatile element than storage of petroleum. In the opinion of the men concerned, the time spent in negotiation would be very much reduced if we restricted our objectives to bases involving a minimum of personnel.

For similar reasons, large bases involving a great many personnel are more easily tolerated by our allies if these bases are placed at a considerable distance from population centers. We could, to take as an example the Moroccan Bases, have had our choice of real estate along great stretches of the French Sahara with very little time wasted in bargaining. However, for large-scale operating bases, this would have meant a morale problem as far as Air Force personnel was concerned; and, since population centers and transportation centers are generally related, it would have meant great increases in supply costs. (This problem is very much reduced for refueling bases.)

The last four points (items 6–9, page 35) mentioned at the beginning of this section are closely related. The availability of bases and the conditions of their use are sensitive not only to the formal commitments of the government of the country granting rights, but also, like that government itself, to the views of the local partisan political movements. For such reasons, the commitments are frequently tentative. A good many of the treaty rights negotiated are on a year-to-year basis. In a large number of the countries with which we are dealing, communism is a considerable force. But even more closely affecting base use, the manner of operation, and the mission to which the base may be devoted, are the widely varying noncommunist views of the inhabitants and the values that they attach to the presence of a U.S. air base in their country. In general, it seems that a base which is looked on as a means of defense of the surrounding area is welcome. A base which is a means for delivering the A-bomb against the Soviet Union and which, in turn, may be the object of Soviet A-bomb attack is not regarded as an unmixed blessing. Questions of both base availability and mission restriction will clearly be answered differently, depending on the degrees of warmth of the cold war. The willingness of the governments of our allies will vary as will the latitude permitted these governments by dissident groups. And in the case of hostilities, the possibility is not excluded that we may take control by a show of force. We did this in the case of Iceland in the last war. And, in another war, it is plain that several areas now scheduled for use by our bombers will be candidates for such control —at the very least to insure that they shall not be used to refuel enemy bombers. The significance of restriction on the mission of a base will depend on whether or not we are at war and on the circumstance of the outbreak, i.e., the relation of the war to the interest of our allies.

It is only natural that the country granting treaty rights to the United States will have a very strong interest in the kind of mission our planes based there will fly. Our strategic striking force will be an obvious target for the Russians in time of war—and the occasion for Russian protests and threats in time of peace. There is some justification, then, for feeling that a strategic base increases both the general security of the allied forces and the specific hazards of the area in which it is based. A fighter base with an overtly defensive mission is something else again.

The question of defense of the country granting military rights is, of course, a key question in base negotiations. Our ally will naturally be reluctant to grant bases if he feels certain that he will be overrun and will have to face Russian retaliation for the act of making available bases for U.S. planes. Therefore, our participation in defense on the ground and our protection of the sea lanes to his country are of great moment in his decision. On the other hand, as we have seen, it would be an error to attribute all the cost of such matters as keeping the air and sea lanes of communication open to the operation of our strategic base.

There are several points to be made on the basis of these considerations. First, the political conditions of base choice have a measurable effect on the cost and destructive power of our strategic force. In this respect they are quite like the technical characteristics of weapons systems which are interdependent with base choice. The unavailability or limited availability of bases in some regions, and in some regions the limitations imposed on the number of men permitted on a base in time of peace, the specific requirements for defense resulting from base negotiation, etc., result in consequences, for the price and effectiveness of strategic base systems, as direct as the effects of the specific fuel consumption of the bombers using our bases. Second, the factors described place constraints on solutions to the base problem: (1) Some areas, no matter how well adapted to base use, may be eliminated as not being likely to yield base rights under any likely circumstance. Sweden, a traditional neutral, may be an example. (2) Other areas which might have yielded base rights may become ill adapted to base use by the political realignment of their neighbors. If Greece or Yugoslavia were to be absorbed into the Russian sphere of influence in advance of the outbreak of war, the usefulness of such base areas as Libya, which are well situated given the present alignment, would be decidedly decreased. (3) The problem that exists for a base-right program is a quite specific one—in what politically autonomous areas are there base locations that can supplement our existing base structure? This involves a choice of several among a comparatively limited number of alternatives—limited enough for analytical handling, but, as our investigation bears out, large enough to provide a considerable degree of flexibility and safety.

Third, while political considerations restrict the number of solutions possible to the base problem, they also operate to reinforce certain technical and economic factors determining the distribution of base functions. (1) For example, the uncertainties of political alignments suggest that it is advisable to have a redundancy good many bases and to have them in a number of politically distinct areas. This reinforces the indications favoring multiplicity and dispersal of bases which are the result of analyses of the vulnerability of bases to enemy attack. (2) As another example, the restrictions placed on obtaining bases for strategic air operations suggest the importance of standardizing some of the facilities required for fighter bases, say, at a level which would permit their strategic use. This device has technical advantages for passive defense and for provision of flexibility. It might also permit conversion to strategic use in the event of a change of heart in the country granting military rights. (3) And finally, the political difficulties involved in extensive manning point in the same direction as certain vulnerability considerations. Both favor at least "Mobility Plan" systems and, even more, ground-refueling systems. The storage of aircraft is a most vulnerable base function. There are considerable advantages, of which the Air Force is aware, in permanently basing personnel and aircraft for the strategic force in the ZI in time of peace, keeping the overseas bases partially manned on a rotating basis, and then moving operating bases forward after the outbreak of war. This was the former plan.

constraints + vulnerability

If, even in time of war, we base aircraft and men at home and merely have landing, take-off, and refueling facilities on foreign soil, the political difficulties involved in extensive manning will be decidedly reduced.

The upshot of these poltical considerations for the base systems compared follows.

1. The formerly programmed overseas operating base system involves many difficulties and uncertainties. However, a great deal has been achieved. One of the most important of these achievements is the very considerable political dispersal and consequent political insurance that characterizes the multiple system of bases now coming into being. This disperal is much greater than is generally recognized. A mere listing of the places involved in our programmed system illustrates this: the United Kingdom, French Morocco, Canada, Greenland, Iceland, Alaska, Japan, Guam, Portugal, Spain, Libya, Egypt, Lebanon, Turkey, Malta, Cyprus, Greece, Italy, Iraq, Iran, Pakistan, Ceylon, Okinawa, Saudi Arabia, Algeria, and Tunisia. By 1956 the preponderant majority of the overseas bases programmed should be firm. Air Force officers concerned with base negotiation anticipate only a moderate slippage, no greater than that in the rest of the program. Taking it all in all, this is an impressive list. If we consider the separate political catastrophes possible in almost any one of these places, we are impressed by the uncertainties. On the other hand, the likelihood of

political disasters involving all or even the major part of this system is very much less. Even given the failure of the North Atlantic Treaty Alliance, it is clear that there is a strong likelihood of the survival of a substantial part of this base system.

2. An extensive refueling-base system is more feasible, has a smaller political price, involves fewer continuing political problems, and is distinctly more secure politically than the programmed overseas operating system, or in fact any comparable extensive overseas operating system. (Some of the remoter operating systems considered, which have fewer bases in fewer countries, have less insurance than the programmed system and are more liable to Russian blackmail.)

3. In comparison with a strategic base system involving no overseas base elements at all, not even the ground transfer of fuel, the ground-refueled intercontinental system has a greater political vulnerability. Therefore, the performance of the systems should be compared not only under the most probable political conditions, but also under less likely circumstances, perhaps even in the extreme case of a catastrophe in which we have no allies whatsoever. The consequences of losing some portion of the system of overseas bases and even of total loss is considered in Part III.

F. Domestic Constraints

The international political problems that complicate a strategic base program are hardly more impressive than the domestic constraints. The latter affect both the size and timing of the program and its detailed composition.

Military construction for the fiscal year 1953 included $1,800,000,000 for bases. Funds authorized by Congress for the fiscal year 1952 included some $3.5 billion for air-base construction, $1.5 billion of it being for overseas bases. These bases were planned to bring existing facilities to the level required by a 95-wing Air Force (80 combat wings). The 126-combat-wing Air Force which has been the goal for 1955 or 1956 needs a very much larger accumulation of construction expenditures. These sums are considerable, and such construction expenditures, moreover, make up a significant proportion of the total investment in Air Force wings—a little less than one-fifth.

It is to be expected that so sizeable a category of expense should be the object of the attention of both Congress and the executive department. In periods of retrenchment in government, as in business, it is not unusual to limit, in particular, expenditures on fixed facilities. Buildings, pavements, and the like are comparatively durable. The use of facilities we have can be extended and new construction can be deferred. And, since construction is in the present, and the returns to be gained from construction are spread over a long time future, the immediate advantages of reducing expenditures in this area are likely to outweigh possible but remote difficulties. Detailed review of military construction requirements by nontechnical or civilian authorities appears to be more feasible than such review of, say, the procurement and performance requirements of military aircraft. Moreover, military public works, like all public works, have local economic effects whose details are a natural concern of the local congressman.

In fact, the base program and budget is particularized much more than the aircraft budget. Item-by-item limitations are imposed by Congress* (money is

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*See the *Congressional Record*, Vol. 99, No. 26, February 16, 1953, p. 1150: "...After an altogether too-brief period for advance study of the requests the subcommittee began hearings on last June 17 on the bill. Those hearings continued on an almost day-and-night basis for 7 days. For the most part we went into the askings on an item-by-item basis—tens upon tens of thousands of items ranging in cost from $1,000 to $15 million per item...."

granted specifically for nine fueling hydrants or so many barrack units on such and such a base) and, in anticipation of Congress, at a succession of points within the Air Force and the executive department. The succession runs from SAC to the Program Section in Headquarters, the Ad Hoc Committee of the Installations Board, the Air Staff's Installation Board itself, the Office of the Secretary of the Air Force, the Office of the Secretary of Defense, and the Bureau of the Budget. Where detailed limitations are not an explicit part of the public law, they are frequently made effective in the form of oral clarifications and commitments to any of the four responsible congressional committees.

Our base programs are important enough to warrant close consideration. However, the course of detailed program and budget development outlined has several shortcomings:

First, the particularity of authorizations for base spending results in a considerable rigidity. Money authorized for a specific item on an individual base may not be reallocated if for one reason or another (perhaps because the base is no longer available for the desired use) the money is not needed for the original purpose. It is apparent that, with the uncertainties of base rights negotiations, to choose one example, such rigidities may be fatal to the usefulness of the authorization. On the other hand, since the State Department may be naturally reluctant to undertake the difficult negotiations for base rights without some prior Congressional commitment for the base construction, the commitment may be made (in considerable specificity) while the outcome of negotiations is very much in doubt.

The second shortcoming is the separation of consideration of the budget and program for air bases from the rest of the Air Force budget. From our point of view this is perhaps the more crucial problem. A separation of base and other weapon decisions has the force of custom and institutional arrangement. The Congressional subcommittees that consider the program for air bases are not the same subcommittees that pass on the program for the aircraft and the personnel. Sometimes even the public laws covering these programs are distinct. To achieve a reasonable allocation of resources might force us to consider the possibility of trading aircraft for runways. Given the present administrative and legislative structure, this is not easy. It is easier to obtain economies in base construction considered separately.

We referred earlier, in describing the programmed base system, to Air Force regulations which effect reductions in the costs of air-base construction by requiring concentration of buildings, hardstands, and the like. The constructions savings effected by applying the criterion of maximum use of existing facilities afford another example. By and large it is cheaper, as far as the cost of an installation of a given standard is concerned, to use an existing base rather than to start from scratch. The availability of existing facilities, capable of reactivation and improvement from the expanding Air Force, has, quite naturally, strongly affected base locations both here and abroad.

However, economizing on the installation costs of strategic bases will not necessarily mean economy in the total cost of the strategic force. Airfield concentration of buildings and bombers parked on hardstands present an excellent target for enemy A-bomb attack. The extra costs of bombers we may expect to lose to such an attack or the cost of active defense to prevent their loss will more than offset the economies in construction and peacetime operation achieved by this concentration. And, similarly, where reactivated facilities are badly located to sustain the strategic operations we project, they may be a bad bargain.

This brings us to the point stressed earlier in another connection: namely, that the decisions we make on bases affect the performance and cost of our total weapons system. This means that the selection of bases and of the elements of bases has an importance that is far greater than is indicated even by the considerable size of the base budget. And the interdependence of base and weapon performance has very practical implications as to the validity of procedures for economizing on bases.

G. How To Look at Bases: Economizing and the Total Strategic Power

The way to look at the strategic-base problem is to recognize that base choice can critically determine the destructive power and the cost of our entire strategic force. Therefore, it is not enough to make a decision on bases merely because it economizes on base cost alone. We have to take into account what a base decision means to systems cost—how it affects the cost of extending the limited range of our aircraft to target, the vulnerability of our force to enemy bombing attack, the difficulties in recuperation from attack, the routes our bombers must fly through enemy territory, and the consequent losses we may suffer to this area defense. From this point of view it is hardly too much to say that many of the Congressional inquiries do not touch the key points to be decided in determining wastes or savings in current base programs. And since Congress is so closely involved in the detailed evaluation of the base program,* this is one of the facts of life that must be considered in estimating the relative feasibility of base alternatives. Construction funds, it appears, are harder to come by than money for aircraft procurement. An overseas base construction program is likely to be looked at more critically than a program for building bases in the United States. Even more, an operating overseas base program which involves the permanent location in the far corners of the world of large numbers of American service personnel raises opposition.

Such difficulties make it all the more vital for the Air Force to develop and present its program having clearly in mind the critical interdependence of base and other weapons-system decisions. The essential justification for vast expenditures on overseas strategic bases must be, as the Air Force has sometimes stated,† that, without such bases, a strategic force capable of doing a given job would cost vastly more, if it were feasible at all.

This interdependence furnishes not only the means of justifying a base program, but the criterion for choice. We analyze the comparative total costs in-

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*See p. 43*f*.

†Senate Committee on Armed Services and Committee on Foreign Relations, U.S. 82d Cong., 1st sess., *Military Situation in the Far East*, Washington, D.C., 1951. See, especially, Gen. H. S. Vandenberg's testimony.

curred in performing a given job of destruction with a fixed bomber force, using the various base alternatives compared.

H. Location and Locality Factors in Strategic Power

Total weapons systems costs and performance are affected by the relative positions of our bases with respect to their source of supply in the ZI, the boundaries of enemy territory (or the points from which they might strike at our bases), the targets which are our objectives, and the defense area which must be penetrated to reach these targets. For convenience we will call the systems costs which are a function of certain critical paths between these points —the base, the ZI, the target, enemy striking power, entry of enemy defense— *location* costs. They may be distinguished from the *locality* costs inherent in a specific site, which are not functions of these critical distances, but which are traceable to local phenomena such as climate. Under this head may be considered variations in (1) the cost of operations traceable to weather; (2) construction costs depending on climate, terrain, existence of a local construction industry and the availability of local construction materials, and the presence of existing base facilities; (3) supply costs affected by local terminal facilities for transportation and the possibility of offshore procurement from local sources, and (4) defense costs affected by terrain and existing defenses such as the U.S. and British air defense systems.

Part II of this report analyzes location factors explicitly and at some length. The present section is intended to indicate in qualitative terms the importance of locality costs.

Locality costs do not vary steadily with the critical distances we have listed, and they are less amenable to presentation in a simple, functional form; but they are, nonetheless, substantial. Costs of basing aircraft in the Arctic and subarctic illustrate this. (Though these are by no means the only important types of locality to be considered.) In brief, Arctic operation involves extra costs in (1) construction, (2) logistics supply and pipelines, (3) equipment and clothing required, particularly for heating purposes, (4) number and training of personnel, (5) increased maintenance needs of matériel, (6) low aircraft utilization, (7) high base vulnerability, and (8) low recuperability after damage.

Construction costs are much higher under these conditions than in the ZI or any other base location. This is so both because the design requirements are greater and because resources are very limited and the conditions of their use critically difficult. Aside from the fact that construction is only possible during an extremely cold and brief season, there is, of course, no existing construction industry. Construction materials of all sorts must be imported, and construction labor must be brought in, fed, housed, and paid extremely high rates to compensate for the comparatively short period of employment and the difficult working conditions. For Alaska, the Army engineers' cost estimates are obtained by multiplying the ZI costs by a factor of 2.5. (Moroccan costs are obtained by multiplying ZI costs by 1.5.) These cost estimates are prepared for budget purposes. Actual costs may exceed these. The Hoover Commission Inquiry, for example, found the costs of Alaskan housing to be considerably higher than was indicated by this factor.* The air base at Thule, in Greenland, some 800 mi below the North Pole, on which base a great amount of effort has been expended, was scheduled to cost some $250,000,000. This compares with some $50 million to $60 million for medium and heavy bomber installations in the United States. The construction of Thule is a tremendous undertaking which involved flying some 11,000 people up to the building site during this past year.

Needless to say, logistics supply problems for such sites are enormous. Initially, fuel had to be flown to Thule, and normal resupply will be complicated by the long periods during which the port will be closed by ice. In such localities a much larger stock of materials, parts, and supplies of all sorts has to be maintained (than is indicated merely by the miles of pipelines to the United States) to take care of periods when there is no flow at all through the pipelines.

To make operation possible in such temperatures, one needs Herman-Nelson heaters for preheating aircraft engines, Arctic survival and rescue kits, portable engine shelters and nose hangars, extra batteries for all equipment, extra vehicles, etc.

Lowered personnel efficiency makes large augmentations of personnel necessary (both in number and skill). Men have to be given special Arctic pilot training courses and have to be sent to special service training schools. Information on the larger number of men required is generally not very precise. One rule of thumb commonly used indicates that, within a large range, the efficiency

*See also *Hearings*, Subcommittee of the U.S. Senate Committee on Banking and Currency, *Alaskan Housing Legislation*, 81st Cong., 1st sess., S.851, Washington, D.C., 1949. According to data presented there, in 1946 and 1947 the cost for rather modest family quarters for noncommissioned officers ranged from $47,000 to $56,000, and from $62,000 to $74,000 per unit for field officers' housing. These figures represent the costs for housing one family.

of personnel is reduced by 2 per cent for each degree that the temperature is lowered below 0°F.* Additional personnel augmentation is required to handle increased maintenace loads. Preflight maintenance involves not only preheating cold-soaked engines, batteries, and electrical connections and instruments, but also finding and repairing leaks in cold-hardened rubber seals and tires.

The system cost to buy and operate, in peacetime, a wing of bombers from operating bases in the Arctic is more than double that in temperate regions.

While each wing has more personnel, it can manage fewer sorties per aircraft under the conditions of operation usual in the Arctic. (One source estimates the sortie rate at half that in the ZI.†) Problems arise from sudden icing conditions peculiar to the Arctic, and from sudden weather changes which put a premium on navigational skill. Chances of survival in case of forced landing are small.

The isolation of these bases makes their defense an especially difficult matter —this in spite of the contrary impression that might be gained from their possession of the frequently referred to virtue of being located in the Western Hemisphere. In winter all of the many Alaskan lakes are possible landing fields for airborne troop attack; and though Alaskan bases are not close to Russian industry, and even though they are in the Western Hemisphere, they are very close to the Russian border and Russian means of attack. The ability of units to recuperate after attack would appear to be low, especially in the winter. Typical problems would be the repairing of cratered runways, the loss of shelter for personnel and equipment, and the length of time required for resupply and reconstruction. (Thule, for example, can be reached only by air for most of the year. An attack in the fall or winter that destroyed a substantial portion of the buildings might put this base out of action until the following summer.)

The seasonal variations in hours of day and night at these bases and along the penetration route of bombing using them are very large in amplitude. This would have considerable effect on the attrition rate, and therefore on the variations in system cost of an Arctic base complex, depending on the time of year in which the campaign was fought. Summer penetrations from the north would have to be made in daylight. This would mean exposing bombers to attack by day fighters, and the Russians are expected to have day fighters in

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* N. G. Morris, "*Ground Support of Fighter Operations in Arctic Regions*," Air University thesis, November, 1948.

† *Wartime Planning Factors Manual*, Planning Division, Management Analysis Service, DCS/Comptroller (registered document).

much larger numbers than night fighters for some time to come. In winter there would be sufficient darkness, both in the south and north. From the standpoint of cover of darkness, then, these bases have on the whole a net disadvantage. On the other hand, multiplication and dispersal of bases around the entire periphery of the Soviet Union forces dispersion of Russian defenses, and the savings in attrition for the system as a whole gained by their dispersion is at least a partial balance for extra Arctic costs. However, it appears that these advantages are not enough to offset the extra costs of operating in the Arctic. If, as the study indicates, operating bases overseas are for the most part inferior to "refueling" bases, this conclusion is particularly true of Arctic operating bases. Although existing bases *can* play a useful role in refueling systems, other regions are better than the Arctic for future *expansion* of such a base system.

While many locality effects were taken into account by the study, we have concentrated our attention largely on the costs which vary with location with respect to the target, the ZI, and the boundaries of enemy striking power and defense.

PART II: LOCATION COSTS

A. Dilemmas of Location

Ambrose Bierce, the American journalist, in defining some such terms as "projectile," remarked that the excellence of this invention, a great improvement over physical conflict, had been qualified up to his time by the apparently ineradicable need for personal attendance at the point of propulsion. Bierce, of course, lived in a period before the development of control through program tapes and such wonders. However, even in the case of the missile, presence in the general vicinity of the launching not only of personnel, but of equipment and perhaps of a large supply of parts for assembly, is likely to be needed for some time to come, so that considerations of vulnerability, which increases with proximity, must be balanced against such advantages as close aim. In short, the advantages of proximity appear, unfortunately, to be symmetrical.

What are the advantages and disadvantages of proximity? It would appear on first examination that, in general, as we move our base operations along a given line away from the target, we achieve the following effects: (1) We diminish the probability of enemy attack against our bases by lengthening his own combat radius; and so we reduce the cost of defending the base or the expected damage for a given level of defense. (2) We shorten our supply lines and thereby lower both the normal peacetime transportation, travel, and stock costs as well as the cost of defending these supply lines and the expected losses to such enemy attackers as submarines. (3) By and large, we increase, though not steadily, the political security of our base operations; in the limiting case back in the Zone of the Interior (ZI), we not only come in under the umbrella of continental defense, but we apparently depend on no political alliance other than the satisfactorily secure one existing between the 48 states.

On the other hand—again in general—as we move our base operations toward the comparative shelter of the ZI, our aircraft grow in size and number and our aircraft personnel increase in proportion to that number. Unrefueled aircraft grow in size, moreover, at an increasingly rapid rate with increasing combat radius. Growth in airframe weight relates directly to increasing costs of procurement; the growth in both dry and gross weights relates to other increased systems costs, such as runway, fuel and fuel storage, and stock and maintenance costs. The increase in size of an individual aircraft or in its plan-projected area means, for a constant mission profile, an increase in the probability of loss to enemy area and local defense; therefore, it means more aircraft and aircrews in replacement to keep a given number of aircraft in operation; hence, higher costs. The increase in mission distance means more petroleum consumed, less payload carried, greater flight fatigue, and perhaps fewer sorties flown per aircraft; therefore, more aircraft and more aircrews to fly a given number of strikes. If the normal base operation of refueling is performed in the air, this means more aircrews and aircraft in the form of tankers, with corresponding increments in cost. Missiles, like unrefueled aircraft, increase in size, costliness, and vulnerability with increasing range; moreover (at any rate in the case of those missiles which may have undamped guidance), their inaccuracy is an increasing function of range; therefore, increased range means higher cost to destroy any given number of targets.

The symmetry and simplicity of this picture, however, are incomplete. First, it is asymmetrical, in that our capabilities differ from those of the Soviet Union, so that the optimum base location for ourselves is not necessarily the best position from the Soviet Union's standpoint. And, fortunately, *this* choice is ours. Second, the realistic physical configuration of the problem involves Russian targets placed at various points with Soviet and satellite boundaries. These boundaries within which area defenses and air bases are disposed in specific ways have a peculiar enough shape to make fruitful a systematic comparison of distance relationships other than that between the base and the target. Third, we can find bases with equal combat radii to target, some of which have the advantage, from our point of view, of being further from enemy striking power or which involve smaller penetration distances over enemy defense. In fact, we discriminate at the start the distances from the ZI to base, from base to target, from the enemy defense penetration point to target, and from our base to the enemy striking power. Because our target, enemy striking power, and the boundaries of enemy defense are all distinct, we have, within limits, the possibility of varying these critical distances separately. Fourth, our bases themselves are composites of functions which it is pertinent to analyze separately in relation to these critical distances. The various base functions—landing and takeoff, refueling, aircraft storage, housing and maintenance—are partially separable. Since these functions have differing vulnerabilities, locating them at differing distances from enemy striking power may be indicated. And since their location with reference to the target has performance effects differing from one to the other, separation may be indicated by this, too. The location question properly posed refers to the positioning of base functions rather than to the positioning of whole bases with the conventional mixture of functions. This is true for considerations of location in a macroscopic sense, i.e., for the world distribution of base functions; and it is true also in a microscopic sense, i.e., for the local dispersal of functions on a specific base.

Since any specific location must compromise some or all of the advantages of (1) proximity to targets, (2) favorable path of approach to targets, (3) logistic economy, and (4) remoteness and comparative invulnerability from enemy attack bases, it is important to analyze quantitatively what each of these advantages means in terms of systems cost and effectiveness, and to apply the results of this analysis to the specific geometry of our targets and alternative base areas. The remainder of the second part of this report is devoted to this analysis.

B. Base to Target: The Cost of Increasing Combat Radius

In this section we examine the manner in which increasing the distance between our home bases and targets affects the cost and performance of our bombing systems. We deal with single-stage unrefueled bombers, air-refueled systems and ground-refueled systems. And, since reasons of politics, logistics, and vulnerability suggest pulling our bases back to extreme distances from Russian targets, we compare systems for using the programmed bombers at full intercontinental radii. These comparisons are made in terms of the relative costs of the various systems to destroy a specific set of defended Russian targets. On the basis of our analysis it becomes apparent that, so far as extending total mission radius is concerned, at any rate, it is very important to discriminate the distinct effects of pulling back various base functions. In particular, if we leave the fuel and the physical plant needed to accomplish fuel transfer overseas, the effect is markedly different from taking all ground base functions back to the ZI.

SINGLE-STAGE BOMBING SYSTEMS AND TARGET RADIUS

Generalized Bomber Studies

As we extend the distance between base and target, the weight of a bomber large enough to reach the target and return without any refueling increases at a growing rate. And the cost to buy the bomber, the facilities for its operation, the cost to train the crew and to keep the bomber and the bomber crew in readiness, also increase. In fact they increase in almost direct proportion to bomber weight. The exact shapes of curves representing these increases in weight and cost with radius depend on a number of factors, including the type of powerplant, payload cruise and over-target speed, and altitude. They are steeper for turbojets than for turboprops, and are steeper for high speeds and for very low as well as very high altitudes. Figure 22 illustrates the growth in the cost to buy and operate for 3 years a turbojet and a turboprop bomber of 40,000-ft altitude, 400-knot speed, 8000-lb bomb load, and a variable range. These curves, which are based on the performance characteristics analyzed in an earlier RAND study,*

*R. B. Murrow, R. S. Schairer, and C. V. Sturdevant, *Bomber Capabilities—1954 Turboprop and Turbojet Powerplants*, The RAND Corporation, Report R-171, February 1, 1950 (Confidential).

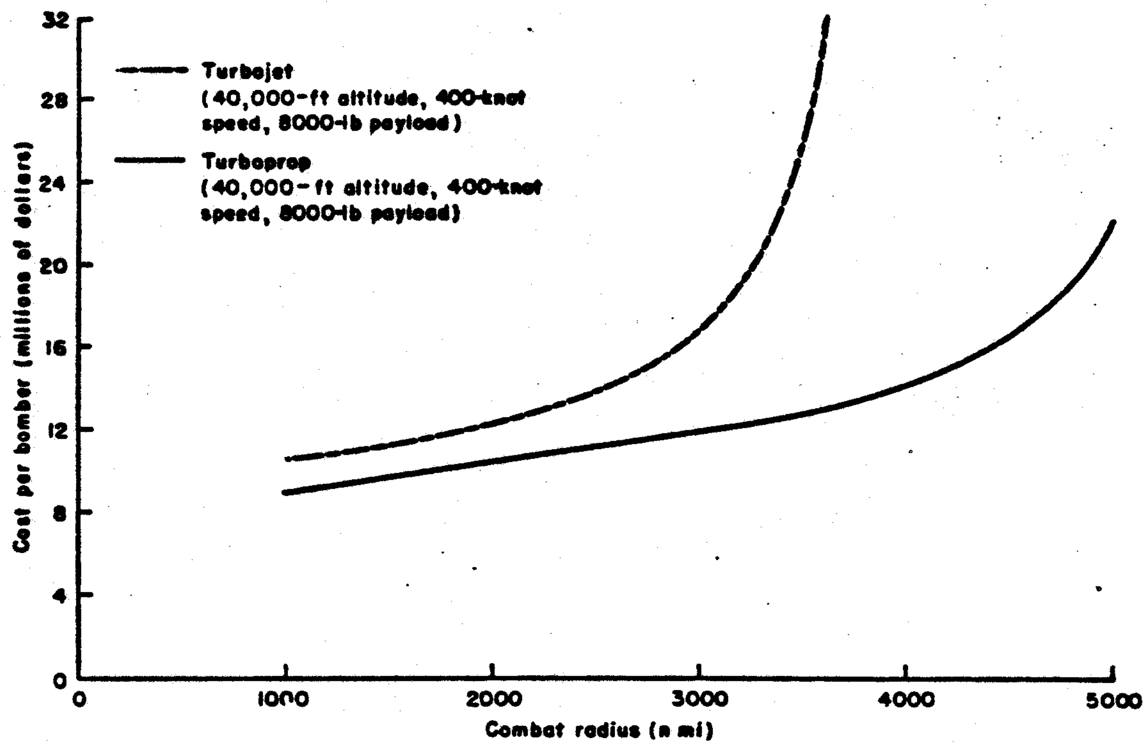

Fig. 22—Three-year systems cost per bomber as a function of combat radius

represent continuous families of aircraft. Each point on a curve corresponds to a different plane operable without refueling at the design radius indicated. The turbojet in the illustration increases by 60 per cent in cost as combat radius increases from 3000 mi to 3600 mi; it increases in cost by two and one-half times from 1700 to 3600 mi. And the radius of this family has a limit of less than 4000 n mi.

The costs presented in Fig. 22 are costs to purchase and operate bombers in time of peace. They are preparedness costs that do not take attrition into account. If we take into account the losses of bombers to enemy area and local defenses, the combat radius for which the bomber was designed also has a direct effect here. As a single-stage bomber increases in weight (and in plan-projected area), its expected combat losses, at a fixed speed and altitude, to a wide range of enemy defense weapons also increase. This growth in vulnerability with weight compounds the cost increases due directly to increases in weight and radius.

The curves presented in Fig. 22 are derived from generalized bomber studies. If we examine the systems cost and the radius of specific bombers that are either now operational or are scheduled to be operational in this decade, comparable observations may be made.

The Current Generation of Bombers

The costs and design radius of the current-design generation of bombers are represented in Table 1. The B-47E is of somewhat earlier design date than the

Table 1

CURRENT GENERATION OF BOMBERS

Model	Cost ($ million)	Combat Radius (n mi)
B-57B	4.8	887
B-66B	5.5	1200
B-47E	9.8	1780
B-47E[a]	9.8	2095
Later B-47 (B-47II)	9.8	2900
RB-52B	23.4	3110
RB-52C	23.4	3625

[a] Range extended. Taxiing gross weight of 220,000 lb; water injection.

remaining planes that represent roughly the same state of the art and have roughly the same performance characteristics, with the exception of radius capability. Because the bombers in the lower tail of this distribution have a somewhat different mission and carry a smaller military load, their costs are somewhat lower than they would otherwise be. Curves for the current bombers would have much the same characteristics as the generalized bomber curves already described. They would be J-shaped. An increase in radius is accompanied by a more than proportionate increase in costs.

Figure 23 makes clear the reasons underlying the limited unrefueled radius of our programmed turbojet bomber force. Bombers of this design generation capable of traveling from the United States to any considerable part of the Russian industrial-target system and back again without picking up any fuel during the trip, if feasible at all, would have had to be enormously large and costly, and, assuming the given range of speed and altitude performance characteristics, would have been likely to suffer high combat losses. Or they would have been smaller and less costly at a drastic sacrifice in speed and altitude performance, which would have meant still greater losses to enemy defenses.

But if we add the Rascal air-to-surface missile, the design generation pictured in Fig. 23 includes all the new bombers likely to figure significantly in our combat-ready force for the rest of this decade. This can be made clear by a rapid survey of major bombing systems under development. Such a survey suggests that the strong influence of combat radius we have examined is by no means temporary.

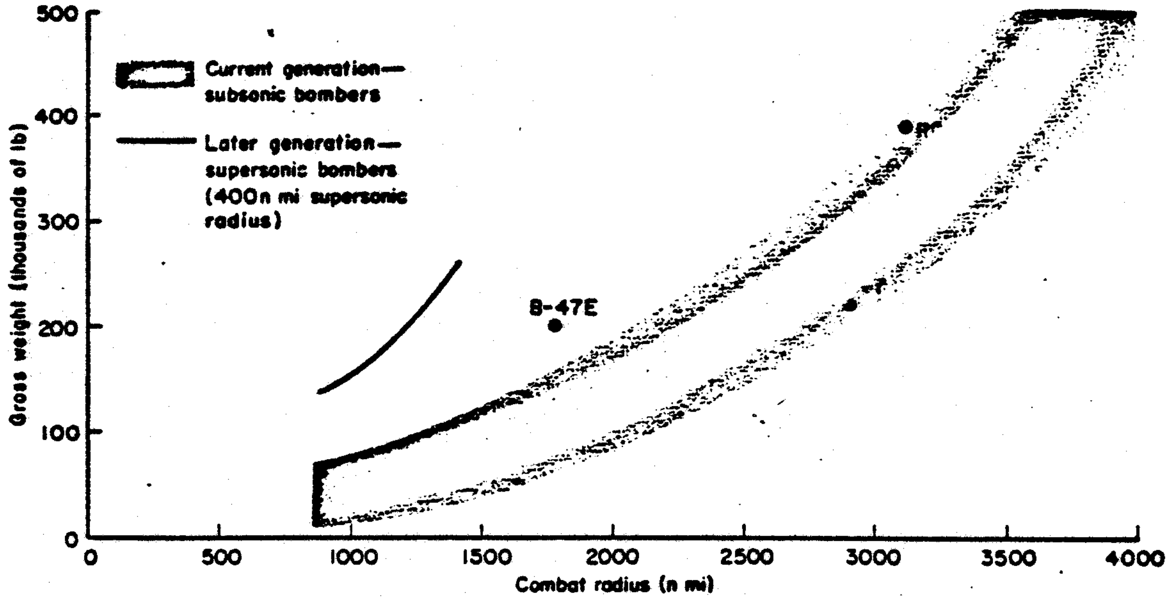

Fig. 23—Gross weight vs combat radius

Future Bombing Systems

Chemically Fueled High-performance Bombers. There is no conventional bomber on the horizon which will fly two-way military missions from bases in the United States to deep targets inside Russia without refueling. The next generation of bombers will emphasize one or more of such alternatives as supersonic and extreme-altitude capabilities in order to meet anticipated advances in enemy defense. There are two opposing tendencies: one, the normal improvement in the state of the art; and the other, the increasing severity of performance requirements. A fixed set of performance conditions can be met at lower weight and costs. But the performance conditions do not stay fixed. The resulting cost-versus-radius curves show no substantial improvement over the present. If anything, it appears that matters are getting worse: combat radius will be more rather than less critical for some time to come.

Figure 23 also presents a weight-versus-radius curve derived from RAND studies of generalized supersonic bombers. The supersonic distance assumed is 400 n mi. For deep penetration through Russian defense likely after 1960, with supersonic fighters and advanced defense missiles, 400 mi of supersonic travel would confer on the penetrating bomber no greater survival probability than the B-47 is anticipated to have against an earlier generation of Russian defense.* Yet it is clear that the costs of a given target-radius capability with such a fixed supersonic leg would not be substantially improved. The curve for the supersonic bombers in Fig. 23 lies to the left of and above the weight-radius region for contemporary bombers shown in this figure. The weight (and therefore the cost) of a member of this supersonic family with the capability of any given radius exceeds the weight of a bomber of the current generation of the same radius. Moreover, the weight and costs of this supersonic family rise more steeply with increasing radius.

Perhaps the most important point to be made, however, regarding supersonic bomber developments concerns their timing. In dealing with the problem of base selection for the strategic striking force, our criterion for improving a bomber type is much more rigorous, for example, than the condition that a single wing be operational. We are concerned with the bomber types which are likely to make up the major part of the combat-ready force, and our campaign analyses pit large numbers of these bombers, variously based, against Russian defenses.

It is clear that for the rest of the decade supersonic bombers are not likely to meet this criterion. There is a long sequence of steps between development and combat readiness in large numbers: planning, budget recommendation, Congressional authorization, purchase commitment, appropriation, production, delivery, testing service training, availability in combat units; and then, some time later, such availability in large numbers. The supersonic bomber development is near the beginning of this sequence.† Not the least of its problems is the evolution of a bombing-navigation system suitable for planes operating at such supersonic speeds. (Historically, bombing-navigation systems have taken

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*We have tested this statement, using, for example, the 1955 and 1960 Russian defenses described in G. H. Clement and C. P. Bahrman, *Missile Systems for Strategic Bombardment*, The RAND Corporation, Report R-248, November 20, 1953 (Secret—Restricted Data), and related documents.

†The following comments are based on an analysis made by R. L. Stewart in an unpublished memorandum.

a long time to develop.) Prophecy concerning the timing of one of our technical developments is, by its very nature, one of the most precarious of pursuits, excepting only the job of prophesying Russian developments. At RAND, the combat availability in large numbers (which might be from 12 to 18 months after *delivery* in large numbers) is placed variously between late 1960 and late 1964. It seems doubtful that this timing will be distinctly bettered.

The availability in large numbers of carriers designed specifically as low-altitude airplanes is also beyond the period of reference of this study. It is quite possible, on the other hand, that within this time members of the current generation will be adapted to such low-altitude use. Such a use may be extremely fruitful. However, it will cut the total radius capability of the current generation even further.

Nuclear-powered Bombers. The only manned bomber under development which differs markedly from our description in its weight-radius characteristics is the nuclear-powered bomber. The weight and cost curves for the reactor-type of nuclear bomber are very flat. Though they do not change substantially with radius, they start very high. Even at very short radii the required weight of the shielding device will set a high minimum. (Recent proposals for using low-powered reactors for cruising and chemically fueled engines for penetration would reduce the weight of the shield.) Most important, for our purpose, is the fact that, on RAND's estimate, the nuclear-powered bomber is several years beyond the time period we are considering.*

Air-to-surface Missiles. The Rascal air-to-surface missile development program, according to the RAND Missiles-Aircraft Study,† has progressed to the point where the first B-36 and B-47 squadrons which will carry the Rascal may be in readiness for this use in 1956; and, provided procurement is not delayed for the development of guidance techniques other than the radar-relay device presently being developed, the production program may be expanded and the stock of operational missiles in combat-ready units increased within a reasonable period after 1956. The effect on radius capabilities of the availability in quantity of air-to-surface missiles is likely to be of some importance, then, in this decade. What is this effect? Essentially, it will amount to a net reduction in the combat

*Nuclear and Aircraft Divisions, *Nuclear Powered Flight—A Preliminary Statement*, The RAND Corporation, Report R-135, February 2, 1949 (Secret—Restricted Data).

†Clement and Bahrman, *op. cit.*

radius of the bombers which carry these missiles. The missiles will be released outside the local defenses, thus reducing the mission distance by perhaps 100 n mi. But the missile will create a drag cutting the radius of the carrier by a greater amount.*

Long-range Surface-to-surface Missiles. The strategic surface-to-surface missile is another important future bombing system. Such missiles are much lighter and less costly per unit than manned aircraft. The Snark, with performance characteristics somewhat superior to the B-47, is one-fourth of its gross weight. How sensitive are these missile costs to change in combat radius? Are increases in combat radius important in the missile case? How do these questions affect our study?

The situation appears to be as follows:

(1) While missiles are lighter and cheaper per unit for comparable performance than are manned bombers,† total costs are important, since the total missile stockpile requirements for a bombing campaign are in general larger than the stockpile of bombers needed. (Missiles, unlike bombers, are not recovered and re-used.) Moreover, a generalized missile weight-radius curve has the same sort of J-shape as the bomber curves. Therefore, in comparing one missile with another operating at a different range, the same kind of relative cost and performance considerations apply.

(2) Bombing missiles operate one way, and therefore their costs and weights should be read lower down on the J-shaped weight-radius curves, i.e., at roughly half radius. In this region these curves are generally flatter, depending on the other performance requirements and the state of the art. If two-way reconnaissance missiles are required, however, they will fall on the curves at a point

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* In this context we are dealing with the radius effects of the air-to-surface missile. For its effect on losses to enemy defenses and on the base-system comparisons made in this section, see p. 125.

† The gross-weight difference between the missile and a manned aircraft having the same range stems from the fact that the missile dispenses entirely with a considerable part of the load carried by a manned aircraft. And this makes possible the familiar train of weight reductions in the structure, engine, and fuel needed to carry this load. As to the load differences: First, the missile, of course, has no crew or equipment for crew comfort. Second, it does not carry a variety of countermeasures against enemy defense, such as guns, rockets, etc. And third, it is not equipped with landing gear, flaps, slats, etc., which are used for the recovery and repeated use of the aircraft, since, even when an escort missile is to return, it is not designed for recovery and re-use. This third element appears to be the most important, accounting perhaps for half the difference in load between the Snark and the B-47. The result of this reduction in load carried is that the missile's initial gross weight is smaller by a greater amount.

comparable to that for manned aircraft. These escort-reconnaissance missiles, though not recoverable, operate two ways.

(3) A broad choice of penetration routes remains of great importance. And such a choice implies a capability for very extended missions, if these missions start well within the interior of the United States.

(4) In the future, for missiles as for aircraft, supersonic and extreme-altitude performance will be useful to evade enemy defenses. Such high performance makes mission distance a critical matter for the missile as well as for the aircraft.

(5) For missiles with undamped guidance, the CEP—and therefore the campaign costs—is an increasing function of range.

(6) Most important, while we believe that our analysis of base location with reference to routes of attack, base defense, and expected damage can be fruitfully extended to the study of missile bases, for the purpose of our present interest such an extension may be deferred, because the date at which the long-range surface-to-surface missile will form a sizeable proportion of the strategic striking force and will generate any major part of the strategic base requirements is rather distant. At any rate, it is beyond the time reference of the present study.

The timing of missile systems availability has recently been reviewed,* and some more extended comment is justified on the basis of its findings.

The Snark is not likely to constitute a large fraction of our combat-ready strategic force before the end of this decade. In 1958 or 1959, the Study estimates, Snark missiles with long-range capability might begin to be phased into the force. The Mark I guidance system, which will have a capability for day as well as night guidance, may be available at that time. However, the present airframe and powerplant design for the Snark would provide it even then with a range capability of less than 4700 mi for the bombing Snark and a radius capability of 3200 mi for the reconnaissance Snark. Both the range for the bombing missile and, even more, the radius of the reconnaissance version fall short of an intercontinental capability. (This would be especially true if we conceive the intercontinental mission as starting well within the boundaries of the United States in order to lessen ground attrition, if we take into account dogleg routes to reduce air loss, and if we require for this time period a flexibility for attacking quite deep target systems.) RAND has recommended a larger-

*See Clement and Bahrman, *op. cit.*

wing-area Snark with a more efficient powerplant, which, it is expected, would have a much-increased radius or range capability (a reconnaissance radius of 5300 mi and a bombing range of 7900 mi). Even this enlarged radius capability for the reconnaissance missile would fall slightly short of the needs imposed by intercontinental operation with a wide selection of routes from a region well within the United States to a deep Russian target system. An alternate version of the Snark is conceived to have a supersonic capability to evade advanced Russian air defense. Using such supersonic speeds, the Snark would have to be operated from overseas bases for bombing as well as reconnaissance. The all-subsonic range is estimated to be 4860 n mi, and the all-supersonic ranges are estimated to be 1450 n mi. This would make feasible a 2200-n-mi mission with the last 1200 n mi at Mach 1.3. The corresponding radii for a reconnaissance missile are shorter than the ranges given above: 3360 n mi for the all subsonic version and 690 n mi for the all-supersonic version.

The Navaho, which is a later-generation missile than the Snark, would travel at much higher speeds and could be brought closer in time if it were developed for operation against targets closer in space. The Navaho II, with a speed of Mach 2.75, would have a bombing range of 3330 n mi. It could not begin to be phased into the force until about 1960 and would not constitute a significant fraction of our force for some years thereafter. The longer-range Navaho III might not begin to be phased in until about 1965 and would not constitute a significant fraction of our combat-ready force until near the end of the next decade.

Summary on Single-stage Systems versus Radius

1. For a fixed speed, altitude, and payload, single-stage bombing-system cost increases at a growing rate with design radius.

2. Where we have a choice, we may not want to operate at our maximum single-stage radius. By reducing mission radius we can gain speed and performance at extreme altitude. Depending on the size and region of the gain and the composition of enemy defenses, this might mean a significant reduction in bomber attrition, and therefore an increase in destructive potential. Even where fairly distant single-stage operation was feasible, it might not be preferred.

3. In considering the problem of base-to-target distances for strategic bombers, our primary concern must be the means of reaching targets with the B-47,

which will be numerically the largest component in the force, with the B-36, the B-52, and with the combinations of these three bombers with the Rascal. No other bombing system is likely to form a significant proportion of our total bombing potential for the rest of this decade.

4. For at least the rest of this decade, and possibly for some time thereafter, no bomber is likely to be available which is capable of operating at full intercontinental radius without any refueling whatsoever. To hit a deep Russian target system, we need either to operate from overseas bases or, if we operate from the ZI, to use the assistance of some form of refueling, that is to say, to operate with a multistage system.

RADIUS EFFECTS ON MULTISTAGE SYSTEMS

Air Refueling

It is possible to use a bomber whose design radius is less than the distance from operating base to target by extending its range with the aid of tankers. Doing this avoids the increased bomber size entailed by increasing radius in a single-stage operation which, in general, means increasing bomber attrition. But, ignoring attrition, there is a parallel to the direct weight and cost changes of the single-stage case. This is visible if we take into account the *weight and cost* of tankers as well as bombers. The *capital and operating costs* of progressively extending the radius with the aid of tankers of a specific bomber or fixed range, e.g., the B-47, increase at an increasing rate. The increase proceeds in steps corresponding to points at which additional fuel is required. With increasing combat radius the treads of these steps become shorter. And, particularly with insurance for the uncertainties of multiple refueling, the "risers" become steeper. In fact, refueling uncertainties may be so severe that consideration of more than, say, two refuelings is too optimistic. It should be noted, therefore, that Figs. 24 through 26 neglect both the possibility that a large number of refuelings is operationally infeasible and, assuming feasibility, they neglect the costs associated with bombers lost or aborted as a result of failures in rendezvous or fuel transfer. These figures present the tanker requirements for extending the combat radii of the B-47, the B-36, and the B-52. The refueling operation on which these charts are based involves the rendezvous and fuel transfer between a single bomber and one or more tankers, or between a single

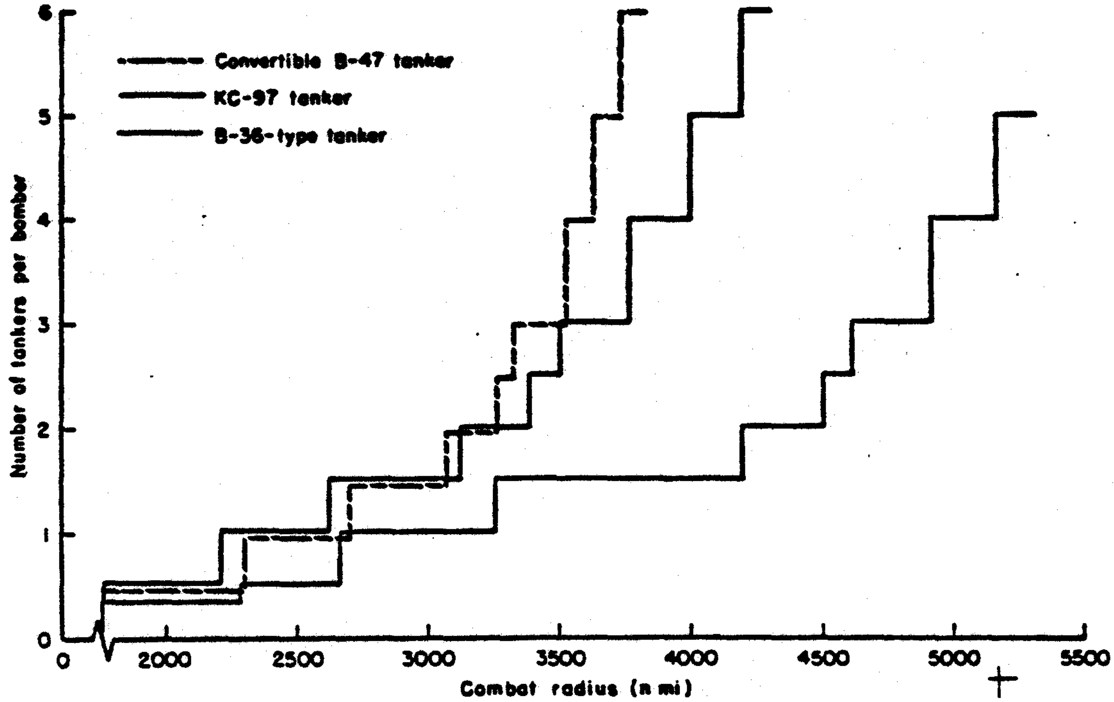

Fig. 24—B-47 tanker requirements for extended combat radii

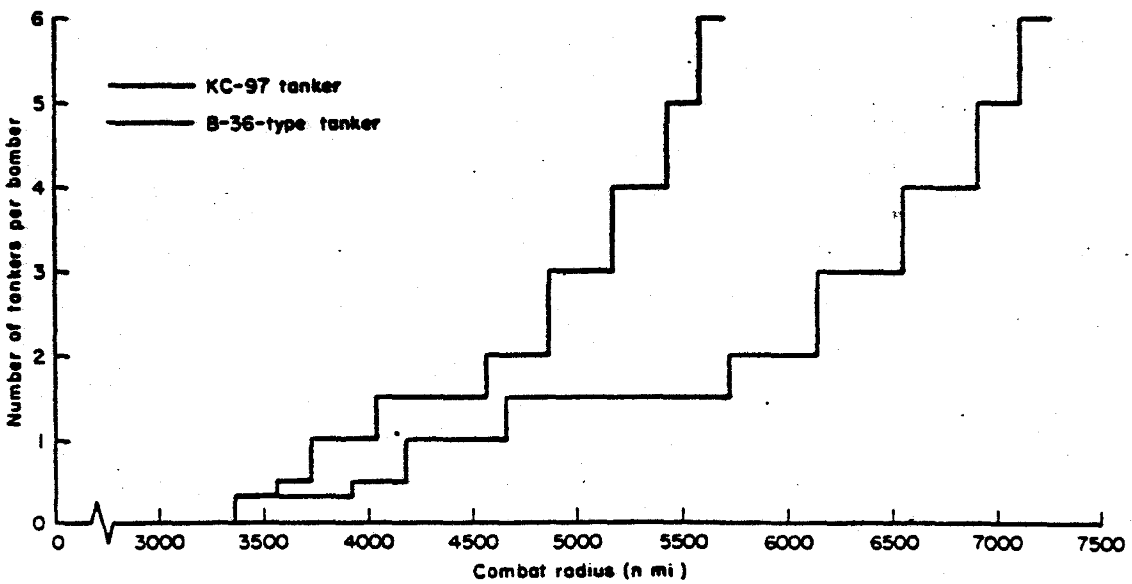

Fig. 25—B-36 tanker requirements for extended combat radii

tanker and several bombers operating as part of a cell. For this reason the ratio of tankers to bombers is frequently shown on these charts as a fraction. Tankers and bombers are based together. All prestrike refueling takes place at a single point of rendezvous. All poststrike refueling also takes place at a single point,

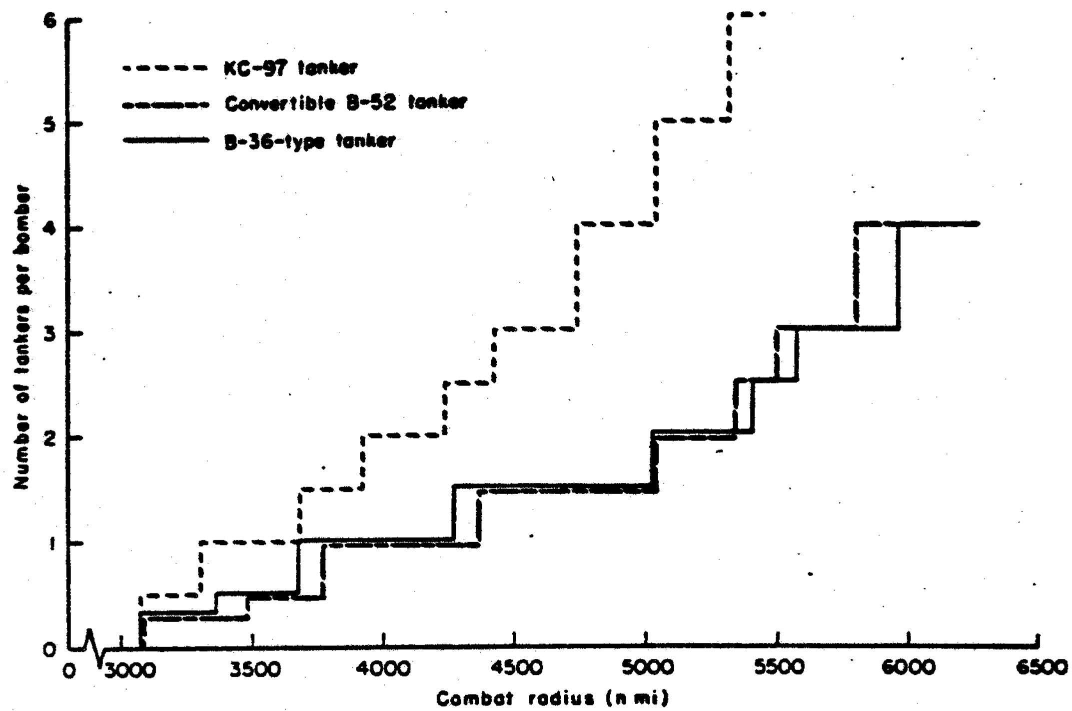

Fig. 26—B-52 tanker requirements for extended combat radii

though not necessarily at the same one. Extra fuel transfers at the prestrike rendezvous point involve extra loiter time for the first-refueled bomber, and this penalty is recognized in the calculations. On the other hand, possibly generous assumptions as to the amount of overloading feasible in the B-52 (about 90,000 lb) have been taken advantage of in the target-bound refueling. And, as has been stated, no allowance has been made in these calculations for problems of rendezvous for the homebound refueling. Rendezvous points have been determined optimally at the distances which match the bomber's fuel needs with the tanker's fuel transfer capability. In practice, rendezvous points are affected by other considerations, such as identifiability.* For each mile shift of the rendezvous toward the base, the combat radius of the system is reduced by half a mile. We have taken this into account in connection with our campaign studies, where we apply these curves to the actual flight paths from specific bases to identifiable refueling points, and from these points to places of entry into enemy defenses and onto specific targets.

*Apart from identifiability, anticipation of problems in even the target-bound refueling have, we understand, led the Air Force to consider, as a further constraint on the location of rendezvous points, that they be close enough to home base to enable bombers to return home in case the fuel transfer is unsuccessful. This constraint limits tanker-radius extension very much more stringently than the identifiability condition. We have not taken this into account.

To translate the curves of tanker requirements as a function of radius into dollar terms, the 3-year systems cost of tankers and bombers has been estimated. These costs are summarized in Table 2.

The dollar amounts presented are the costs to buy the tankers and bombers and to operate them in time of peace. They do not include any current costs of wartime operation. Such stockpile costs are those relevant to a short strategic air campaign of the kind the Air Force contemplates. Such a campaign would have to be fought largely out of stockpile. In the short period of its projected duration, total new bomber production would be less than 10 per cent of the total programmed D-day bomber force, and the contribution of newly mobilized personnel would be similarly limited.

Intercontinental air-refueled operations would require some tankers capable of transferring large amounts of fuel at distances far from ZI bases. Of the aircraft that might be made available for this mission, the B-36 was found to be the most economic. The B-36 costs presented in Table 2 allow for the operation of existing B-36's and the possible procurement of additional ones, as tankers. This use would permit almost a 25 per cent reduction in the new 3-year systems cost for this aircraft through the elimination of armament and electronics and reducing manning and maintenance. It should be noted that the cost of maintaining existing B-36's (assuming that they are retired from combat), $5.7 million per aircraft over a 3-year period, hardly makes them "free" for tanker use.

In the case of the KC-97, two unit cost figures are presented: $6.4 million and $4.5 million. The lower of these costs is based on the projected program in which tankers would form a small fraction of the total force of aircraft and, it might be plausibly assumed, would be accommodated partially "free" on bomber bases. This convention of costing might be questioned. The commitment of bases for B-47's is not a "sunk" cost independent of and preceding the decision for basing the KC-97's. The B-47 and the KC-97 are being produced simultaneously, and it would be possible to base each separately—1 squadron, 1 wing, or 2 wings to a base, depending on location. In any case, it is clear that the convention that KC-97's cost nothing in bases, etc., is not at all plausible when we take cases of the sort under consideration here, in which we have two, four, and six times as many tankers as bombers. For an intercontinental air-refueled B-47 system, our measurements show that tanker requirements average two or more KB-36's to every B-47 in the operation force and, in addition, about one KC-97 for every two B-47's. (These ratios change for various routes of

Table 2

AIRCRAFT SYSTEMS COST

(Millions of dollars)

Item	B-47		B-52		KC-97 Based with B-47's		KC-97 Separately Based		B-36-type Tanker	
	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual
Installations										
Technical facilities	29.5	....	45.0	....	5.3	....	22.6	....	31.8	....
Personnel facilities	15.6	....	17.3	....	1.5	....	16.9	....	21.8	....
Maintenance	.....	2.2	.....	3.1	....		0.4	2.0	.....	2.7
Major equipment										
Mission aircraft	100.0	11.1	240.0	4.0	27.6	1.0	47.0	1.7	100.2	3.7
Support aircraft	10.0	....	24.0	....	2.8	....	4.7	....	10.0	....
Minor equipment										
Organizational equipment	6.5	0.4	9.2	0.6	0.7	0.1	4.5	0.2	5.2	0.3
Ground radar	0.6	0.1	0.6	0.1	....	....	0.6	0.1	0.6	0.1
Stocks										
Initial stock level	2.5	....	3.4	....	0.5	....	1.3	....	2.6	....
Readiness reserve	2.2	....	4.6	....	2.3	....	3.2	....	2.0	....
Spares	47.2	....	115.2	....	12.5	....	18.0	....	37.0	....
Transportation	0.9	1.1	1.1	1.4	0.1	0.1	0.5	0.5	1.0	1.2
Personnel										
Training	22.8	5.7	23.8	6.0	2.6	0.6	14.0	3.5	18.2	4.5
Pay and allowances	.....	10.2	.....	13.2	....	1.7	.....	6.0	.....	9.8
Travel	0.6	0.5	0.8	0.7	....	0.1	0.4	0.4	0.6	0.5
Maintenance										
Mission aircraft	.....	8.6	.....	15.6	....	2.1	.....	4.5	.....	12.0
Support aircraft	.....	0.6	.....	0.8	....	0.1	.....	0.4	.....	0.6
POL										
Mission aircraft	.....	4.8	.....	5.9	....	0.9	.....	1.6	.....	4.6
Support aircraft	.....	0.3	.....	0.4	....	0.4	.....	0.2	.....	0.2
Miscellaneous	.....	1.3	.....	1.7	....	0.2	.....	0.8	.....	1.5
Service and miscellaneous	.....	0.4	.....	0.6	....	0.1	.....	0.2	.....	0.4
Intermediate commands	.....	3.0	.....	4.0	....	1.0	.....	2.1	.....	2.0
Overhead	.....	17.2	.....	19.4	....	2.9	.....	8.0	.....	14.6
Total	238.4	67.5	485.0	77.5	55.9	11.7	133.7	32.2	231.0	58.7
Cost per aircraft	5.3	1.5	16.0	2.6	2.8	0.6	3.7	0.9	7.7	2.0
TOTAL 3-YEAR COST	9.8		23.8		4.6		6.4		13.7	

attack.) An operating base which housed along with a single B-47 wing such a tanker complement would have to accommodate, besides the bombers, about 90 or 100 KB-36's and 25 or so KC-97's. This would make it about a 5-wing base. When the number of tankers approaches the number of bombers, the higher cost clearly applies.

All the costs we have presented are costs to buy and operate a single aircraft or a wing of aircraft without taking into account the elements of the cost which have already been purchased or committed. In fact, many of the components of our strategic force are in being: bases, aircraft, trained personnel, etc. And many of these assets are usable in the various base-aircraft systems we consider, though different systems make use of different parts of the inheritance. These inherited assets involve no new outlays. In determining the total economic costs of the decision among various base-aircraft alternatives, the billion dollar costs of these inherited elements should be subtracted from estimates of the total cost to start anew under each of the alternatives. However, this job must be done in connection with total systems cost rather than wing or single-aircraft cost. The average savings per wing or per single aircraft which are made possible by using inherited elements depend on the size of total force requirements in relation to the fixed inheritance. And this relation will vary with the job of destruction considered, the level of enemy defense, etc. We have therefore dealt with inheritance on an item-by-item basis, subtracting inherited elements from the total requirements indicated by our campaign results.

Figure 27 presents the 3-year unit cost to achieve the capability of operating the B-47 at various target distances with tanker refueling as an aid. Figure 28 is the analogous step curve for the B-52. These cost-versus-radius curves were obtained by applying the unit-tanker and unit-bomber costs of Table 2 to the tanker per bomber requirement curves presented earlier (the lower cost—$4.5 million—was used for the KC-97 where the tanker-bomber ratio was less than 1; otherwise the higher cost—$6.4—was used).

Extending Radius with Refueling Bases

It is evident from the preceding discussion that, in the case of both tanker-refueled bombers and single-stage bombers, increasing combat radius is extremely costly. Two alternatives are (1) to put operating air bases near the targets, and (2) to keep operating bases at a great distance and extend the limited radius of our aircraft by a system of staging or refueling bases.* The

* We refer to "refueling" bases rather than to "staging" bases throughout this section to indicate the essential function of these bases in our conception.

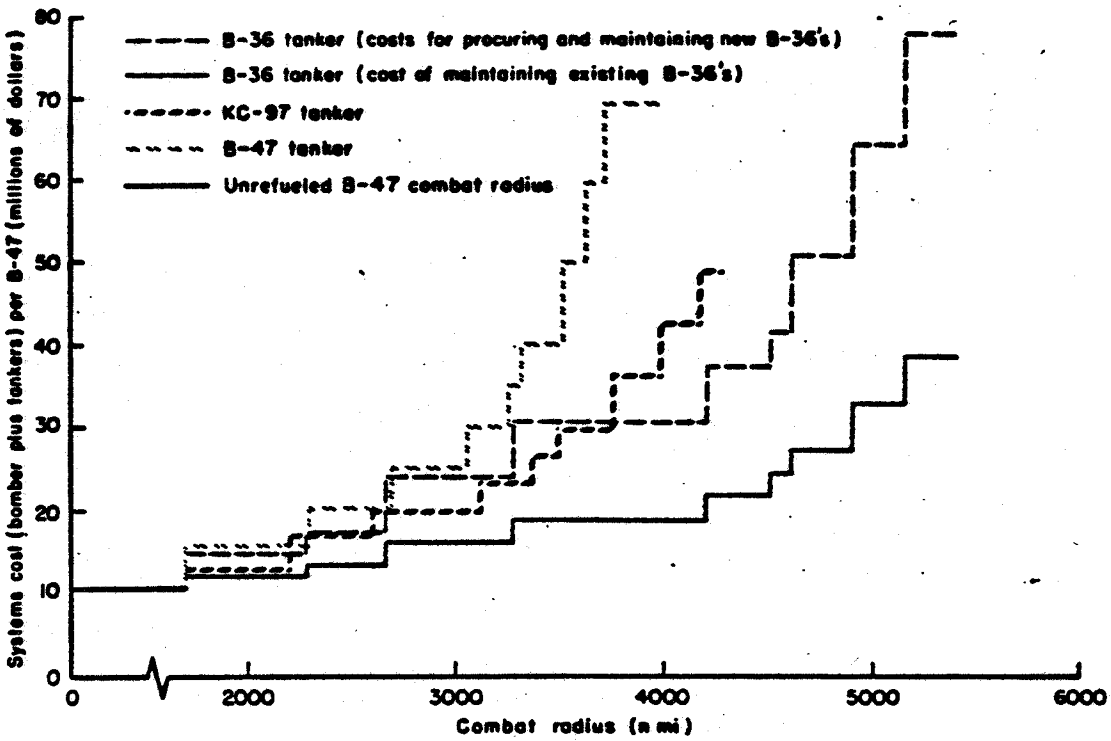

Fig. 27—Three-year systems cost for a tanker-refueled B-47 as a function of mission combat radius

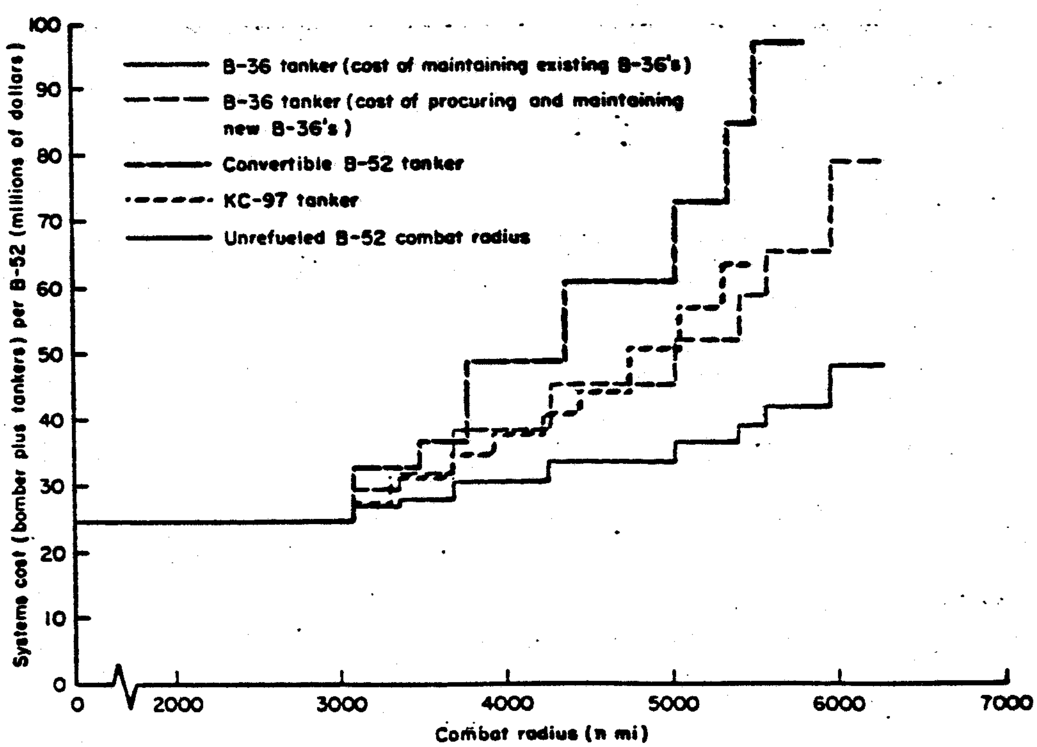

Fig. 28—Three-year systems cost for a tanker-refueled B-52 as a function of mission combat radius

effectiveness of these alternatives depends on their vulnerability to Russian air and ground attack.

Staging plays an important role in the operation of the strategic air force. It permits the *intermittent* use of bases not suitable for permanent aircraft basing because of proximity to the enemy, extreme climate, base-rights limitations, inadequate maintenance facilities, or difficulties of supply in wartime. It provides a good measure of flexibility in the choice of routes of approach to targets, and, most important, it permits the parking of bombers on bases more remote from Russian striking power. The section entitled "Base to Border: The Effect of Base Vulnerability," page 225, provides an analysis of base vulnerability and the costs of defense and expected ground attrition for primary and refueling bases. In the present context some summary statements will suffice regarding refueling base systems as supplements to U.S. operating bases.

adv. of overseas refuelling

The transfer of fuel on the ground at a point between the bomber operating base and the target necessitates a runway, parking apron, fuel and a fuel-transfer system, ground-handling equipment, navigational aids, a minimal base-personnel complement, and associated structures. A base with these facilities is capable of at least the services performed by aerial tankers at altitude; and the landing of bombers at advanced bases permits other tasks to be accomplished as well. Crew rest and briefing, minor aircraft repair and maintenance (with some additional equipment and personnel), and bomb test and loading are among the functions typically performed on SAC staging bases. While the functions performed on refueling bases are minimal and constrained by considerations of vulnerability, the facilities provided for them need not be. As we shall see later, a small amount spent on additional concrete, refueling hydrants, blast-resistant construction, or repair equipment may result in savings during a campaign very much greater than the added cost of these elements. The overseas cost of a refueling base equipped with the best landing, take-off, and fueling facilities and having extensive microscopic passive defenses and a high capability for recuperation is $24.6 million.*

This base is provided with the following facilities: one 10,900-ft runway† plus taxiways (which could serve as an additional emergency runway), 3 dispersed refueling aprons, 30 high-speed hydrants, and 6.6 million gallons of jet fuel, 1 B-47 Station Set (prestocked equipment), housekeeping equipment, runway repair equipment, housing, and a permanent complement of 149 men

*See Table 32, p. 197.

†A two-runway base costs $36.9 million.

(exclusive of those manning defense weapons). Mobile En Route Teams and Control and Maintenance Task Forces are deployed for brief periods during the campaign.

The 3-year cost to purchase, operate, and support such a refueling base comes to $60.7* million (apart from the costs of active defense, which are dealt with in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225). And this base is capable of handling the transfer of fuel to 30 B-47's within 2 hr, or 30 B-52's within 3 hr.† Moreover, unlike the tanker, which increases combat radius by a fraction of the unrefueled radius (a fraction which diminishes with increasing numbers of refuelings as the extra tankers fly out and back), the refueling base is capable of providing as much range as an operating base.

Figure 29 illustrates the difference between the cost of air- and ground-refueling for the B-47, refueled in one case by the KC-97 tanker and in the

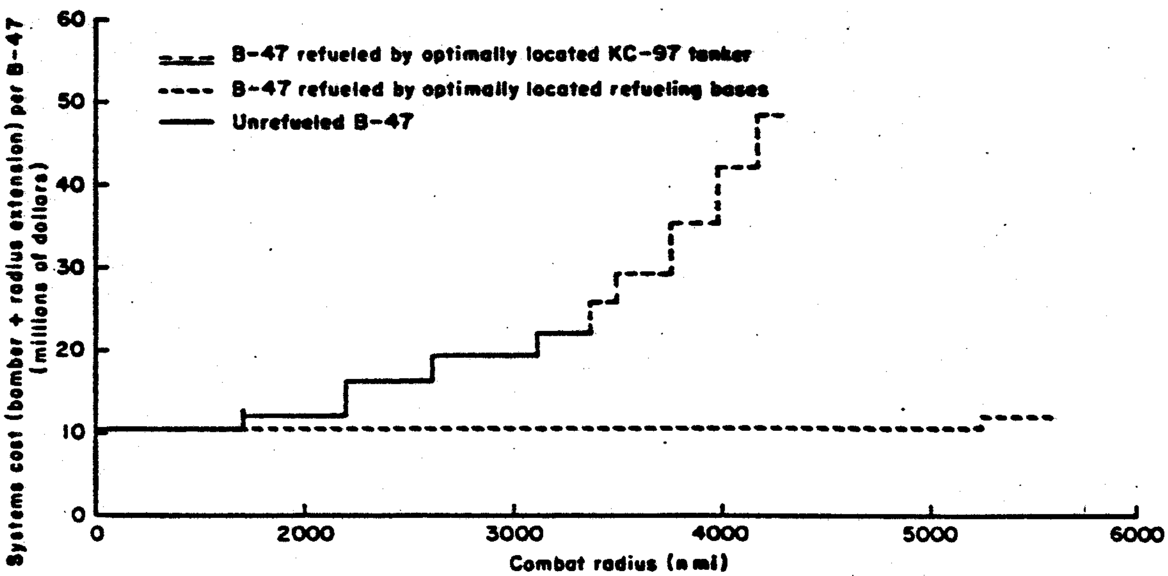

Fig. 29—Multistage B-47 systems vs combat radius

other by a refueling base. This figure assumes that both air- and ground-refueling points are available at optimal locations. At a combat radius of 4000 n mi, the total systems cost of the air-refueled B-47 is four times that of the ground-refueled B-47. The difference in the *radius extension portion of the cost* is a

*See Table 35, p. 204. The additional 3-year cost for a two-runway base is $14.4 million.

†This is the time required to perform the minimum functions of landing, taxiing, fuel transfer (from hydrants pumping out 600 gpm), and take-off. This time might be extended for reasons of strike coordination, crew rest, or aircraft maintenance. However, the threat of enemy attack would make long stops dangerous.

factor of 25. For a B-52 at the same combat radius, the total systems cost is about 50 per cent higher when refueled by a KC-97 than when refueled by a ground-refueling base, and the difference in the radius extension portion of the cost is a factor of 7. At greater combat radii these differences increase very rapidly. However, at shorter radii, in the neighborhood of 2000 to 3000 n mi, the differences are much less marked. This fact suggests that a base system with combat legs in this neighborhood may obtain the characteristic advantages of aerial refueling (certain kinds of flexibility and insurance) at relatively moderate cost. The ground-refueling system takes advantage of this opportunity.*

If a peacetime period longer than 3 years is taken, the differences between air- and ground-refueling systems increase. A base involves a substantial initial investment, but the costs of maintaining it are comparatively low. Tankers, on the other hand, are expensive to operate as well as to procure. Table 3 compares

Table 3

COST OF RADIUS EXTENSION[a]

(Millions of dollars per bomber)

Aircraft	Total Combat Radius					
	3000 n mi		4000 n mi		5000 n mi	
	Air	Ground	Air	Ground	Air	Ground
Three-year period						
B-47	10.3	1.3	32.7	1.3	....	1.3
B-52	0.7	0	13.5	2.0	26.3	2.0
Eight-year period						
B-47	17.1	2.1	55.2	2.1	....	2.1
B-52	0.7	0	22.5	3.1	44.3	3.1

[a] Radius extension for air-refueled systems shown in this table consists of KC-97 and en route bases in the ZI.

these systems over an 8-year period as well as over a 3-year period. This longer period is relevant, since a considerable part of our strategic force 8 years hence will be made up of B-47 and B-52 aircraft.

There are, in addition, substantial differences in the fuel-transfer *rate* over time. A KC-97 can transfer *60,000 gal* over a period of *one month* at projected

* Systems which require more than one tanker (KC-97) per bomber not only incur higher costs for radius extension than do those involving refueling bases, but they have greater *base costs* as well for the extra facilities required for the tankers.

sortie rates; a refueling base can deliver its *6.6 million gal* of fuel in about *6 hr.* Where aircraft must be refueled in a stream, on a given strike or a rapid succession of strikes, this continuing fuel-transfer capability is of importance.

Geography, and the geometry of Russian targets, will not permit operations at a ratio of one refueling base per bomber wing. More important is the effect of enemy action, for the total number of bases needed is determined by the *joint* effect of the maximum strike the Strategic Air Command (SAC) must mount plus the capability of the enemy to neutralize our bases. Some allowances must be made for "insurance" bases. If we provide, say, three times the base capacity needed on traffic grounds alone, the 3-year systems cost per B-47 comes to $4.0 million. In the case of the B-47, this adds about 40 per cent to the cost of buying and operating a bomber in the ZI. This is less than the cost of having available a KC-97 with a much more limited refueling capability.

It appears that an extensive overseas refueling-base system is politically feasible. As we indicated in the section entitled "The Intercontinental Mission," page 27, it is more easily accomplished than a heavily-manned, overseas operating base system. Such a system can be made relatively secure from attack at reasonable cost. And obtaining sufficient bases to support the 1956 force should be quite feasible. In addition to the 72 bases scheduled to be available for strategic use, there are about 130 sites capable of improvement to B-47 standards in areas of interest.

INTERCONTINENTAL CAMPAIGNS WITH THE B-47

The costs presented so far are important components of an analysis of the cost to destroy a Russian target system. However, they are not the whole of such an analysis in themselves. To present a complete analysis, it is necessary first of all to introduce some of the detailed physical and political geography which determines the actual relationships between home bases, refueling points in the air and on the ground, and the targets. Second, we need to introduce the costs exacted by enemy defenses. As our bombers penetrate to target and withdraw, they will be subject to attack by enemy fighters and by enemy local defenses. The support apparatus used to extend the radius of our bombers, on the other hand, will not be attrited by enemy defenses (though, like the bombers, it is vulnerable to enemy bombing). It will be capable of re-use with the bombers that will replace air losses. We have displayed large differences in unit radius-extension costs with increasing combat radius. These costs are incurred to support the operating part of the force. How large do radius-extension costs bulk in the costs to destroy a Russian industry-target system? Given a fixed type of bomb carrier and a system of U.S. bases, how much difference in campaign costs does it make to use one method of radius extension rather than another?

Radius-extension Requirements To Visit a Russian Industry System

Targets, refueling points, and bases are not in general spaced so that each added fuel transfer occurs at a point at which the bomber can make the best use of the fuel it takes on. There are large stretches of ocean between our home bases and Russia, in which of course no staging bases are possible. And there are a great many land areas which are equally unavailable for this purpose, either because we cannot obtain base rights or because the areas are close enough to enemy borders to make their availability a matter of the enemy's control rather than ours. Similarly, in the case of air-refueling points, these have to be kept well outside the enemy's early-warning network and, moreover, are for all practical purposes limited to points above identifiable land masses. For these reasons, and for others connected with the choice of routes to reduce attrition, to be discussed in the section entitled "Bases, Targets, and Penetration Paths," page 135, "great circle" distances from home base to targets have a very limited utility and may seriously mislead us in judging our radius-extension needs.

Tables 4*a* and 4*b* present one set of routes for the B-47 operating intercontinentally from bases in the ZI against the 100-point Russian industrial-target system with radius extension provided exclusively by tankers. Refueling points are limited to regions at least 500 mi outside enemy boundaries and to points satisfying the condition of identifiability referred to above. The starting points are taken as either Limestone or Spokane, depending on which one is closer to the target. In fact, for reasons of vulnerability, the home operating bases for an intercontinental system would have to be both less concentrated and further inside the programmed early-warning network. Limestone and Spokane might be taken as staging areas, though here again traffic requirements would involve some multiplication of bases and the removal of others rather further from targets than Limestone and Spokane themselves.

We have excluded routes involving flight over a probable European battle front. The routes presented in this table were chosen to minimize tanker costs. This means, since home bases are limited to the United States, that, for the air-refueled system, these routes in all but two cases enter enemy defenses

Table 4a

MINIMUM-TANKER PATHS FOR AIR-REFUELED B-47 AIRCRAFT

100 pt target system.

WAC No.*	RGZs	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
168	1	Limestone	1470	66°N/37°W	1480	59°N/14°E	540	Minsk	540	59°N/14°E	1850	66°N/46°W	1100	3490	2.5	...
167	1	Limestone	1470	66°N/37°W	1480	59°N/14°E	840	Stalinogorsk	840	59°N/14°E	870	65°N/10°W	2080	3790	4.0	...
250	1	Limestone	1470	66°N/37°W	1480	59°N/14°E	940	Krivoy Rog	940	59°N/14°E	870	68°N/32°W	2080	3890	4.0	...
234	2	Limestone	1470	66°N/37°W	1480	59°N/14°E	950	Dnepro-dzerzinsk	950	59°N/14°E	870	68°N/32°W	2080	3900	4.0	...
234	3	Limestone	1470	66°N/37°W	1480	59°N/14°E	965	Dnepro-petrovsk	965	59°N/14°E	870	68°N/32°W	2080	3915	4.0	...
249	1	Limestone	1470	66°N/37°W	1480	59°N/14°E	1000	Zaporozhye	1000	59°N/14°E	870	68°N/32°W	2080	3950	4.0	...
234	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1020	Konstan-tinovka	1020	59°N/14°E	890	64°N/15°W	2000	3910	...	1.5
234	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1035	Kramatorsk	1035	59°N/14°E	890	64°N/15°W	2000	3925	...	1.5
234	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1050	Makeyevka	1050	59°N/14°E	890	64°N/15°W	2000	3940	...	1.5
234	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1050	Lisichansk	1050	59°N/14°E	890	64°N/15°W	2000	3940	...	1.5
234	2	Limestone	1970	64°N/16°W	920	59°N/14°E	1055	Gorlovka	1055	59°N/14°E	890	64°N/15°W	2000	3945	...	1.5
249	2	Limestone	1970	64°N/16°W	920	59°N/14°E	1065	Stalino	1065	59°N/14°E	890	64°N/15°W	2000	3955	...	1.5
325	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1070	Dzaudzhikau	1070	59°N/14°E	890	64°N/15°W	2000	3960	...	1.5
156	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1080	Kamensk	1080	59°N/14°E	890	64°N/15°W	2000	3970	...	1.5
249	2	Limestone	1970	64°N/16°W	920	59°N/14°E	1090	Zhdanov	1090	59°N/14°E	890	64°N/15°W	2000	3980	...	1.5
249	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1125	Taganrog	1125	59°N/14°E	890	64°N/15°W	2000	4015	...	1.5
249	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1140	Krasnyy Sulin	1140	59°N/14°E	890	64°N/15°W	2000	4030	...	1.5
249	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1230	Krasnodar	1230	59°N/14°E	890	64°N/15°W	2000	4120	...	1.5
235	2	Limestone	1970	64°N/16°W	920	59°N/14°E	1230	Stalingrad	1230	59°N/14°E	890	64°N/15°W	2000	4120	...	1.5
324	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1450	Batumi	1450	59°N/14°E	290	61°N/7°E	2600	4340	...	2.0
325	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1490	Groznyy	1490	59°N/14°E	290	61°N/7°E	2600	4380	...	2.0
325	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1555	Makhachkala	1555	59°N/14°E	290	61°N/7°E	2600	4445	...	2.0
325	1	Limestone	1970	64°N/16°W	920	59°N/14°E	1560	Rustavi	1560	59°N/14°E	290	61°N/7°E	2600	4450	...	2.0
325	3	Limestone	2600	61°N/7°E	290	59°N/14°E	1760	Baku	1760	59°N/14°E	290	61°N/7°E	2600	4650	...	3.0
326	1	Limestone	2600	61°N/7°E	290	59°N/14°E	1935	Krasnovodsk	1935	59°N/14°E	290	61°N/7°E	2600	4825	...	3.0
247	1	Limestone	1970	64°N/16°W	1070	66°N/23°E	1335	Guryev	1335	66°N/23°E	650	61°N/7°E	2600	4480	...	2.0
153	3	Limestone	1470	66°N/37°W	1620	66°N/26°E	340	Leningrad	340	66°N/26°E	1990	66°N/46°W	1100	3430	2.5	...
153	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	360	Kolpino	360	66°N/26°E	1990	66°N/46°W	1100	3450	2.5	...
154	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	550	Shcherbakov	550	66°N/26°E	1470	68°N/32°W	1620	3640	3.0	...
154	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	565	Konstant-inovskiy	565	66°N/26°E	1470	68°N/32°W	1620	3655	3.0	...
154	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	590	Yaroslavl	590	66°N/26°E	1470	68°N/32°W	1620	3680	3.0	...

167	6	Limestone	1470	66°N/37°W	1620	66°N/26°E	650	Moscow	650	66°N/26°E	1470	68°N/32°W	1620	3740	3.0	...
167	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	665	Noginsk	665	66°N/26°E	1470	68°N/32°W	1620	3755	3.0	...
167	2	Limestone	1470	66°N/37°W	1620	66°N/26°E	700	Kolomna	700	66°N/26°E	1010	65°N/10°W	2080	3790	4.0	...
154	2	Limestone	1470	66°N/37°W	1620	66°N/26°E	715	Dzerzhinsk	715	66°N/26°E	1010	65°N/10°W	2080	3805	4.0	...
154	3	Limestone	1470	66°N/37°W	1620	66°N/26°E	730	Gorkiy	730	66°N/26°E	1010	65°N/10°W	2080	3820	4.0	...
155	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	755	Kirov	755	66°N/26°E	1010	65°N/10°W	2080	3845	4.0	...
165	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	865	Kazan	865	66°N/26°E	1010	65°N/10°W	2080	3955	4.0	...
165	1	Limestone	1970	64°N/16°W	1070	66°N/26°E	910	Ulyanovsk	910	66°N/26°E	1040	64°N/15°W	2000	3950	...	1.5
165	1	Limestone	1970	64°N/16°W	1070	66°N/26°E	955	Syzran	955	66°N/26°E	1040	64°N/15°W	2000	3995	...	1.5
235	1	Limestone	1970	64°N/16°W	1070	66°N/26°E	1000	Saratov	1000	66°N/26°E	1040	64°N/15°W	2000	4040	...	1.5
165	2	Limestone	1970	64°N/16°W	1070	66°N/26°E	1010	Kuybyshev	1010	66°N/26°E	1040	64°N/15°W	2000	4050	...	1.5
165	3	Limestone	1970	73°N/22°W	1150	66°N/26°E	1060	Ufa	1060	66°N/26°E	1120	74°N/22°W	2000	4120	...	1.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	330	Berezniki	330	64°N/53°E	1650	74°N/22°W	2000	3980	...	1.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	360	Gubakha	360	64°N/53°E	1650	74°N/22°W	2000	4010	...	1.5
156	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	395	Molotov	395	64°N/53°E	1650	74°N/22°W	2000	4045	...	1.5
155	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	440	Votkinsk	440	64°N/53°E	1650	74°N/22°W	2000	4090	...	1.5
156	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	455	Nizhiniy Tagil	455	64°N/53°E	1650	74°N/22°W	2000	4105	...	1.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	480	Alapayevsk	480	64°N/53°E	1650	74°N/22°W	2000	4130	...	1.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	505	Sarana	505	64°N/53°E	1650	74°N/22°W	2000	4155	...	1.5
156	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	515	Sverdlorsk	515	64°N/53°E	1650	74°N/22°W	2000	4165	...	1.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	530	Severskiy	530	64°N/53°E	1650	74°N/22°W	2000	4180	...	1.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	555	Polerskoy	555	64°N/53°E	1080	78°N/15°E	2600	4220	...	2.0
164	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	590	Zlatoust	590	64°N/53°E	1080	78°N/15°E	2600	4255	...	2.0
164	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	605	Miass	605	64°N/53°E	1080	78°N/15°E	2600	4270	...	2.0
164	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	615	Chelyabinsk	615	64°N/53°E	1080	78°N/15°E	2600	4280	...	2.0
164	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	645	Beloretsk	645	64°N/53°E	1080	78°N/15°E	2600	4310	...	2.0
164	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	690	Magnitogorsk	690	64°N/53°E	1080	78°N/15°E	2600	4355	...	2.0
236	3	Limestone	1970	73°N/22°W	1680	64°N/53°E	805	Orsk	805	64°N/53°E	1080	78°N/15°E	2600	4470	...	2.0
163	2	Limestone	1970	73°N/22°W	1840	63°N/65°E	530	Omsk	530	63°N/65°E	1275	78°N/15°E	2600	4370	...	2.0
328	1							Begovat[b]								
161	2	Limestone	2800	80°N/38°E	1380	60°N/77°E	425	Kemerovo	425	60°N/77°E	2160	74°N/22°W	2000	4595	...	2.5
161	1	Limestone	2800	80°N/38°E	1380	60°N/77°E	500	Stalinsk	500	60°N/77°E	2160	74°N/22°W	2000	4670	...	2.5
159	1	Limestone	2800	80°N/38°E	1460	62°N/90°E	325	Krasnoyarsk	325	62°N/90°E	2300	74°N/22°W	2000	4605	...	2.5
166	1							Petrovsk[b]								
204	2	Spokane	1970	58°N/172°E	1880	44°N/139°E	420	Komsomolsk	420	44°N/139°E	1250	55°N/172°E	2600	4260	...	2.0

[a] World Aeronautical Charts, *Bombing Encyclopedia Manual and Code Book*, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.
[b] Target cannot be reached.

attack 6 mts Central SU over the pole.

refuel through Kuriles! is over the pole + in.

go to p. 139

Table 4b

SUMMARY OF MINIMUM-TANKER PATHS FOR AIR-REFUELED B-47 AIRCRAFT[a]

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
					Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
66°N/26°E	1599	3.71	3085	7.16	1060	721	340	2.46	1.67	0.79	4145	3806	3425	9.62	8.83	7.95
64°N/53°E	1970	4.57	3650	8.47	805	558	330	1.87	1.29	0.77	4455	4208	3980	10.34	9.76	9.23
63°N/65°E	1970	4.57	3810	8.84	530	530	530	1.23	1.23	1.23	4340	4340	4340	10.07	10.07	10.07
60°N/77°E	2800	6.50	4180	9.70	500	450	425	1.16	1.04	0.99	4680	4630	4605	10.86	10.74	10.68
62°N/90°E	2800	6.50	4260	9.88	325	325	325	0.75	0.75	0.75	4585	4585	4585	10.64	10.64	10.64
44°N/139°E	1970	4.57	3850	8.93	420	420	420	0.97	0.97	0.97	4270	4270	4270	9.91	9.91	9.91
66°N/23°E	1970	4.57	3040	7.05	1335	1335	1335	3.10	3.10	3.10	4375	4375	4375	10.15	10.15	10.15
59°N/14°E	1912	4.44	2906	6.74	1935	1178	540	4.49	2.73	1.25	4841	4084	3446	11.23	9.47	7.99

[a] These averages would, in some cases, be increased if we included the two targets Petrovsk and Begovat, which cannot be reached at all, and if we measured from the actual multiplicity of ZI-base locations instead of from the two points of Limestone and Spokane.

9 hours to entry pt from Spokane.

+ 1 hour to target. → 9.9 = 10 hours to target in Far East from the north, and that the leg of the mission traveled over enemy territory is frequently quite long. (Penetrations vary from 325 n mi to over 1800.) Some doglegging is involved in these routes so as to reduce the time of penetration over enemy territory. But this was done only so far as it was possible without adding tankers. While we shall refer to these routes as *minimum-tanker paths* for exclusively air-refueled B-47's, their more precise description is *routes minimizing penetration subject to a minimum tanker constraint.* In spite of the relative directness of these routes, the radii for 98 of the 100 points average almost 4100 n mi, with a minimum of over 3400 and a maximum of 5200. Two points of the 100-point target system cannot be reached from bases in the United States at all if radius extension is provided by tankers only, even if large numbers of tankers are used prestrike and poststrike. As indicated earlier, we have taken at most one refueling point prestrike and one refueling point poststrike for each target. The elements of the base-to-target path consist of:

1. A base to refueling point leg,
2. A refueling point to entry point leg, and
3. An entry point to target leg.

The path back from target to home base is divided similarly. The measurements for each of these legs of the trip are included in Table 4*a*. Table 4*b* presents averages and extreme values by target group for distance and mission times.

Tables 5*a* and 5*b* present the analogous measurements for each element of the paths of a B-47 system operating intercontinentally with the aid of ground-refueling, and with the supplement of a small number of tankers where appropriate refueling bases are not available. Here again the routes are chosen so as to keep tanker requirements at a minimum, with doglegging to reduce penetration distances subject to this constraint. However, since the ground-refueled system includes refueling stations around most of the periphery of Russia, tankers are kept at a minimum, with moderate penetrations. About three-quarters of the entry is from the south, and the maximum penetration is a little less than 1300 n mi. The approach distance to the refueling points is therefore more extended than in the minimum tanker routes for the exclusively air-refueled system. Home bases, as in the intercontinental air-refueled system, are in the United States, and measurements start with Limestone or Spokane, whichever is nearer. The refueling-base locations assumed have been governed by two

Table 5a

MINIMUM-TANKER PATHS FOR GROUND-REFUELED B-47 AIRCRAFT

WAC No.*	RGZ's	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	320	Berezniki	320	63°N/65°E	2100	64°N/19°W	2000	4420	...	0.5
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	325	Gubakha	325	63°N/65°E	2100	64°N/19°W	2000	4425	...	0.5
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	325	Alapayevsk	325	63°N/65°E	2100	64°N/19°W	2000	4425	...	0.5
156	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	360	Nizhniy Tagil	360	63°N/65°E	2100	64°N/19°W	2000	4460	...	0.5
156	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	400	Sverdlovsk	400	63°N/65°E	2100	64°N/19°W	2000	4500	...	0.5
156	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	410	Molotov	410	63°N/65°E	2100	64°N/19°W	2000	4510	1.0	...
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	420	Polovskoy	420	63°N/65°E	2100	64°N/19°W	2000	4520	1.0	...
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	430	Severskiy	430	63°N/65°E	2100	64°N/19°W	2000	4530	1.0	...
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	465	Sarana	465	63°N/65°E	2100	64°N/19°W	2000	4565	1.0	...
155	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	480	Votkinsk	480	63°N/65°E	2100	64°N/19°W	2000	4580	1.0	...
164	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	490	Chelyabinsk	490	63°N/65°E	2100	64°N/19°W	2000	4590	1.0	...
164	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	510	Zlatoust	510	63°N/65°E	2100	64°N/19°W	2000	4610	1.0	...
164	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	510	Miass	510	63°N/65°E	2100	64°N/19°W	2000	4610	1.0	...
153	3	Limestone	2000	64°N/19°W	1100	66°N/26°E	340	Leningrad	340	66°N/26°E	1100	64°N/19°W	2000	3440	0	...
153	1	Limestone	2000	64°N/19°W	1100	66°N/26°E	360	Kolpino	360	66°N/26°E	1100	64°N/19°W	2000	3460	0	...
168	1	Limestone	2650	53°N/2°W	640	59°N/14°E	540	Minsk	540	59°N/14°E	640	53°N/2°W	2650	3830	0	...
249	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	375	Krasnodar	375	39°N/35°E	1070	33°N/13°E	3660	5105	0	...
249	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	470	Zhdanov	470	39°N/35°E	1070	33°N/13°E	3660	5200	0	...
249	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	480	Zaporozhye	480	39°N/35°E	1070	33°N/13°E	3660	5210	0	...
250	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	490	Krivoy Rog	490	39°N/35°E	1070	33°N/13°E	3660	5220	0	...
234	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	500	Dneprod-zerzinsk	500	39°N/35°E	1070	33°N/13°E	3660	5230	0	...
234	3	Limestone	3660	33°N/13°E	1070	39°N/35°E	500	Dneprop-etrovsk	500	39°N/35°E	1070	33°N/13°E	3660	5230	0	...
249	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	500	Taganrog	500	39°N/35°E	1070	33°N/13°E	3660	5230	0	...
249	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	530	Stalino	530	39°N/35°E	1070	33°N/13°E	3660	5260	0	...
234	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	530	Makeyevka	530	39°N/35°E	1070	33°N/13°E	3660	5260	0	...
325	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	540	Dzaudzhikau	540	39°N/35°E	1070	33°N/13°E	3660	5270	0	...
234	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	550	Konstant-inovka	550	39°N/35°E	1070	33°N/13°E	3660	5280	0	...
234	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	560	Gorlovka	560	39°N/35°E	1070	33°N/13°E	3660	5290	0	...
249	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	565	Krasnyy Sulin	565	39°N/35°E	1070	33°N/13°E	3660	5295	0	...
234	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	570	Kramatorsk	570	39°N/35°E	1070	33°N/13°E	3660	5300	0	...

156	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	575	Kamensk	575	39°N/35°E	1070	33°N/13°E	3660	5305	0	...
234	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	600	Lisichansk	600	39°N/35°E	1070	33°N/13°E	3660	5330	0	...
235	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	680	Stalingrad	680	39°N/35°E	1070	33°N/13°E	3660	5410	0	...
235	1	Limestone	4520	30°N/32°E	630	39°N/35°E	850	Saratov	850	39°N/35°E	630	30°N/32°E	4520	6000	0	...
167	1	Limestone	4520	30°N/32°E	630	39°N/35°E	900	Stalinogorsk	900	39°N/35°E	630	30°N/32°E	4520	6050	0	...
167	6	Limestone	4520	30°N/32°E	630	39°N/35°E	980	Moscow	980	39°N/35°E	630	30°N/32°E	4520	6130	0	...
167	2	Limestone	4520	30°N/32°E	630	39°N/35°E	960	Kolomna	960	39°N/35°E	630	30°N/32°E	4520	6110	0	...
165	1	Limestone	4520	30°N/32°E	630	39°N/35°E	990	Syzran	990	39°N/35°E	630	30°N/32°E	4520	6140	0	...
167	1	Limestone	4520	30°N/32°E	630	39°N/35°E	1000	Noginsk	1000	39°N/35°E	630	30°N/32°E	4520	6150	0	...
165	2	Limestone	4520	30°N/32°E	630	39°N/35°E	1030	Kuybyshev	1030	39°N/35°E	630	30°N/32°E	4520	6180	0	...
154	2	Limestone	4520	30°N/32°E	630	39°N/35°E	1060	Dzerzhinsk	1060	39°N/35°E	630	30°N/32°E	4520	6210	0	...
154	3	Limestone	4520	30°N/32°E	630	39°N/35°E	1070	Gorkiy	1070	39°N/35°E	630	30°N/32°E	4520	6220	0	...
165	1	Limestone	4520	30°N/32°E	630	39°N/35°E	1090	Ulyanovsk	1090	39°N/35°E	630	30°N/32°E	4520	6240	0	...
154	1	Limestone	4520	30°N/32°E	630	39°N/35°E	1120	Shcherbakov	1120	39°N/35°E	630	30°N/32°E	4520	6270	0	...
154	1	Limestone	4520	30°N/32°E	630	39°N/35°E	1120	Konstant-inorskiy	1120	39°N/35°E	630	30°N/32°E	4520	6270	0	...
154	1	Limestone	4520	30°N/32°E	630	39°N/35°E	1120	Yaroslavl	1120	39°N/35°E	630	30°N/32°E	4520	6270	0	...
165	1	Limestone	4520	30°N/32°E	630	39°N/35°E	1125	Kazan	1125	39°N/35°E	630	30°N/32°E	4520	6275	0	...
155	1	Limestone	4520	30°N/32°E	630	39°N/35°E	1270	Kirov	1270	39°N/35°E	630	30°N/32°E	4520	6420	0.5	...
324	1	Limestone	4520	30°N/32°E	740	38°N/40°E	230	Batumi	230	38°N/40°E	740	30°N/32°E	4520	5490	0	...
325	1	Limestone	4520	30°N/32°E	740	38°N/40°E	280	Rustavi	280	38°N/40°E	740	30°N/32°E	4520	5540	0	...
325	1	Limestone	4520	30°N/32°E	740	38°N/40°E	360	Groznyy	360	38°N/40°E	740	30°N/32°E	4520	5620	0	...
325	1	Limestone	4520	30°N/32°E	740	38°N/40°E	420	Makhachkala	420	38°N/40°E	740	30°N/32°E	4520	5680	0	...
325	3	Limestone	4520	30°N/32°E	740	38°N/40°E	430	Baku	430	38°N/40°E	740	30°N/32°E	4520	5690	0	...
326	1	Limestone	4520	30°N/32°E	740	38°N/40°E	600	Krasnovodsk	600	38°N/40°E	740	30°N/32°E	4520	5910	0	...
247	1	Limestone	4520	30°N/32°E	740	38°N/40°E	750	Guryev	750	38°N/40°E	740	30°N/32°E	4520	6010	0	...
236	3	Limestone	4520	30°N/32°E	740	38°N/40°E	1090	Orsk	1090	38°N/40°E	740	30°N/32°E	4520	6350	0.5	...
165	3	Limestone	4520	30°N/32°E	740	38°N/40°E	1150	Ufa	1150	38°N/40°E	740	30°N/32°E	4520	6410	0.5	...
164	2	Limestone	4520	30°N/32°E	740	38°N/40°E	1170	Magnitogorsk	1170	38°N/40°E	740	30°N/32°E	4520	6430	0.5	...
164	1	Limestone	4520	30°N/32°E	740	38°N/40°E	1200	Beloretsk	1200	38°N/40°E	740	30°N/32°E	4520	6460	0.5	...
328	1	Limestone	5420	26°N/50°E	1000	34°N/68°E	350	Begovat	350	34°N/68°E	1000	26°N/50°E	5420	6770	0	...
163	2	Limestone	6600	25°N/67°E	650	34°N/68°E	1250	Omsk	1250	34°N/68°E	650	25°N/67°E	6600	8500	0.5	...
161	1	Limestone	6600	25°N/67°E	1720	49°N/90°E	310	Stalinsk	310	49°N/90°E	1720	25°N/67°E	6600	8600	0.5	...
161	2	Limestone	6600	25°N/67°E	1720	49°N/90°E	400	Kemerovo	400	49°N/90°E	1720	25°N/67°E	6600	8720	0.5	...
159	1	Limestone	6600	25°N/67°E	1720	49°N/90°E	450	Krasnoyarsk	450	49°N/90°E	1720	25°N/67°E	6600	8770	0.5	...
166	1	Spokane	4240	36°N/140°E	1490	47°N/113°E	330	Petrovsk	330	47°N/113°E	1490	36°N/140°E	4240	6060	0.5	...
204	2	Spokane	4240	36°N/140°E	575	44°N/139°E	420	Komsomolsk	420	44°N/139°E	575	36°N/140°E	4240	5235	0	...

* World Aeronautical Charts, *Bombing Encyclopedia Manual and Code Book*, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.

Table 5b

SUMMARY OF MINIMUM-TANKER PATHS FOR GROUND-REFUELED B-47 AIRCRAFT

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
					Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
63°N/65°E	2000	4.64	4100	9.51	510	423	320	1.18	0.98	0.74	4610	4523	4420	10.70	10.49	10.25
66°N/26°E	2000	4.64	3100	7.19	360	345	340	0.84	0.80	0.79	3460	3445	3440	8.03	7.99	7.98
59°N/14°E	2650	6.15	3290	7.63	540	540	540	1.25	1.25	1.25	3830	3830	3830	8.88	8.88	8.88
39°N/35°E	4099	9.51	4945	11.47	1270	786	375	2.95	1.82	0.87	6215	5731	5320	14.42	13.30	12.34
30°N/40°E	4520	10.49	5260	12.20	1200	788	230	2.78	1.83	0.53	6460	6048	5490	14.99	14.03	12.74
34°N/68°E	6207	14.40	6973	16.18	1250	950	350	2.90	2.20	0.81	8223	7923	7323	19.10	18.38	16.98
49°N/90°E	6600	15.31	8320	19.30	450	390	310	1.04	0.90	0.72	8770	8710	8650	20.35	20.21	20.07
44°N/139°E	4240	9.84	4815	11.17	420	420	420	0.97	0.97	0.97	5235	5235	5235	12.15	12.15	12.15
47°N/113°E	4240	9.84	5730	13.29	330	330	330	0.77	0.77	0.77	6060	6060	6060	14.06	14.06	14.06

principal constraints. First, these bases are located in areas where the present Air Force program calls for an overseas base, either for operating or staging use. (However, the precise location of the programmed bases has been avoided in order to make these measurements more generally usable without trespassing on top-secret information.) Second, for the purpose of determining tanker-bomber ratios in the ground-refueled system, it was felt appropriate to rule out all base areas within 1000 n mi of Soviet or satellite borders. This puts these refueling points assumed well beyond enemy light-bomber radius. With an appropriate strategy for the use and defense of refueling bases, staging areas closer than this can be employed without excessive risk to enemy bombing attack (see the section entitled "Base to Border: The Effect of Base Vulnerability," page 225). The limitation to areas beyond 1000 n mi introduces some insurance against the loss of closer bases either through political misfortunes or the advance of enemy ground troops. It also provides a reserve in system radius which might be useful in evading enemy pursuit on the homebound flight.

If the distance measurements in Tables 4 and 5 are used, together with the tanker-requirement curves presented earlier for the KC-97 and KB-36 tankers refueling the B-47's, the tankers needed to assist each bomber on a mission to and from any of the 100 targets can be determined. These tanker-bomber ratios are presented in Tables 4 and 5 for the air-refueled and ground-refueled systems, each system following routes that minimize tanker requirements. For each target the cheapest combination of KC-97's and KB-36's has been selected. The average bomber-tanker requirement for the intercontinental air-refueled system is 1.3 KB-36's and 1.1 KC-97's. For the intercontinental ground-refueled system, some 0.19 KC-97's and 0.035 KB-36's are needed for each bomber in the operating force. This amounts to a radius-extension cost in the air-refueled case of $25.3 million per bomber on a 3-year basis, including a token cost of staging bases in the ZI. The tanker costs for the ground-refueled system amount to $1.3 million per bomber. In addition to these tanker costs, the ground-refueled system involves expenditures for refueling-base construction and operation which amount to some $60 million *per base*, with an average of one such base per wing in the operating force.*

*In campaigns including consideration of ground attrition, this number is increased as a defense measure. See the section entitled "Requirements and Costs for Overseas Operating Bases," p. 194, and that entitled "Base to Border: The Effect of Base Vulnerability," pp. 225*ff*.

Conditions and Strategies of Attack and Criteria for Evaluation

Summer. We assume that the campaign is conducted in summer. There is good reason for this. The task of destroying Russian strategic targets is very much more difficult and costly at this time of year than it is in winter. A large proportion of the target system is in daylight adequate for the operation of day fighters. The cost of a summer campaign, it appears, is several times that of a winter campaign in dollars and in crew losses. It is important, therefore, to consider the strategic-bombing capability for this worse contingency. Moreover, the time of outbreak may very well be decided by the enemy, and it appears that he has a comparative advantage in choosing this season. (Strategic targets in the United States are in much more southerly latitudes, making Russian night attacks feasible in summer as well as winter. And the firm summer ground has advantages also for advancing Russian ground forces in the European theater.) Because the decision is very likely to be the enemy's, the most unfavorable season for the campaign from our standpoint is also the most probable. In consequence, this is the basic case we consider both here and in later sections. (However, we have also run some winter campaigns. See page 119.)

Size of Target System and Size of Strikes. We have required all systems to be capable of destroying at least 80 of 100 industrial targets. And we have also required all systems to be able to visit a minimum of 17 geographically dispersed targets on at least one strike with the expectation of destroying approximately 12.

The Air Force projects massive raids of much larger size against widely separated targets. The total strategic target system envisaged is much more numerous than our 100-point system. As we explained earlier, it is not part of the purpose of this report to evaluate Air Force objectives. Instead, we have examined various base systems and systems of radius extension in regard to their adequacy for the Air Force's present objectives and for some alternatives. It is clear that, for the Air Force's objectives as they stand, the minimum conditions placed on strike size and total target destruction are quite mild constraints. A capability of visiting something less than 20 targets on at least one strike is about as weak a requirement as one might impose for relevance to Air Force objectives. We therefore have also looked at more rigorous constraints on strike size and larger target systems.

The geographic dispersal of the points that may be visited on a single raid is argued for on the basis of operational considerations of flexibility and surprise, and also on the grounds of the purposes to be realized. This also has been discussed in the section entitled "Criteria for Base Evaluation: Objectives, Obstacles, Uncertainties," page 13. It is possible that SAC may have an urgent need to visit a large number of regions in Russia early in the campaign for the purpose of destroying or obtaining reconnaissance information on, for example, counter-air targets. The industry raids would then have to be considered jointly with this requirement. In the section entitled "Base to Border: The Effect of Base Vulnerability," page 225, we consider the characteristics and advantages of such a joint raid by Russia against SAC bases and against our industry. Such considerations may govern our own strategic target priorities. If so, this alone would suggest the visiting of dispersed points. There are other reasons as well suggested in the section entitled "Criteria for Base Evaluation: Objectives, Obstacles, Uncertainties," page 13. On the other hand, the possibility of saturating the Russian target system region by region has certain advantages. Such an attack is therefore treated in the section entitled "Bases, Targets, and Penetration Paths," page 135.

Time Constraints and Time Patterns. We have imposed as a condition that the 100 target points be visited within a 2-month period with the expectation of destroying 80. This is also clearly a mild constraint, considering present Air Force objectives. For the intercontinental systems, the sortie rates achievable make this condition equivalent to the strike-size limitation already treated. For the overseas operating base systems to be considered later, it appears that optimum campaign lengths are in any case shorter than is permitted by this constraint because these units are particularly subject to bombing attack. Therefore this constraint is not operative in the campaigns considered.

For reasons to be explained, the air-refueled systems operate at least cost with an even level of destruction over the whole period. The ground-refueled system can operate in the manner of the Air Force programmed system with a high early rate of destruction, or, at an even rate, with roughly the same costs. In the least-cost criterion for evaluating the systems, the job is defined merely in terms of cumulative destruction over the 2-month period without attaching any weight to a higher-than-average rate of destruction in the first part of the period.

Crew Survival Constraint and Cumulative Crew Losses. Each crew entering enemy defenses is required to have a chance of survival greater than or equal to 0.5, and no crew is required to take part in more than one nonabortive mission.

While each individual crew has a survival probability of at least 0.5, cumulative crew losses over the campaign differ among systems because of the differing tactics as to strike size, number of strikes, etc. Although the basic criterion of least cost to destroy the targets does not take this into account, the least cost system in the comparison has in fact the least total crew loss.

Mass Raids. We assume that bombers penetrate enemy defenses at high altitude and that large groups of cells headed for targets in the same region enter the enemy radar network at the same point. These fly in a formation close enough to prevent recycling of the same fighters against the formation on the inbound leg, but, within the limits set by this, spread out to saturate enemy ground-radar facilities for handling data.* The cells branch off from the main formation to go to individual targets along the track. Cells withdraw separately from targets, along the same tracks as were used inbound. Each system is given a choice of tactics as to number of targets attacked, cell size, and total number of strikes in the campaign. It also chooses between the policy of using all bombers available for combat on each strike, the strikes diminishing in size as bombers are lost, or the policy of keeping a steady rate of target visits, some bombers being held in reserve to replace losses on preceding strikes. The meaning of this last choice is important enough to be discussed in a separate heading.

Reserve versus Impact Campaigns. The bombers that take part in the strike require tankers to extend their radius to target in both the air- and ground-refueled case. In the ground-refueled system, refueling bases are also needed. This apparatus of radius extension, unlike the bombers themselves, is not subject to attrition by enemy defense systems. Therefore, if we start out with a radius-extension apparatus capable of supporting our entire stockpile of bombers in a strike, then, as the campaign goes on and some bombers are lost, some part of this radius-extension apparatus may become redundant. On the other hand, if we equip ourselves with the means of extending the radius of only a portion of our force, then as bombers are attrited they can be replaced out of the stockpile of bombers that have been withheld. The costs per bomber in this reserve force are by assumption smaller than the costs per bomber in the operating force, since the latter include the costs of radius extension. When the costs of radius extension per operating bomber are very high in comparison with the costs of a bomber in the reserve force, then it may be economic to keep

* The saturation of enemy fighter defense, which is a consequence of the method of attack and the requirement that the attacking bombers have at least a 50 per cent survival probability, insures a large enough ratio of bombers to fighters to force the employment of fighters under "semibroadcast" techniques. In this situation a linear model of the air battle provides a satisfactory approximation for the calculation of attrition.

the number of operating bombers small and approximately constant. By sending fewer than the maximum number of available bombers on each strike, we lose some of the advantages of saturating the enemy area defense. We need to stretch out the campaign somewhat and make more strikes. This means entering the enemy area defenses more often and therefore means repeated losses to the same enemy fighters. The cumulative aircraft and aircrew losses over the entire campaign will be larger for a fixed job of destruction. But keeping the operating force small means a saving of tanker procurement and operation. The tanker force is also small and substantially constant. As the total stockpile of bombers (including the reserves as well as operating bombers) dwindles, the tanker force is used at a steady rate.

Whether or not it pays to follow a reserve policy depends on the ratio of operating to reserve costs and on the relative weight of area- and local-defense losses. Figure 30 compares the reserve and impact campaign tactics. It shows how the total campaign costs to destroy 80 per cent of a Russian industry-target system using each of these two tactics increase with increasing ratios of operating to reserve cost. And it shows these costs for two Russian defense distributions, one of which is superior to the other in its utilization of fighters and therefore has a higher ratio of area- to local-defense kill potential. In the case of each of these Russian defense distributions, the impact tactic results in lower campaign costs as long as the ratio of unit operating costs to unit reserve costs exceeds unity by only moderate amounts. The point of indifference, which is insensitive to variations in relative weights of local and area defense within the range shown, occurs at a ratio of unit operating costs to unit reserve costs equal to 1.6. Beyond this indifference point, the costs of the impact campaigns are higher than the costs of the campaigns with reserves.

Two qualifications should be observed in these comparisons of reserve versus impact policy. First, the curves shown are cost curves which say nothing about cumulative crew losses, campaign time, or comparative fissile-material use under the two tactics. Second, the reserve policy presupposes an accurate anticipation of the air losses to be replaced out of the reserve stockpile. The optimally balanced reserve force and operating force anticipating a given level of attrition may be far from optimal, if the attrition turns out to be unexpectedly different. The performance of various systems under conditions of uncertainty is considered in Part III. Suffice it to say at this point that the reserve policy imposes considerable rigidity on the system using it.

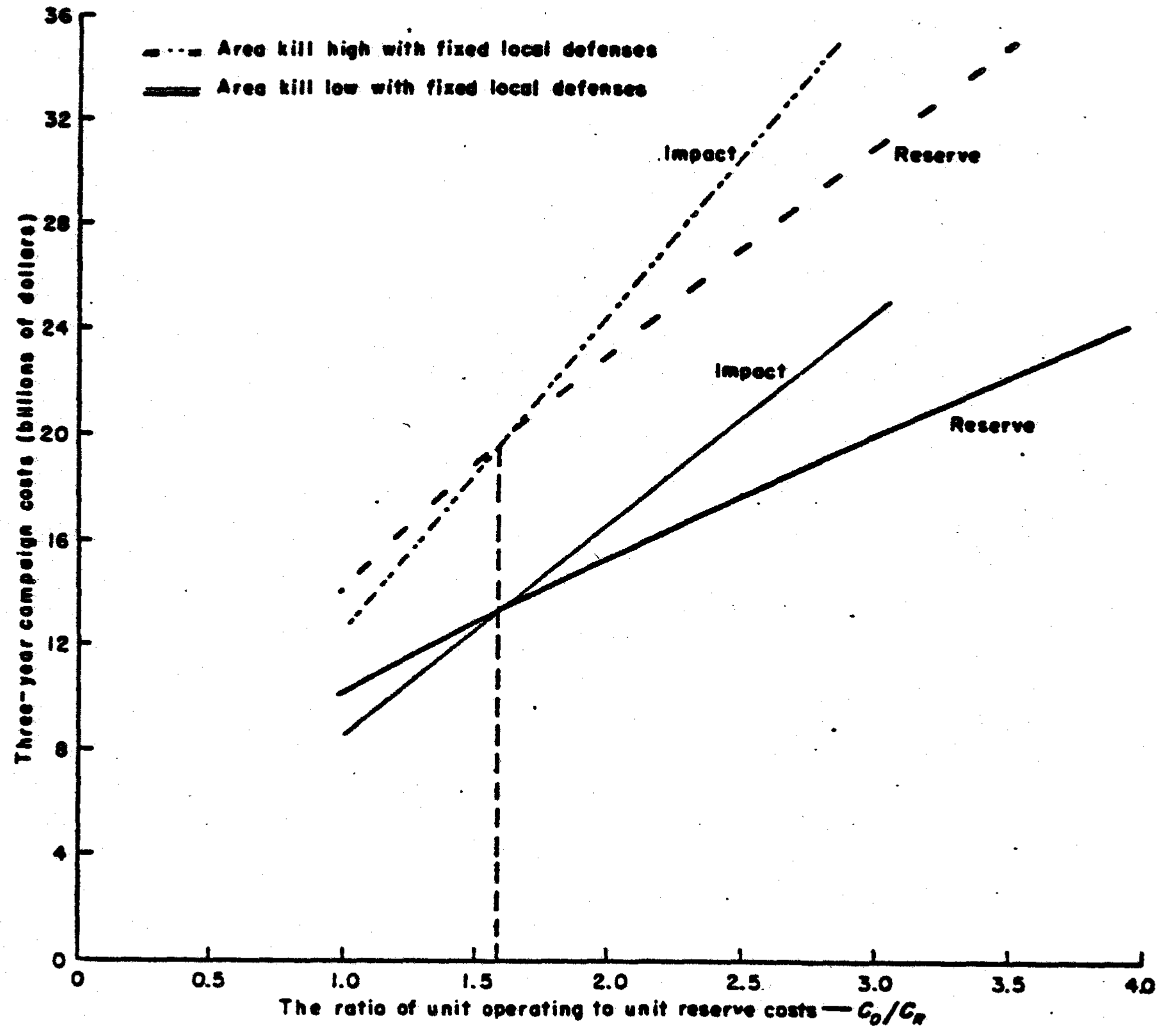

Fig. 30—Reserve vs impact tactics

The measurements of radius-extension costs presented earlier for the B-47 operating intercontinentally against a Russian industry-target system yielded different operating to reserve ratios for the exclusively air-refueled system on the one hand and the ground-refueled system on the other, where both systems followed routes intended to minimize these ratios. The ratio in the ground-refueled case is rather close to the points of indifference for reserve and dissipative campaigns, as displayed in Fig. 30. The air-refueled system is far to the right of the points of cross-over. And for this system, in operating against the Russian defense distributions assumed, the reserve policy clearly pays.

Bomber and Tanker Availability, Reliability, and Refueling Aborts

We make the customary assumptions on availability, namely, that two-thirds of the bombers and tankers are available for the mission in any given strike.

(This proportion is of course an expected value, and no quantitative account is taken of variance from this expected value. Similar comments are in order about the reliability and attrition expectancies. However, we do consider qualitatively the direction of the effect of variance.)

An expected value of 0.85 is taken for the reliability of the B-47 and of the KB-36 as a refueling plane for the B-47. A reliability of 0.9 is assumed for the KC-97. In other words, it is assumed that 15 per cent of the bombers which are available for combat and which are assigned to the mission abort before entering enemy territory. In analogous fashion, 15 per cent of the KB-36's and 10 per cent of the KC-97's abort before completing refueling.

In addition to the 15 per cent that abort as described above, it is assumed that 10 per cent of the planes which have not already aborted will do so whenever they land to take on fuel at a staging base. In the ground-refueled system, the operating force may be diminished by such staging aborts as many as two (less than twice on the average) times on the way to the target. A very small proportion of such staging aborts can be accounted for by mechanical or other equipment failures associated with the landing and take-off at the refueling base. A very high proportion of failures found at the staging base will have been incurred in flight prior to reaching the base (and the 15 per cent abort rate includes those failures discovered by the crew while in flight). However, even in a staging operation of the kind postulated, which involves merely a touchdown for taking on fuel and a new crew, but no repair or inspection, it is felt that there will be a considerable number of aborts for psychological reasons. This 10 per cent extra diminution of the operating force at each refueling stop is intended to allow for such aborts.

In the air-refueled case, we have made no degradation for failures to rendezvous due to weather or difficulties with the rendezvous equipment. We have assumed further that the expected aborts of tankers and bombers are mostly matched, and that the fuel transfer is invariably accomplished with success. Since the refueling points selected in order to achieve the maximum radius extension are beyond the point of no return for the bombers, a refueling failure could mean not merely an abort, but the actual loss of the bomber. A rough inspection of the problem of weather alone at the refueling points selected suggests that the costs involved, either in the form of extra tankers needed to support alternative refueling points in case of emergency, or of bomber losses where there are no emergency alternates, are significantly large. These costs have not been taken into account.

Air Losses Imposed by Enemy Defenses

As our bomber forces penetrate enemy territory to target and withdraw, they will be subject to diminution successively by enemy fighter attack, enemy local defense, and enemy fighter attack on the outbound leg. The extent of the losses sustained will depend on the quantity and performance characteristics of enemy fighter and local defense, their manner of disposition in relation to the targets attacked, and the relative success of our countermeasures.

Quantity and Performance of Enemy Fighters. These matters are of course extremely uncertain. Intelligence data on plants producing MiG's, floor area and production per floor area estimates, and serial-number analysis can provide some indications, but the allocation of fighters as between defense and support of the ground forces is uncertain and in any case subject to change. For the purposes of campaign calculations, in this section we have taken an approximation of the low estimate of the number of jet fighters assigned to air defense developed in a prior RAND study.* We assume that the Russians will deploy for defense some 1500 MiG-15 day fighters, another 1500 Type-38 day fighters, and about 300 "1955" All Weather fighters. We assume further that 300 of the day fighters will be used at night, along with the MiG's that are equipped with airborne intercept (AI), in areas in which our bombers will have cover of darkness. Since we assume in addition that such day fighters used on the buddy system will be as effective as the night fighters, this amounts to the same thing as assuming some 2700 day fighters and 600 night fighters.

In other RAND studies, this low estimate of the number of Russian fighters has been used in combination with a high estimate which approximately triples the numbers cited, but a single value has been taken for the probability of interception and kill of a given type of bomber by a single type of fighter. The probabilities of interception and kill represent a very large source of variation, and we have taken the alternative of assuming a ten-to-one variation in total air losses without fixing the source of variation as between fighter quantities and individual fighter or ground control intercept (GCI) effectiveness. (The ten-to-one variation is treated on p. 117*f*.)

The performance characteristics and armament of the three types of fighters assumed are summarized in Table 6.

The Distribution of Area Defense. In the campaigns treated in this part, a layout of the early warning (EW) and the GCI radar network is assumed which

* W. E. Gasich, *An Estimation of Soviet Interceptor Defenses through 1960*, The RAND Corporation, Research Memorandum RM-826, May 22, 1951 (Secret).

Table 6

CHARACTERISTICS OF THREE TYPES OF SU FIGHTERS

	MiG-15	Type 38	"1955" All Weather Fighter
Engine type	VK-1	VK-1A	Axial Flow
Thrust (lb)	6,000	7,000	10,000
Maximum speed (kn)			
At sea level	582	595	620
At 40,000 ft	518	534	565
Service ceiling (ft)	52,000	56,000	57,000
Combat radius (n mi)			
Clean	225	255	250
External fuel	360	400	400
Time to climb to 40,000 ft (min)	7.2	6.5	5.5
Armament			
23-mm cannon	2	2	
30-mm cannon			4
37-mm cannon	1	1	

[a] Data for Type 38 and "1955" All Weather Fighter were taken from *Estimated Characteristics of Soviet Air Weapons*, Study No. 102-AC-54/1-34, No. 1, Project No. 10140, ATIC, Wright Patterson AFB, January 1, 1954 (Secret). Data for the MiG-15 were taken from *MiG-15 Flight Test*, TR-AC-27, Project No. 10181, ATIC, Wright Patterson AFB, October 13, 1953 (Secret).

is designed to protect the target system from all axes of attack* (see Fig. 31). It was assumed, in developing this possible Russian radar net, that attacks along all axes are equally likely. A fighter deployment within this GCI area is assumed which is derived essentially from the RAND Missiles–Aircraft Study.† This deployment is based on analogous assumptions as to the equal likelihood of attacks from all directions. In its essentials it amounts to a uniform coverage of the entire GCI area by day fighters and, in summer campaigns, a uniform deployment of the night fighters available below the Fiftieth Parallel. (Alternative strategies by which the Russians may deploy their fighter defenses are

*This deployment of radars was developed by J. J. Larkin in *Some Comments on Possible Russian Radar Networks of 1954*, The RAND Corporation, Research Memorandum RM-625, June 15, 1951 (Secret).

†See J. W. Ellis, Jr., R. B. Murrow, and C. V. Sturdevant, *Deployment and Employment of Enemy 1955 Fighter Defenses*, The RAND Corporation, Research Memorandum RM-828, August 5, 1953 (Secret).

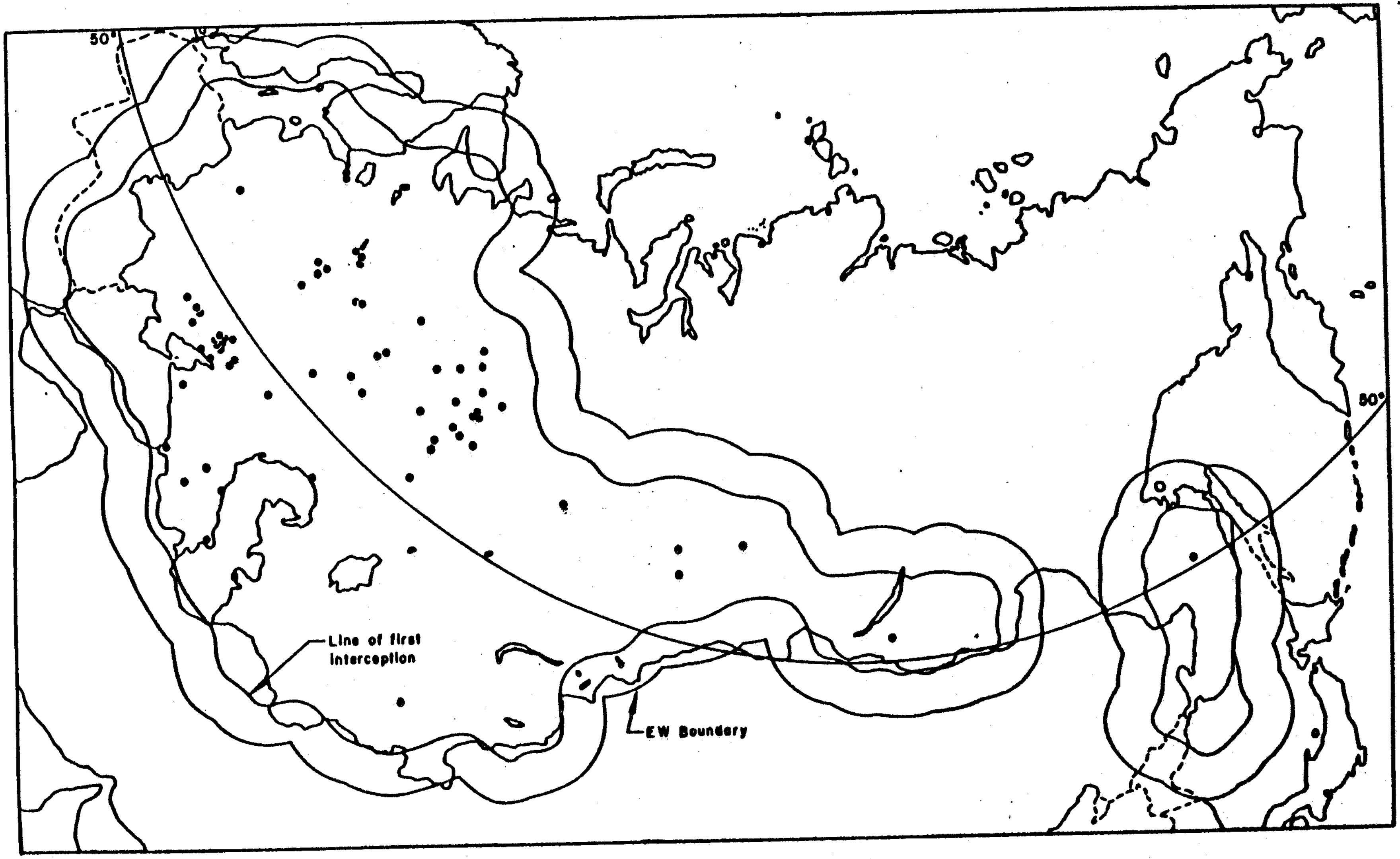

Fig. 31—Soviet Union EW and GCI net

discussed in the section entitled "Bases, Targets, and Penetration Paths," page 135, with particular reference to the problem of matching the defense deployment to alternative offensive base systems with unequal capabilities for entry along different axes.)

Fighters in Range of Bomber Tracks. The mass formation of bombers containing groups of cells headed for various targets penetrates enemy territory along a treelike track, individual cells peeling off to follow side branches to their individual targets (see Fig. 32 for an illustration of the tracks followed in the case of minimum-tanker routes for the ground-refueled B-47 system). Areas within which MiG's, with the performance characteristics described, can intercept the B-47 flying along these tracks are shown by shading in Fig. 33. Figure 34 is analogous to Fig. 33 for the air-refueled system following minimum-tanker routes. It will be observed that the point of first interception is well within the early-warning network. The corridors below the Fiftieth Parallel are represented by darker shading to suggest the different and lower density of fighters available to combat our attacks in a summer campaign. The proportion of night fighters within radius of a strike is approximated by the ratio of the darker-shaded area to the total area of the GCI network below the Fiftieth Parallel and 150 mi or more inside the boundaries of the network. The proportion of the day fighters within radius of a strike is taken as being roughly equal to the ratio of the lighter-shaded areas to the total area enclosed by a boundary lying 150 mi inside the GCI network. (In the case of the day fighters, only the lighter-shaded areas are included, since the strikes are staged so as to give us the advantage of darkness below the Fiftieth Parallel in summer.)

It is assumed that, on the way out, for the distance the B-47 could travel in the period required to perform one-half a fighter cycle, a bomber cell would encounter no fighters that could not have been committed against it inbound up to the point of bomb release. Similar considerations of possible fighter-recycling would affect the independence of bomber cells on the way out. The bomber cells would withdraw separately along the same tracks after bombing their respective targets. Cells that went to targets less far apart than the distance traveled in one-half a fighter cycle would be separated during the return trip by roughly twice the distance between their targets, since the cells that went to the shallower targets were already returning while the others were going deeper. However, so long as the target separation was less than the half-cycle distance, bomber-cell separation on the way back would still be short enough to prevent a recycling of the fighters, which would permit more than

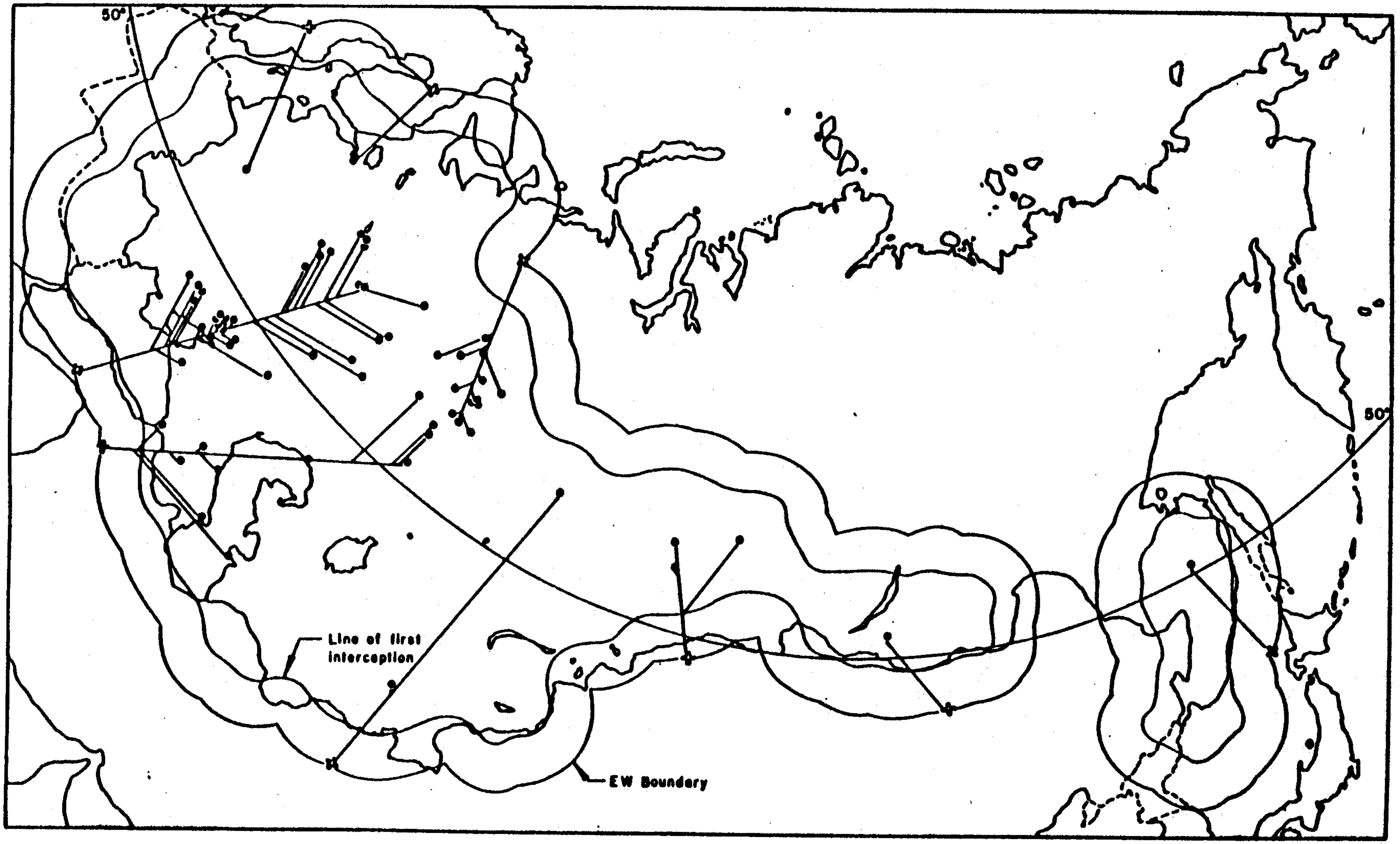

Fig. 32—B-47 tracks: ground-refueled minimum-tanker routes

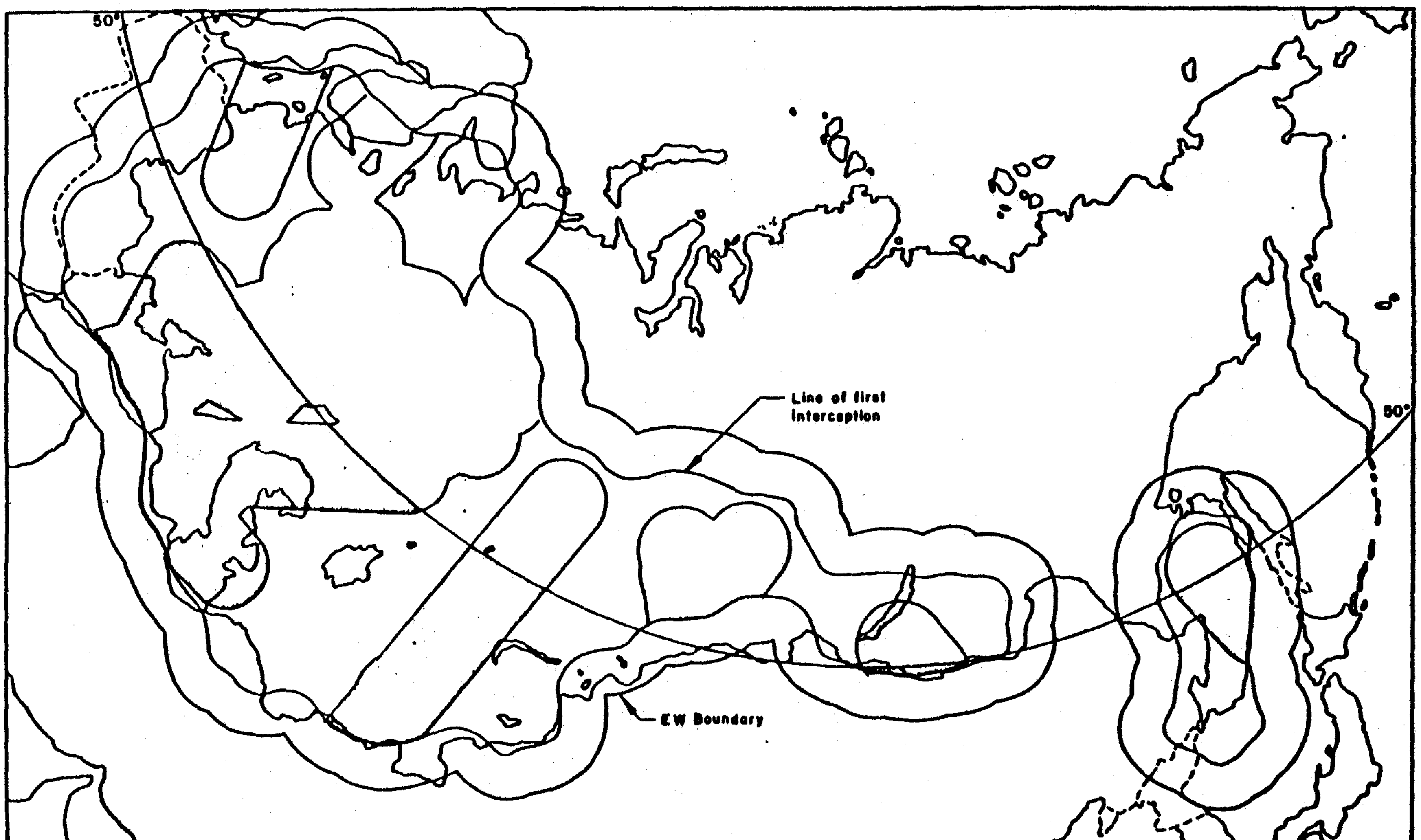

Fig. 33—Fighter areas swept out: ground-refueled minimum-tanker routes

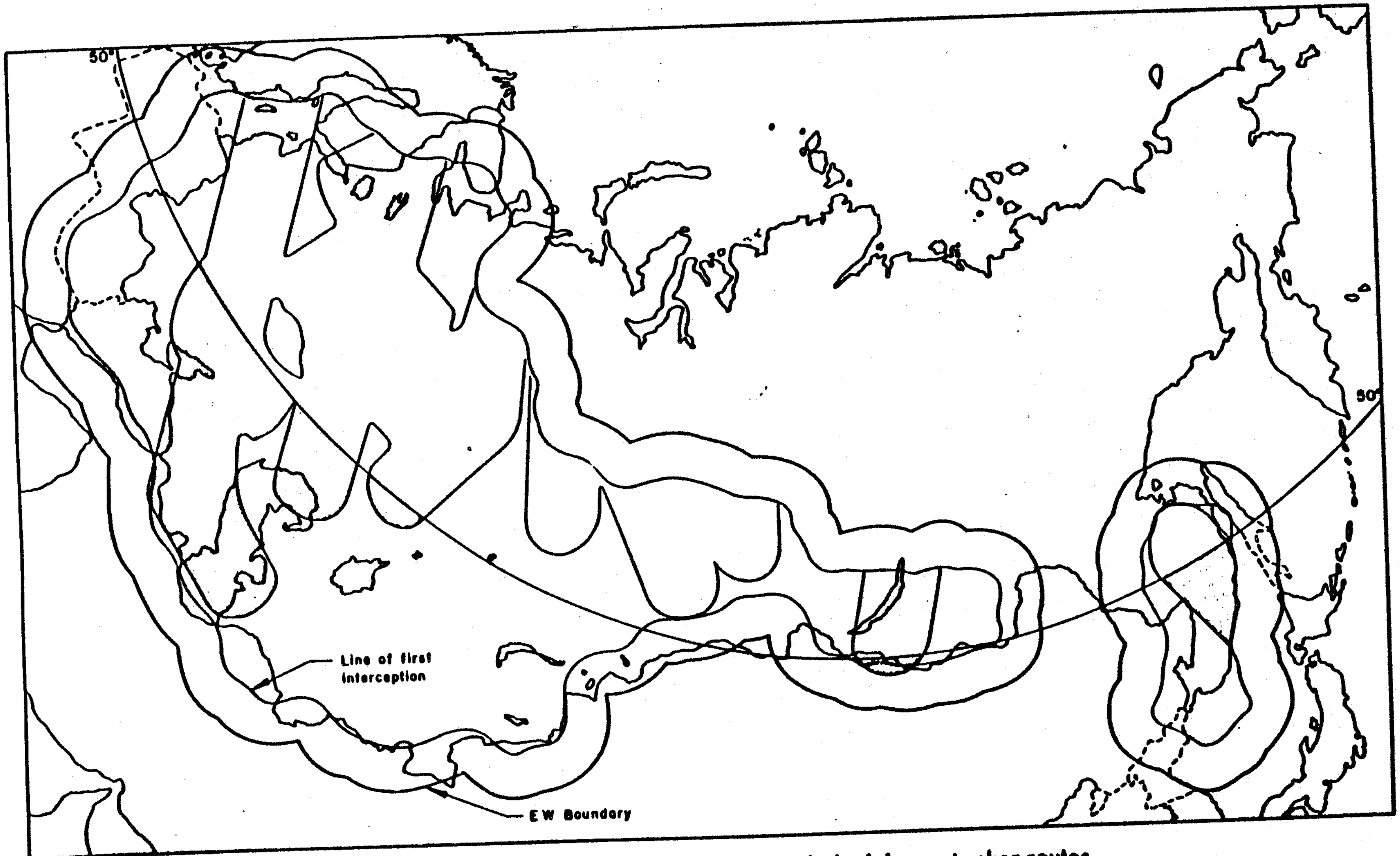

Fig. 34—Fighter areas swept out: air-refueled minimum-tanker routes

one sortie against this particular formation. Bomber cells that went to targets separated by more than this distance would be subject to essentially independent attacks on the way back. The measurement of the proportion of fighters in a position to intercept the bombers on the way out is therefore a very much more complicated matter than the inbound measurement. The inbound fighter corridors are fixed by distances to the deepest targets; the outbound fighter corridors may include several which overlap on the same track, each defined by the area of fighters aroused by successive, separately withdrawing bomber cells. Figure 35 illustrates schematically the outbound areas swept out by a bomber returning from a group of targets.

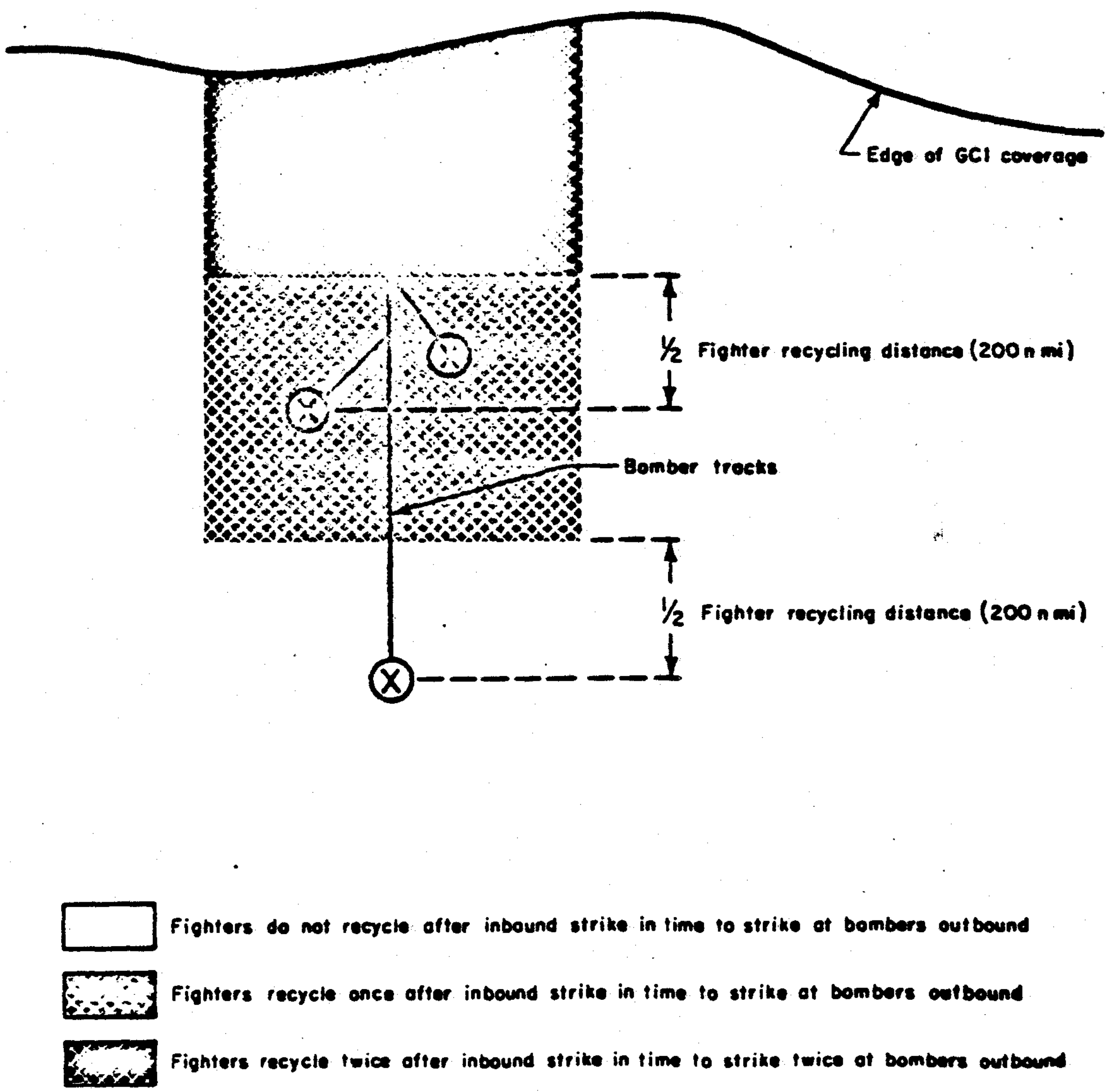

Fig. 35—Schematic illustration of outbound attrition by fighters

Bomber Kills by Fighters. Before the fighters within combat radius of the bomber track can actually engage in successful air battle with the bombers, they must surmount a succession of obstacles: The raid must first of all be detected and tracked; it must be identified as hostile; the fighters must be available for combat; they must be committed by the commander of the base; they must survive the hazard of aborting; similarly they must survive the hazard of committing gross errors; they must detect the bomber from a position permitting successful attack; they must convert this detection into an actual attack; and finally, they must kill the bomber in the duel.

The probabilities of a fighter's surmounting each of the nine barriers listed to successfully kill a B-47 is of course a matter of great uncertainty. We are unsure of the performance of Russian AI radar and of the tightness of the Russian GCI net, the effect of countermeasures, feints, etc. Table 7 presents a range of values for the nine component probabilities of a fighter's intercepting and killing a B-47.

The range of uncertainties indicated in Table 7 for the probabilities of interception and kill is very much wider even than the uncertainties as to the number of Soviet fighters that will be assigned to Air Defense. The expected attrition our bombers will suffer is affected therefore by these uncertainties. We have made campaign calculations for ten-to-one variations in bomber losses. This variation might easily be accounted for, as Table 7 indicates, by the variation in the probability of interception and kill, though of course it is possible to think of some of the variation as being due to this factor and the rest to differences in possible force assignment.

As in the case of Soviet offensive capabilities, so with her defensive capabilities—it is reasonably certain that they are increasing rapidly over time. The higher attrition values considered may be taken as a measure of the losses to be incurred by the B-47 following the given tactic of offense at a later date.

In our calculations we have used probabilities of interception and kill as given in the above table, but we have limited fighter commitments to a 150-mi lateral distance from the bomber track. In effect, this assumes that P_4 in the above table is equal to unity within this corridor and to zero outside it, though the combat radius of each of the Russian fighters considered is greater than 150 mi by a considerable amount. (In the section entitled "Bases, Targets, and Penetration Paths," page 135, we vary the commitment policy as a function of the relative speed of the fighter and the bomber, the distance of the fighter base from the bomber track, and the distance of the bomber penetration and

COMPONENTS OF THE PROBABILITY OF U.S. BOMBER KILL BY MiG'S[a]

Probability Level	Bomber	Fighter	P_1 Raid Tracked	P_2 Raid Identified	P_3 Availability	P_4 Committed	P_5 Nonabort	P_6 No Gross Errors	P_7 Detection	P_8 Conversion	P_9 Kill	P_T Total
High	B-47	MiG 15	1	1	0.66	1	0.95	0.85	1	0.85	0.19	0.086
Moderate	B-47	MiG 15	0.75	0.9	0.5	1	0.9	0.8	0.95	0.8	0.13	0.024
Low	B-47	MiG 15	0.5	0.8	0.4	1	0.85	0.75	0.8	0.7	0.08	0.0046
High	B-47	Type 38	1	1	0.66	1	0.9	0.85	1	0.9	0.21	0.095
Moderate	B-47	Type 38	0.75	0.9	0.5	1	0.85	0.8	0.95	0.85	0.15	0.028
Low	B-47	Type 38	0.5	0.8	0.4	1	0.8	0.75	0.8	0.75	0.10	0.0058
High	B-47	"1955" AW	1	1	0.66	1	0.85	0.85	1	0.85	0.19	0.069
Moderate	B-47	"1955" AW	0.75	0.9	0.5	1	0.75	0.8	0.95	0.8	0.09	0.014
Low	B-47	"1955" AW	0.5	0.8	0.4	1	0.65	0.75	0.8	0.65	0.06	0.0024
High	B-52	MiG 15	1	1	0.66	1	0.9	0.8	1	0.8	0.18	0.068
Moderate	B-52	MiG 15	0.8	0.95	0.5	1	0.85	0.75	0.95	0.7	0.12	0.019
Low	B-52	MiG 15	0.6	0.9	0.4	1	0.8	0.7	0.9	0.6	0.09	0.0066
High	B-52	Type 38	1	1	0.66	1	0.85	0.8	1	0.9	0.24	0.097
Moderate	B-52	Type 38	0.8	0.95	0.5	1	0.8	0.75	0.95	0.85	0.18	0.033
Low	B-52	Type 38	0.6	0.9	0.4	1	0.75	0.7	0.9	0.7	0.12	0.0086
High	B-52	"1955" AW	1	1	0.66	1	0.8	0.8	1	0.8	0.18	0.061
Moderate	B-52	"1955" AW	0.8	0.95	0.5	1	0.7	0.75	0.95	0.75	0.12	0.017
Low	B-52	"1955" AW	0.6	0.9	0.4	1	0.6	0.7	0.9	0.65	0.09	0.0048
High	B-36	MiG 15	1	1	0.66	1	0.95	0.9	1	0.9	0.33	0.168
Moderate	B-36	MiG 15	0.85	0.95	0.5	1	0.9	0.85	0.95	0.85	0.21	0.052
Low	B-36	MiG 15	0.7	0.9	0.4	1	0.85	0.8	0.9	0.8	0.15	0.019
High	B-36	Type 38	1	1	0.66	1	0.95	0.9	1	0.9	0.33	0.168
Moderate	B-36	Type 38	0.85	0.95	0.5	1	0.9	0.85	0.95	0.85	0.21	0.052
Low	B-36	Type 38	0.7	0.9	0.4	1	0.85	0.8	0.9	0.8	0.15	0.019
High	B-36	"1955" AW	1	1	0.66	1	0.9	0.9	1	0.9	0.21	0.101
Moderate	B-36	"1955" AW	0.85	0.95	0.5	1	0.8	0.85	0.95	0.85	0.14	0.031
Low	B-36	"1955" AW	0.7	0.9	0.4	1	0.7	0.8	0.9	0.7	0.10	0.0089

[a] These estimates of the components of the kill probabilities are intended to suggest the range of uncertainty inherent in these parameters. Needless to say, the estimate of the range is itself uncertain. The high and low values for the component probabilities were chosen to give a reasonable probability of occurrence to the over-all probability of kill.

of the fighter base area from the early-warning network. This has been done in such a way as to take account of the possibility of feints.) We have degraded the outbound probability of fighter availability to take account of the progressive deterioration in recycling fighters with combat damage and cumulative maintenance needs.

Local-defense Losses. We know rather less about Russian local defenses than we do about her area defenses. It seems likely, with the heritage of Peenemunde, that Russia has been able to develop an advanced local-defense surface-to-air missile of the Wasserfall type. And it appears plausible to assume that she will have such missiles in quantity by 1956. Until such a time, local-defense losses at the altitudes of target area penetration assumed in our tactics will be substantially zero. The high-altitude local-defense kill potential of Russia, then, will be a step function of calendar time with a jump at the point of introduction of high-altitude local-defense missiles. It will have another step downward at the point of time in which we shall have local-defense-escaping air-to-surface missiles of the Rascal type. We take as our basic case for 1956 an assumption that local defenses of the Russians will be approximately the equal of our own at the same time: following other RAND studies,* we assume 150 Wasserfall battalions. Each of these units has a round-trip kill potential against the B-47, for the cell sizes and tactics used, of approximately 1.5 bombers, and an inbound kill potential which is roughly half this. In the campaign calculations contained in this section, we have distributed the units according to the number of specified aiming points (RGZ's) in each target area, so that the Moscow local defenses are assumed to have a kill potential of 13.8; the Gorky local defenses, 6.9; Begovat, 2.3; and so on.†

Air Losses per Strike. It is characteristic of area attrition that a given number of fighters serve to defend many more than one single point target. Therefore visits to a small number of targets, in comparison with strikes against many targets, involve a more than proportionate loss to area defense. We have assumed, for the minimum-sized strike considered (a few less than 20 targets visited, with an expected destruction of a few more than 12), that the bomber

*K. I. Martin, *An Estimate of Possible Russian Local Missile Defenses through 1960*, The RAND Corporation, Research Memorandum RM-845, May 20, 1952 (Secret).

†This is substantially the assumption of the Missiles-Aircraft Study. See E. S. Quade, *The Computational Model for the Missiles and Aircraft for Strategic Bombardment Study*, The RAND Corporation, Research Memorandum RM-986, November 10, 1952 (Secret—Restricted Data); *idem*, *Simple Models for a Strategic Bombing Campaign*, The RAND Corporation, Research Memorandum RM-879, July 11, 1952 (Secret—Restricted Data).

tracks come within radius of about 45 per cent of the Russian interceptors assigned to air defense, and that after this point the number of fighters within radius increases in a linear fashion to some two-thirds of the Russian interceptors for a strike against a 100-point target system.*

The surface-to-air missile defenses with a radius of about 20 mi are clearly more nearly assignable to specific point targets than are fighter bases. For the purposes of the campaign calculations in this section, we have taken the local-defense kills as varying with the number of targets visited and specifically in proportion to the number of RGZ's.† This is an approximation which appears to be reasonable as long as we deal with fairly large strikes. For strike sizes below the ranges we are considering, this assumption is less satisfactory, for local defenses have some of the characteristics of the area defense. A single local-defense area may contain a number of RGZ's. This is obviously the case with Moscow, Leningrad, Gorky, etc., in the target systems we are using. Moreover, if we were to value the targets, these local-defense regions would contain a considerable fraction of the value of the target system under attack. And it is likely that the local defenses will be concentrated here, too. Even if we were to attack one target in Moscow, we should meet substantially all the air-to-surface missile kill potential assigned to the job of defending not only the six Moscow targets included in our 100-point target system, but also some 25 or so RGZ's which might be included in a broader target system. However, for the range of strike sizes we are considering, the usual assumption that the local defenses encountered will vary in proportion to the number of targets attacked is a useful first approximation. We consider some alternatives later.

The Probabilities of Target Destruction

Because we are not concerned with choice among bombers, the campaign analysis is made somewhat easier than it might otherwise have been. In the base and radius-extension-method comparisons we make in the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, the systems compared are, so to speak, identical at the point of bomb release. They employ the same type of bomber and bombing radar in aiming and releasing the same

*The mathematical model for the campaign and the method of treating enemy losses as well as local defense losses is essentially that of Quade, in *Simple Models for a Strategic Bombing Campaign*. We have also tested the results by calculations in which the area defenses encountered are assumed to increase as a fractional power function of targets visited.

† See Quade, *The Computational Model for the Missiles and Aircraft for Strategic Bombardment Study*; and Martin, *op. cit.*, p. 13.

type of bomb over the same target points. Therefore a great many hard questions as to CEP, the physical vulnerability of the industrial plants to be destroyed, lethal radius, and optimal bomb size may be bypassed. The answers to these questions are essentially the same for each of the systems we are comparing. For this reason we are able to assume, given the various probabilities of survival inbound to the point of bomb release and the cell sizes needed to achieve either these probabilities of survival inbound or satisfactory crew-survival probability, that enough bombs are assigned per cell, and that these are bombs with large-enough coverage so that the visiting of 100 targets insures the expected destruction of 80 targets with a high degree of confidence. In most of the campaigns conducted, assuming yield from only one bomb, this has meant an assignment of three bombs per target with a yield of between 500 and 600 KT per bomb. Given this bomb assignment and bomb size, the probability for at least one bomb-carrier of not aborting and of surviving the area and local defenses is a little over 0.95, and the coverage is a little under 0.85.

The tactic of visiting 100 targets to achieve an expected confirmed destruction of at least 80 is fairly close to the optimal strategy, as presented in the RAND Missiles-Aircraft Studies, except where fissile material is extremely scarce. In this case it may pay to make more visits per target destroyed. We examine such a repeated-visit case below for its effect on our comparisons.

The simplification which results from identity at the point of bomb release for most of the comparisons we make among U.S. bombing systems is not available for all the cases we consider. Where flight profiles differ, the altitudes for bombing may also differ, sometimes enough to warrant our taking the differences into account. This is the case when the B-52 ground-refueled poststrike is compared with the B-52 air-refueled prestrike. And such a simplification at the point of bombing the target is of course not at all possible in our analysis of the reverse side of the air war: the effects of Soviet attack against alternative base systems for our strategic force. Our base systems, considered as objects of Russian bombing attack, differ widely in the elements left at risk at the time of bombing and in the concentration and disposition of these elements. Here enemy bomb size, lethal radii, the physical vulnerability of various elements at risk, and the operational consequences of their destruction form a critical part of the study. In the section entitled "Base to Border: The Effect of Base Vulnerability," page 225, therefore, these matters are considered in great detail.

The Campaign Results

Figure 36 summarizes the costs, neglecting inheritance, to achieve a confirmed expected destruction of at least 80 of the 100 industrial targets, using a B-47 system operating intercontinentally, in one case with the aid of overseas ground-refueling bases and in the other with the aid of air-refueling only. The defense is the uniform one described, and the routes followed by both systems are calculated to minimize the number of tankers required. The air-refueled system, using a policy of reserve, destroys targets at an even rate, completing the campaign in six strikes. The ground-refueled system, using a dissipative policy, destroys the targets in a sequence of four strikes of diminishing size. (Table 8 presents some of the detailed campaign characteristics.)

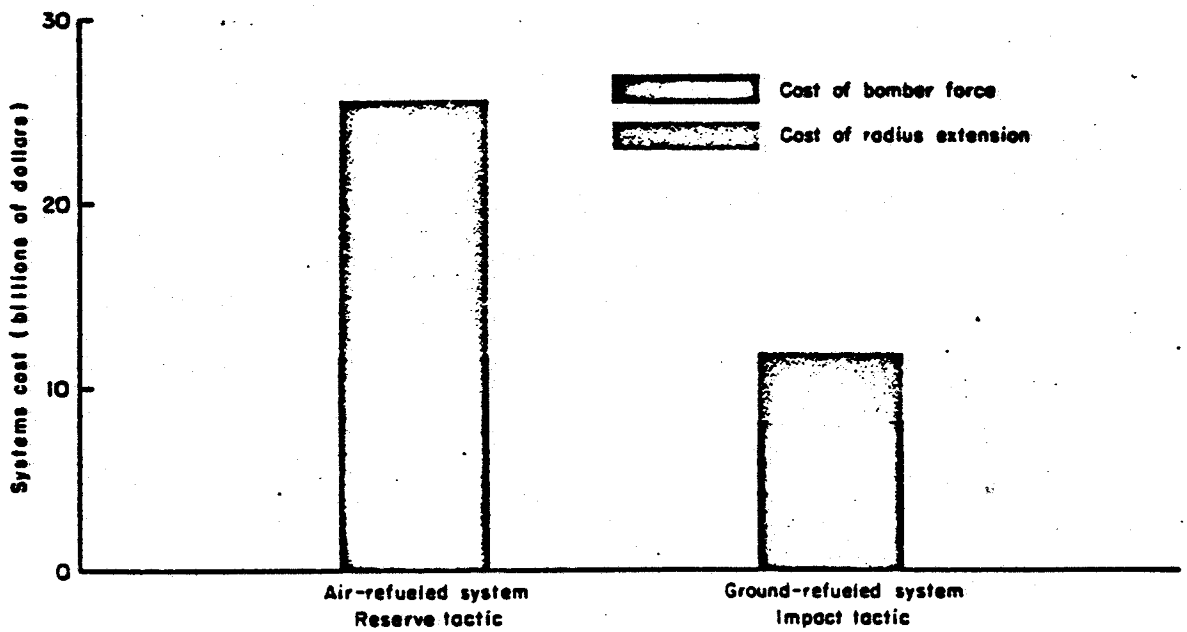

Fig. 36—New 3-year cost to destroy Russian industry targets: intercontinental air- vs ground-refueled B-47 systems

The campaign calculations show three significant differences in cost: (1) Even though the air-refueled system follows a policy of reserve, withholding bombers to replace air losses so as to reduce the size of the operating force and the number of tankers required, the total radius-extension costs are over six times those of the ground-refueled system. (2) To limit radius-extension costs even to this high level, the air-refueled system has to trade some bomber crews for tankers. The extra loss of bombers over and above the number lost by the ground-refueled system amounts to slightly less than 30 per cent of the value of the ground-refueled system's total stockpile of bombers. (3) The total

Table 8

INTERCONTINENTAL AIR- VERSUS GROUND-REFUELED B-47
COST TO DESTROY RUSSION INDUSTRY TARGETS

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System
Tactic	Reserve	Impact
Number of strikes	6	4
Number of B-47's in operating force	535	813
Number of B-47's in reserve for air attrition	642	0
Total number of B-47's	1177	813
Number of B-36-type tankers	696	28
Number of KC-97's	588	154
New cost of bomber force	11.5	8.0
New cost of radius extension[a]	14.0	2.2
NEW COST OF TOTAL SYSTEM	25.5	10.2

[a] Includes en route bases, refueling bases, and tanker costs.

systems cost for the exclusively air-refueled system, including all the bombers in their primary bases in the United States, is two times the analogous total for the ground-refueled system. This third point is in a way surprising, since a large number of elements are fixed by assumption in the comparison: the bombers, and the operating bases. The meaning of the difference between the two systems compared, which is essentially a difference in the refueling operation, is best displayed by a measure of the *differences* in total systems cost brought about by this variation in operation. The sum of the differences described in points (1) and (2) is such a measure. Yet the third comparison, which blurs the relevant differences by including elements fixed by assumption, shows a very decided superiority for the ground-refueled system.

Aside from the contrast in campaign costs, the systems exhibit differences in crew losses, fissile-material requirements, rate of destruction, and number of strikes. The air-refueled system involves a slower rate of destruction and a larger number of strikes. For this reason cumulative round-trip attrition is greater. And since inbound attrition for the air-refueled system exceeds that of the ground-refueled system, the number of bomb carriers, as well as escorts, shot down on their way to the target is also larger. The fissile-material requirements at the point of bomb release are identical. Therefore, the fissile-material usage for the campaign as a whole, including the fissile material shot down by fighters, is greater for the air-refueled case.

The costs presented in Fig. 36 and Table 8 make no allowance for inheritance. In fact, as has been discussed, a large portion of the initial outlay for both the air- and the ground-refueled system has already been made or committed. Some of the personnel needed for each system have been trained; some installations are in existence; equipment has been procured, and so on. Since the cost of such inherited elements does not represent an economic cost of a decision as between these two alternatives, they are subtracted from the new costs and the results of these subtractions are shown in Table 9. The comparative incremental costs of campaigns, using the air-refueled system on the one hand and the ground-refueled system on the other, are shown in Fig. 37. The availability of various elements of our inheritance in systems for refueling the B-47 is not always easy to determine. The KB-36 tankers are a case in point. Some 300 B-36 and RB-36 bombers are programmed to be in the strategic force in 1956. They will be phased out of bombing use as the B-52 becomes available in combat-ready units. A large proportion of these (about 240) are firmly committed as of the present date. However, the Air Force plans to use these as bombers and has a program for increasing their altitude performance and reducing their vulnerability in this connection. Moreover, even after the B-36's are withdrawn from first-line combat use, they are expected to have other uses than their employment as tankers: e.g., as carriers of Ficon. The costs of using these B-36's as tankers at any given period should be measured in terms of the

Table 9

INCREMENTAL COST TO DESTROY RUSSIAN INDUSTRY TARGETS: INTERCONTINENTAL AIR- VERSUS GROUND-REFUELED B-47 SYSTEM

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System
New cost	25.5	10.2
Inheritance (with 240 B-36's considered free)	4.1	3.5
Incremental cost	21.4	6.7
Inheritance (less cost of 240 B-36's)	2.5	3.1
Incremental cost	23.0	7.1

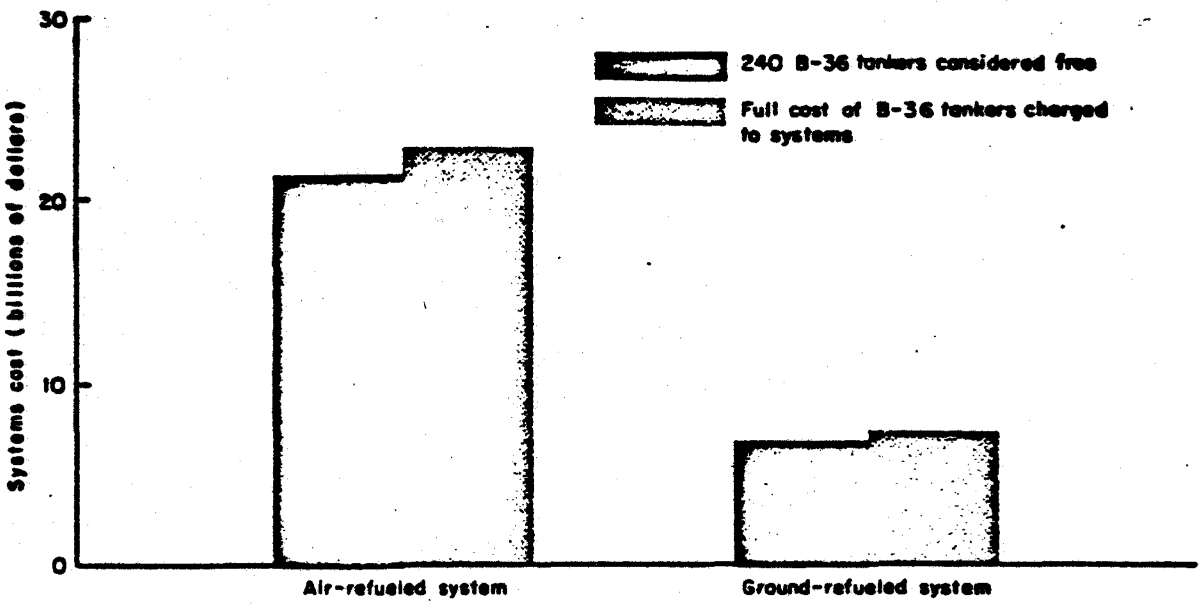

Fig. 37—Incremental cost to destroy Russian industry targets: intercontinental air- vs ground-refueled B-47 systems

alternative uses which are surrendered by so doing. It is clear that these alternative uses are of substantial importance to the Air Force in the first part of this period, and that the B-36 inheritance is not likely to be available to any considerable extent as tankers at this time; in the latter part of the period, we consider that the alternative uses are of diminishing importance. Since the heritage of B-36's represents a considerable dollar cost, we have shown the incremental costs of the air-refueled system in two ways (see Fig. 37 and Table 9): (1) excluding the costs of the committed B-36's along with the costs of other relevant inherited elements; (2) including all the B-36 costs. From this point on in this report, we shall assume that these 240 KB-36's are "free."

If the air-refueled system were constrained to follow a strike policy more like that which the Air Force presently plans, it would sortie substantially all available bombers in combat-ready units. Like the ground-refueled system, its campaign would then consist of a sequence of strikes of diminishing size. This would involve a great increase in support costs. Figure 38 and Table 10 compare the results of an impact campaign by the air-refueled B-47 system with the results of such a campaign by the ground-refueled system. The cost contrast in this case is, of course, much broader.

Biases

There are several biases in the assumptions underlying the preceding campaign calculations. Many of these favor air-refueling; some favor the ground-

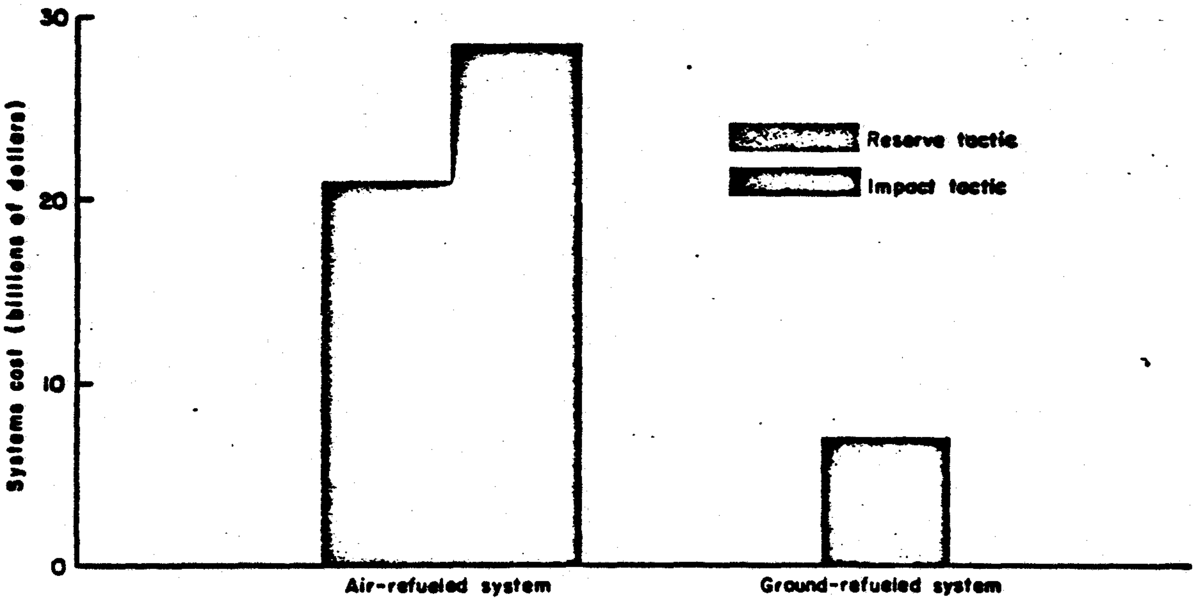

Fig. 38—Impact tactics in intercontinental campaigns to destroy Russian industry targets: air- vs ground-refueled B-47 systems (incremental 3-year cost)

Table 10

IMPACT TACTICS IN INTERCONTINENTAL CAMPAIGNS TO DESTROY RUSSIAN INDUSTRY TARGETS

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System
Tactic	Impact	Impact
Number of strikes	4	4
Number of B-47's in operating force	905	813
Number of B-47's in reserve for air attrition	0	0
Total number of B-47's	905	813
Number of B-36-type tankers	1190	28
Number of KC-97's	1021	154
New cost of bomber force	8.9	8.0
New cost of radius extension[a]	23.5	2.2
NEW COST OF COMPLETE SYSTEM	32.4	10.2
Inheritance	4.1	3.5
INCREMENTAL COST OF COMPLETE SYSTEM	28.3	6.7

[a] Includes en route bases, refueling bases, and tanker costs.

refueled system. The most important of the latter are

1. The exclusion of the costs of expected damage and the costs of base defense (these are greater for the ground-refueled system).
2. Partial neglect of costs associated with the political vulnerability of the refueling-base system (although our target radius measurements involve some insurance against the possibility of base losses, other contingencies warrant consideration).

Some less obvious possible biases are connected with the strategy of attack. Against enemy defenses disposed as we have assumed so far, the air-refueled system improves its performance by techniques of regional saturation and by following less direct routes, even at the expense of extra costs of radius extension. On the other hand, the ground-refueled system is more flexible as to strike route and portion of the target system attacked. These questions of route choice and target region choice are part of the subject discussed in the section entitled "Bases, Targets, and Penetration Paths," page 135. The critical question of base vulnerability to enemy bombing attack is the subject treated in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225. And the comparative performance of the various base systems under different political eventualities is treated in Part III. In short, by successive approximations the campaign analyses presented later embrace these unfavorable factors so far left out of account.

The biases in favor of the air-refueled system comprise a long list. We have already mentioned some relevant factors as being excluded from the costs to destroy the specified defended target system: the air-refueled system, aside from its greater cost, involves more crew losses, greater fissile-material expenditure, a slower rate of destruction and a longer campaign, large neglected costs of attrition on aborts and rendezvous, and, in its even-strike policy, a considerable inflexibility in the face of variance from mean attrition values, or unanticipated large differences in the mean attrition values themselves. A few others deserve mention:

1. We have not degraded the combat-radius capabilities of the bombers and tankers for the necessities of formation flight. Since individual bombers would differ in state of repair, fuel consumption, and pilot technique, the radius capabilities of the mass formations we have assumed would in fact be less than the average for single flight. This could seriously increase the requirements for radius extension and so worsen the position of the air-refueled system.

2. We have assumed overloading of the B-47 in the air, but not on take-off. In the case of the B-47 the air overloading has been tested, and the assumption is quite justified (as we have mentioned, our assumptions on overloading for the B-52 by 90,000 lb extra appear optimistic). The Air Force is considering overloading on take-off, and this would tend to favor the ground-refueled system.

3. A number of concessions were made in measuring target radius, some of which were minor and some of which could have a considerable influence on the costs of the air-refueled system. To illustrate minor concessions, doglegs within the penetration part of the mission were neglected. Some parts of the target system which could not be reached at all by the air-refueled system, even by following direct routes, were treated as if they could be reached (for less direct routes, there are more such targets). An example of a more important concession was the choice of Limestone and Spokane as starting points for the measurements of target radius. Reasons both of traffic and base vulnerability make this assumption unrealistic. If the distances were measured from a multiplicity of points on the northeastern seaboard, the average target radius would be extended, and these extra distances would be added to the costs of a system steeply affected by small distance increments. Besides this, there would be cost and feasibility questions connected with the multiplication of bases.

4. Though we have penalized the ground-refueled system for extra aborts on staging, we have not given it any of the benefits that might be derived from crew exchange inbound or the reduction in delayed kills made possible by landing nearer enemy territory on the way home. Since these are intercontinental missions that we are comparing, fatigue of a small crew might be considerable, though difficult to quantify. Similarly, the example of Iwo Jima in World War II suggests the usefulness of poststrike staging bases for reducing the number of bombers that are lost because, although they leave enemy territory, they are unable to make it all the way home.

Most of these biases in favor of the air-refueled system are retained in the later campaign analyses.

Sensitivity Tests

We have made a considerable number of sensitivity tests, some of which may be introduced at this point. The first test examines the effect of the requirement that repeated target visits be made to the 100-point target system. The second treats higher-survival-probability constraints. The third displays the result of ten-to-one variations in anticipated air losses from local and area defenses. The fourth tests the effect of changes in the ratio of area- to local-defense losses.

Repeated Target Visits. The large numbers of bombs and the bomb sizes assumed in the campaigns presented permit a lower investment in bombers and bomber crews than would otherwise be the case. Such a use of fissile material makes possible the required destruction of 80 per cent of the 100-point system with a total of 100 target visits made, given the other conditions assumed. This manner of using fissile material corresponds increasingly to the situation created by our growing stockpile of nuclear weapons. If fissile material were to become comparatively scarce, requiring more frugal use even at the cost of extra bombers and crew lives, this more frugal use could be accomplished in several ways. One method would involve reducing the number of bombs per cell and making several visits to individual targets. This method would tend to obtain greater yield from each bomb dropped by eliminating the uncertainties of predetonation that are present in simultaneous bomb drops, by permitting better use of reconnaissance to avoid over-killing the targets, etc. The repetition of visits can insure a high probability that at least one bomb will survive to be effectively dropped on target. In a similar way, repeated visits can make more effective use of smaller bombs.

We have, therefore, compared air- and ground-refueling in campaigns involving repeated visits. In these campaigns two visits to the same target may occur on successive strikes; or they may occur on the same strike: e.g., in two successive waves spaced closely enough to provide saturation and mutual protection from fighter defense, but separated widely enough for the second cell to avoid the blast effects of the first bomb drop and to obtain full yield from its own bomb drop. Either separation, on successive strikes or in successive waves on the same strike, means independent penetration of the local defense and an extra increment of losses to these defenses.

Table 11 and Fig. 39 present results for campaigns involving 250 and 300 visits to the 100-point target system under conditions otherwise identical with those assumed in the 100-visit case. They show an increase in the absolute margin of superiority of the ground-refueling system. The air-refueled system is forced into larger strike sizes to accomplish the larger number of visits, in spite of its high operating costs.

High Survival-probability Constraints. By increasing cell size we can increase the probability of survival inbound, and, like repeated visits, this will economize on a specific resource other than dollars, such as fissile material.

Table 11

REPEATED VISITS TO TARGETS IN THE 100-RGZ SYSTEM IN INTERCONTINENTAL B-47 CAMPAIGNS

(Three-year cost in billions of dollars)

	Air-refueled System		Ground-refueled System	
	250 Visits	300 Visits	250 Visits	300 Visits
Tactic	Reserve	Reserve	Impact	Impact
Number of strikes	6	6	6	6
Number of B-47's in operating force	813	905	......	......
Number of B-47's in reserve for air attrition	975	1085	......	......
Total number of B-47's	1788	1990	1318	1485
Number of B-36-type tankers	1057	1176	46	52
Number of KC-97's	894	996	250	282
New cost of bomber force	17.5	19.5	12.9	14.6
New cost of radius extension[a]	22.3	23.5	3.6	4.0
NEW COST OF COMPLETE SYSTEM	39.8	43.0	16.5	18.6
Inheritance	4.1	4.1	3.9	4.0
INCREMENTAL COST OF COMPLETE SYSTEM	35.7	38.9	12.6	14.6

[a] Includes en route bases, refueling bases, and tanker costs.

Increasing the cell size also has the important advantage of reducing round-trip losses in percent of total number of bombers in the cell, thereby increasing the individual crew's chance of surviving a single mission. Campaigns with higher survival-probability constraints than we have imposed so far also increase the margin between the air- and ground-refueled systems. They increase the size of the operating force needed, and the operating costs of the air-refueled system are high. Table 12 (page 119) and Fig. 40 (page 120) show results of a high campaign with a minimum survival-probability constraint of 0.75.

Variations in the Level of Defense. The larger uncertainties in the estimation of Soviet area- and local-defense effectiveness at any given date and the variability of Soviet defenses over time make it essential to consider the effects of a wide alteration in the air losses to be anticipated. Figure 41 (page 121) and Table 13 (page 122) present the results of campaigns in which the total defense kill potential assumed earlier is in one case doubled, and in the other, divided by five. The relative standings of the air-refueled system and the ground-

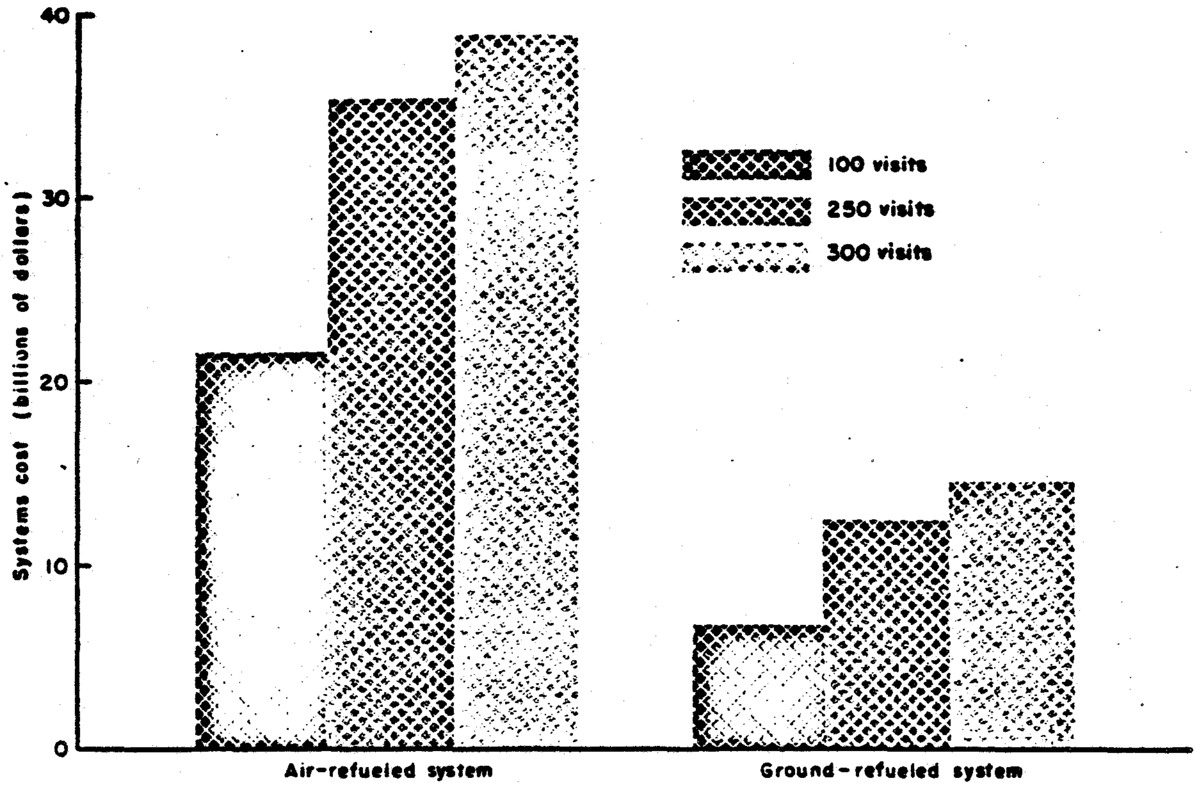

Fig. 39—Repeated visits to targets in the 100-RGZ system: intercontinental B-47 campaigns (incremental 3-year cost)

refueled system are unchanged, even with these ten-to-one variations in the total losses the enemy may inflict.

This is readily intelligible, for the air- and ground-refueled systems compared use identical bombers, namely the B-47, with the same likelihood of being intercepted and killed. If the attrition parameters were cut much further, the crew-survival constraint would be inoperative, and cell sizes would be too small to accommodate several bombs. To insure sufficiently high inbound survival probabilities of at least one bomb carrier per target in spite of aborts, etc., would mean repeated visits or larger cell sizes. Neither one, as the preceding tests show, would improve the relative standing of the air-refueled system.

Changing the Ratio of Area to Local Defense. Since estimates of Russian local defenses in particular are affected by an extreme paucity of actual data, it is useful to consider the separate variation of local-defense kills, i.e., differing values of local-defense losses for a fixed level of area-defense loss. It appears that the estimates of the Russian local-defense kill potential may be rather high, considering the lack of direct evidence that they will have any local-defense

Table 12

RAISING THE MINIMUM PROBABILITY OF CREW SURVIVAL IN INTERCONTINENTAL B-47 CAMPAIGNS

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System
Tactic	Reserve	Reserve
Number of strikes	6	6
Number of B-47's in operating force	1066	948
Number of B-47's in reserve for air attrition	640	551
Total number of B-47's	1706	1499
Number of B-36-type tankers	1190	28
Number of KC-97's	1021	154
New cost of bomber force	16.7	14.7
New cost of radius extension[a]	27.8	2.6
NEW COST OF COMPLETE SYSTEM	44.5	17.3
Inheritance	4.1	3.6
INCREMENTAL COST OF COMPLETE SYSTEM	40.4	13.7

[a] Includes en route bases, refueling bases, and tanker costs.

missiles in operation at all at the time we are considering in this study. A shift upward in the ratio of area-defense to local-defense kills affects our comparisons. The air-refueled system is penalized more heavily by fighter losses because, in general, it uses more strikes in a campaign than the ground-refueled system. It therefore suffers, by comparison, in consequence of the upward shift described. This is shown by Table 14 (page 123) and Fig. 42 (page 124).

On the other hand, given our almost total ignorance of the subject of Russian local-defense missiles, it is worth considering the consequences of a decrease in the ratio of area to local defense. If the Russians have local-defense missiles, then, until they achieve a large night-fighter capability, these will constitute their main defense in a winter campaign. We have tested the comparison of air- and ground-refueling for decreases in the ratio of area to local defense. The result in brief is to improve somewhat the position of the air-refueled system, but still to leave it markedly inferior. So long as any reasonable time constraints are placed on the campaign, even if we assume area defenses as zero and assume that unit local-defense kill potentials are isolable by RGZ, ground-refueling is decisively less expensive. These comments are illustrated by the campaign results presented in Table 15 and Fig. 42 (page 124).

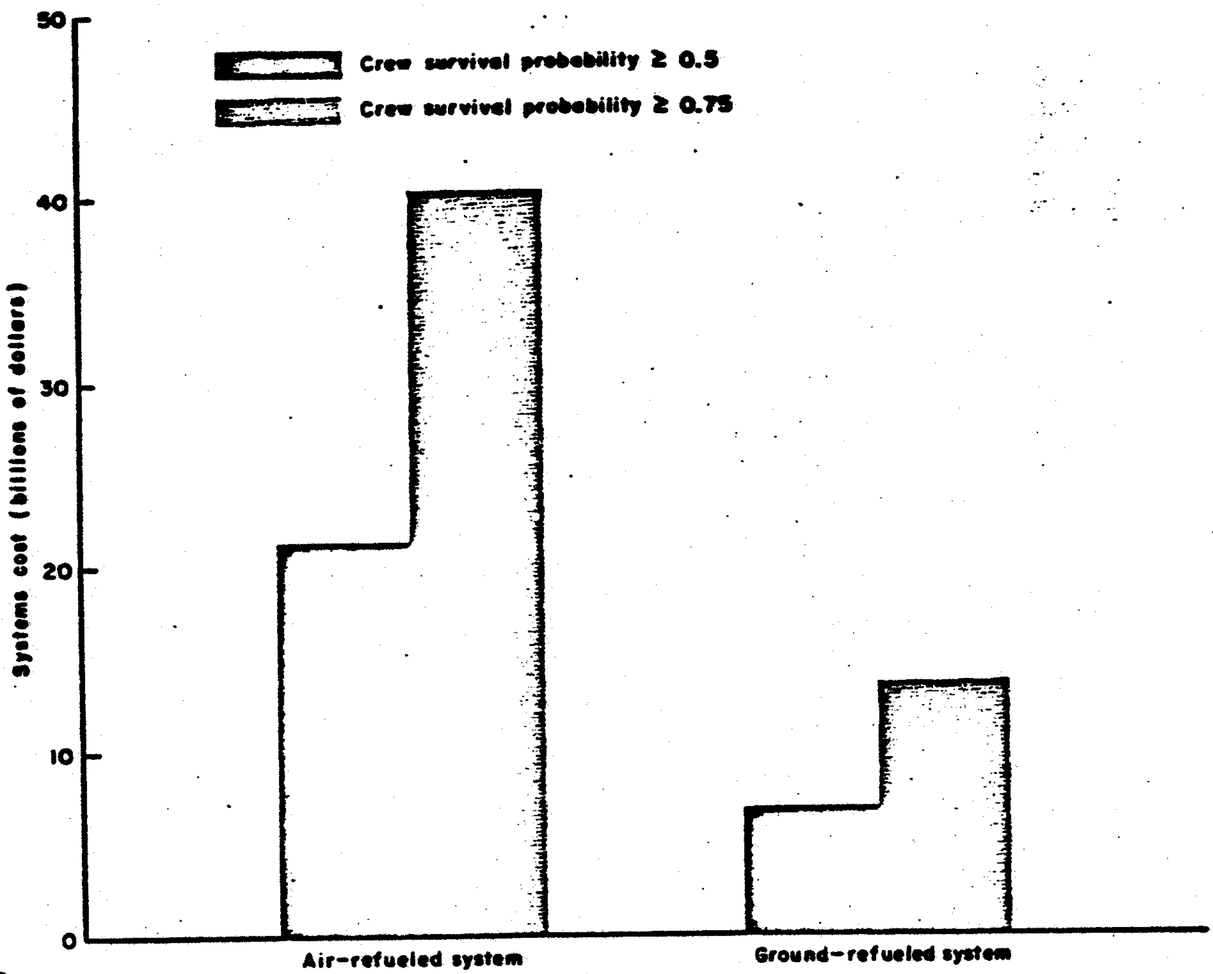

Fig. 40—Raising the minimum probability of crew survival: intercontinental B-47 campaigns (incremental 3-year cost)

INTERCONTINENTAL CAMPAIGNS WITH HEAVY BOMBERS

A comparison of an exclusively air-refueled system with a ground-refueled intercontinental system for radius extension of the programmed heavy bombers shows the same result as in the case of the programmed mediums: The ground-refueled system is distinctly the better. This conclusion merely serves to confirm for the future the essentials of SAC's present method of using heavy bombers.*

The comparison with which we are concerned has to do with a choice of base systems and not, it must be underscored, a choice of bombers. We are concerned here with air- versus ground-refueling, not the B-47 versus the B-36

*The analysis of base vulnerability in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225, indicates the need for some modification, without alteration, of the basic principle of intercontinental operation with the aid of staging overseas.

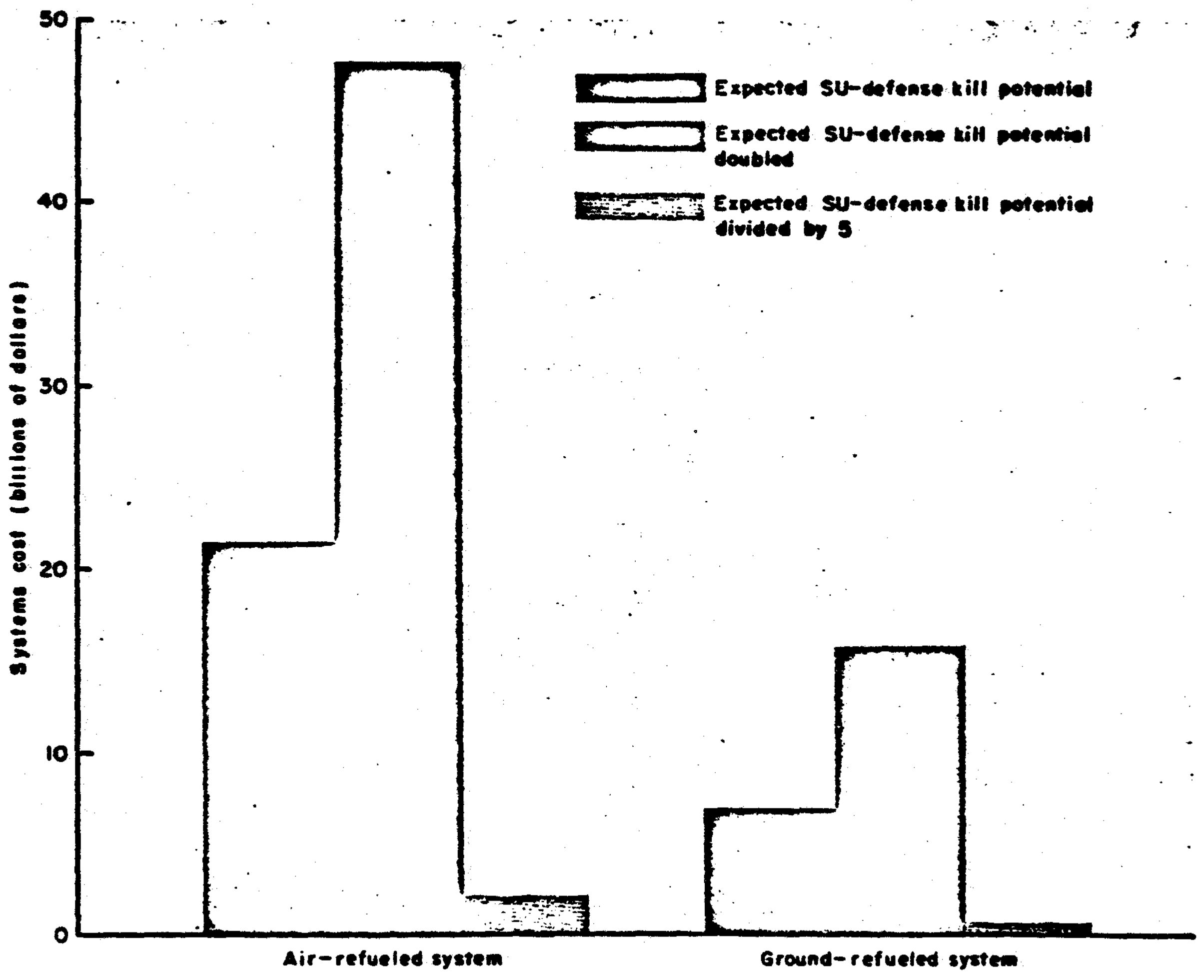

Fig. 41—Variations in total SU-defense kill potential: intercontinental B-47 campaigns (incremental 3-year cost)

or the B-52, or the B-36 versus the B-52. All three of these types of bombers will constitute significant parts of our strategic force at one time or another during the rest of the decade. They are of different design vintages; they will have partially overlapping periods of use, but, in the periods in which they overlap, their missions will to some extent differ. A comparison of any two of these aircraft would require an evaluation of the relative defense effectiveness at varying times of their use, and would be quite sensitive to assumptions about enemy defense-force composition. Similiarly, it would be affected by the choice of flight profile on a target-by-target basis. We have not made this study.

The comparison we do make permits simplification both as to the defense calendar date and the *target-by-target profile choice*. The increase in defense effectiveness over time, as we have seen, does not affect the comparisons we make of air- and ground-refueling. The detailed study of profile choice would

Table 13

VARIATIONS IN TOTAL SU DEFENSE KILL POTENTIAL IN INTERCONTINENTAL B-47 CAMPAIGNS

	Air-refueled System		Ground-refueled System	
	SU Defense Kill Potential Doubled	SU Defense Kill Potential Divided by 5	SU Defense Kill Potential Doubled	SU Defense Kill Potential Divided by 5
Tactic	Reserve	Reserve	Impact	Impact
Number of strikes	6	6	4	4
Number of B-47's in operating force	1090	109	1596	160
Number of B-47's in reserve for air losses	1300	130	0	0
Total number of B-47's	2390	239	1596	160
Number of B-36-type tankers	1417	142	56	6
Number of KC-97's	1199	120	303	30
New cost of bomber force	23.4	2.3	15.6	1.6
New cost of radius extension[a]	28.5	2.9	4.4	0.4
NEW COST OF COMPLETE SYSTEM	51.9	5.2	20.0	2.0
Inheritance	4.1	3.0	4.1	1.3
INCREMENTAL COST OF COMPLETE SYSTEM	47.8	2.2	15.9	0.7

[a] Includes en route bases, refueling bases, and tanker costs.

widen the gap between air- and ground-refueling in the case of the heavy bombers, since, as the section entitled "Bases, Targets, and Penetration Paths," page 135, illustrates, the ground-refueled system's greater flexibility in this regard is a distinct advantage. In the campaigns presented in this section, however, we have assumed that the B-52 flies at identical altitudes, whether radius is extended by tankers or by prestrike and poststrike staging; and similarly for the B-36. The absolute magnitudes of the campaign costs and force requirements are of lesser significance than the ratios of air-refueled to ground-refueled campaign results, and, in particular, are not strictly comparable with those of the B-47 campaigns.

B-52 Campaigns

Tables 16 (pages 126–128) and 17 (pages 130–132) present measurements of various elements of the minimum-tanker routes to the 100-point industry target set in the case of the air-refueled and of the ground-refueled system. They also show the tanker requirements to reach each of the targets, using the

Table 14

INCREASE IN RATIO OF SU AREA TO LOCAL DEFENSE BY A FACTOR OF 5 IN INTERCONTINENTAL B-47 CAMPAIGN

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System
Tactic	Reserve	Impact
Number of strikes	4	3
Number of B-47's in operating force	442	502
Number of B-47's in reserve for air attrition	286	0
Total number of B-47's	728	502
Number of B-36-type tankers	575	18
Number of KC-97's	486	95
New cost of bomber force	7.1	4.9
New cost of radius extension	12.5	1.4
NEW COST OF COMPLETE SYSTEM	19.6	6.3
Inheritance	4.1	2.7
INCREMENTAL COST OF COMPLETE SYSTEM	15.5	3.6

tanker-bomber relationships presented in Fig. 26 (page 72). These relationships are based on the probably generous assumption that the B-52 may be overloaded in the air to a gross weight of 480,000 lb. This exceeds the gross take-off weight by 90,000 lb.

Table 17 presents the probability of interception and kill parameters used in the measurement of attrition. The campaign assumptions made are analogous to those presented in detail in connection with the B-47 campaign. Table 18 (page 133) presents the campaign results.

The contrast in radius-extension costs is approximately the same as in the medium-bomber comparisons. The contrast in the total systems costs, including the costs of both bombers and radius-extension apparatus, is smaller than in the case of the medium bombers, since the elements that are fixed by assumption, namely the bombers, bulk larger in the heavy-bomber case. However, the contrast both in the total and in the radius-extension costs is still very marked. The intercontinental ground-refueled operation has a capability of destroying the target system at a total net cost which amounts to 57 per cent of that of the air-refueled system. The radius-extension costs of the air-refueled system are four times those of the ground-refueled system.

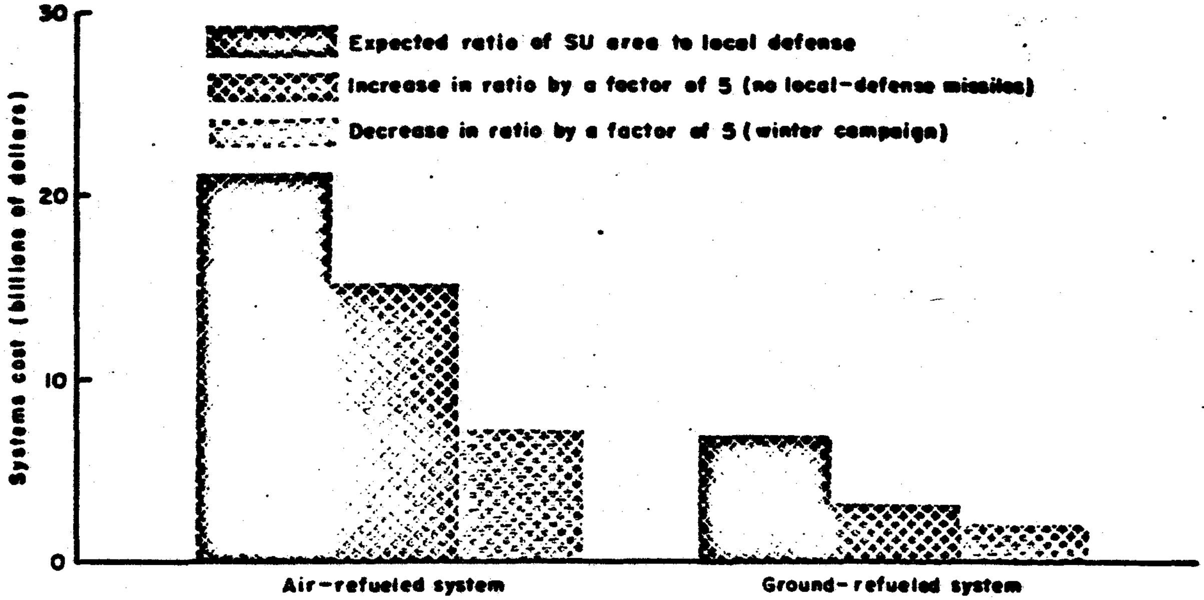

Fig. 42—Variations in ratio of SU area- to local-defense kill potential: intercontinental B-47 campaigns (incremental 3-year cost)

Table 15

DECREASE IN RATIO OF SU AREA TO LOCAL DEFENSE BY A FACTOR OF 5 (WINTER CAMPAIGN) IN INTERCONTINENTAL B-47 CAMPAIGNS

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System
Tactic	Reserve	Impact
Number of strikes	6	6
Number of B-47's in operating force	233	394
Number of B-47's in reserve for air attrition	280	0
Total number of B-47's	513	394
Number of B-36-type tankers	320	14
Number of KC-97's	256	75
New cost of bomber force	5.0	3.9
New cost of radius extension	6.2	1.0
New Cost of Complete System	11.2	4.9
Inheritance	4.1	2.8
Incremental Cost of Complete System	7.1	2.1

B-36 Campaigns

Table 18 also presents the results for the B-36 campaign. The air-refueled system is about two times as expensive as the ground-refueled system. This margin of superiority is larger than in the case of the B-52 heavy bombers, because the B-36 target speed and altitude are not as unfavorable by comparison with those of the B-52 as is its performance through area defenses. Therefore the B-36 suffers a larger proportion of area-defense losses. A high ratio of area- to local-defense losses, as we have seen, is unfavorable to the air-refueled system.

THE EFFECT OF INTRODUCING THE RASCAL

The introduction of the Rascal in combination with either the medium or the heavy programmed bomber changes two of the critical parameters in our campaign comparisons of air- and ground-refuelings. First, it means a net reduction in the combat radius of these planes. The radius capability of the B-47 is cut by 200 mi, and the mission it must accomplish is cut by 100 mi. The resulting reduction of 100 mi in effective radius capability means an increase in the radius-extension requirements for the B-47. In the case of the B-52, the net reduction amounts to about 50 mi. Second, the use of air-to-surface missiles means a saving in local-defense loss and a reduction in its importance in comparison with area defense.* The effect of both of these changes is to widen the margin of difference between the air- and ground-refueled systems.

SMALLER PLANES

These may be used as escorts, as decoys, or possibly as bombers. The smaller weight, lower vulnerability, and lower cost of aircraft designed for short, unrefueled radii suggest the importance of considering a mixed force of strategic bombers which would include short-range airplanes for use against the nearest targets. Sixty-five per cent of the industrial targets in the 100-point system studied are less than 1200 mi from the most advanced staging and forward operating bases scheduled for use in 1956. Although the short-range airplanes will be confronted with target-location (navigational) problems and difficulties in bombing associated with weather over the target, both of which must be

*See E. S. Quade, *The Computational Model for the Missiles and Aircraft for Strategic Bombardment Study*, The RAND Corporation, Research Memorandum RM-986, November 10, 1952 (Secret—Restricted Data).

Table 16a

MINIMUM-TANKER PATHS FOR AIR-REFUELED B-52 AIRCRAFT

WAC No.*	RGZ's	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
166	1	Spokane	450	55°N/123°W	3600	57°N/111°E	360	Petrovsk	360	57°N/111°E	3500	56°N/123°W	550	4410	2.5	...
159	1	Limestone	450	54°N/62°W	3800	62°N/90°E	325	Krasnoyarsk	325	62°N/90°E	3070	66°N/53°W	1180	4575	3.0	...
161	2	Limestone	450	54°N/62°W	3800	60°N/77°E	425	Kemerovo	425	60°N/77°E	3070	66°N/53°W	1180	4675	3.0	...
161	1	Limestone	450	54°N/62°W	3800	60°N/77°E	500	Stalinsk	500	60°N/77°E	3070	66°N/53°W	1180	4750	3.0	...
163	2	Limestone	450	54°N/63°W	3420	63°N/65°E	530	Omsk	530	63°N/65°E	3320	55°N/62°W	550	4400	2.5	...
156	1	Limestone	700	58°N/63°W	2930	64°N/53°E	330	Berezniki	330	64°N/53°E	....	....	3630	3960	...	1.0
156	1	Limestone	700	58°N/63°W	2930	64°N/53°E	360	Gubakha	360	64°N/53°E	....	....	3630	3990	...	1.0
156	2	Limestone	700	58°N/63°W	2930	64°N/53°E	395	Molotov	395	64°N/53°E	....	....	3630	4025	...	1.0
155	1	Limestone	700	58°N/63°W	2930	64°N/53°E	440	Votkinsk	440	64°N/53°E	....	....	3630	4070	...	1.0
156	2	Limestone	700	58°N/63°W	2930	64°N/53°E	455	Nizhiniy Tagil	455	64°N/53°E	....	....	3630	4085	...	1.0
156	1	Limestone	700	58°N/63°W	2930	64°N/53°E	480	Alapayevsk	480	64°N/53°E	....	....	3630	4110	...	1.0
156	1	Limestone	700	58°N/63°W	2930	64°N/53°E	505	Sarana	505	64°N/53°E	....	....	3630	4135	...	1.0
156	2	Limestone	700	58°N/63°W	2930	64°N/53°E	515	Sverdlovsk	515	64°N/53°E	....	....	3630	4145	...	1.0
156	1	Limestone	700	58°N/63°W	2930	64°N/53°E	530	Severskiy	530	64°N/53°E	....	....	3630	4160	...	1.0
156	1	Limestone	700	58°N/63°W	2930	64°N/53°E	555	Polevskoy	555	64°N/53°E	....	....	3630	4185	...	1.0
164	2	Limestone	700	58°N/63°W	2930	64°N/53°E	590	Zlatoust	590	64°N/53°E	....	....	3630	4220	...	1.0
164	1	Limestone	700	58°N/63°W	2930	64°N/53°E	605	Miass	605	64°N/53°E	....	....	3630	4235	...	1.0
164	2	Limestone	700	58°N/63°W	2930	64°N/53°E	615	Chelyabinsk	615	64°N/53°E	....	....	3630	4245	...	1.0
164	1	Limestone	700	58°N/63°W	2930	64°N/53°E	645	Beloretsk	645	64°N/53°E	....	....	3630	4275	...	1.0
164	2	Limestone	450	54°N/63°W	3180	64°N/53°E	690	Magnitogorsk	690	64°N/53°E	3080	55°N/60°W	550	4320	2.5	...
236	3	Limestone	450	54°N/63°W	3180	64°N/53°E	805	Orsk	805	64°N/53°E	2450	60°N/44°W	1180	4435	3.0	...
168	1	Limestone	610	55°N/58°W	2260	59°N/14°E	540	Minsk	540	59°N/14°E	....	....	2870	3410	1.0	...
167	1	Limestone	610	55°N/58°W	2260	59°N/14°E	840	Stalinogorsk	840	59°N/14°E	2320	53°N/57°W	550	3710	1.5	...
250	1	Limestone	610	55°N/58°W	2260	59°N/14°E	940	Krivoy Rog	940	59°N/14°E	2320	53°N/57°W	550	3810	1.5	...
234	2	Limestone	610	55°N/58°W	2260	59°N/14°E	950	Dneprod-zerzhinsk	950	59°N/14°E	1720	60°N/44°W	1180	3835	2.0	...
234	3	Limestone	610	55°N/58°W	2260	59°N/14°E	965	Dneprop-etrovsk	965	59°N/14°E	1720	60°N/44°W	1180	3850	2.0	...
249	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1000	Zaporozhye	1000	59°N/14°E	1720	60°N/44°W	1180	3885	2.0	...
234	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1020	Konstant-inovka	1020	59°N/14°E	1720	60°N/44°W	1180	3905	2.0	...
234	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1035	Kramatorsk	1035	59°N/14°E	1720	60°N/44°W	1180	3920	2.0	...
234	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1050	Makeyevka	1050	59°N/14°E	1720	60°N/44°W	1180	3935	2.0	...

234	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1050	Lisichansk	1050	59°N/14°E	1720	60°N/44°W	1180	3935	2.0	...
234	2	Limestone	610	55°N/58°W	2260	59°N/14°E	1055	Gorlovka	1055	59°N/14°E	1720	60°N/44°W	1180	3940	2.0	...
249	2	Limestone	610	55°N/58°W	2260	59°N/14°E	1065	Stalino	1065	59°N/14°E	1720	60°N/44°W	1180	3950	2.0	...
325	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1070	Dzaudzhikau	1070	59°N/14°E	1720	60°N/44°W	1180	3955	2.0	...
156	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1080	Kamensk	1080	59°N/14°E	1720	60°N/44°W	1180	3965	2.0	...
249	2	Limestone	610	55°N/58°W	2260	59°N/14°E	1090	Zhdanov	1090	59°N/14°E	1720	60°N/44°W	1180	3975	2.0	...
249	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1125	Taganrog	1125	59°N/14°E	1720	60°N/44°W	1180	4010	2.0	...
249	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1140	Krasnyy Sulin	1140	59°N/14°E	1720	60°N/44°W	1180	4025	2.0	...
249	1	Limestone	610	55°N/58°W	2260	59°N/14°E	1230	Krasnodar	1230	59°N/14°E	1720	60°N/44°W	1180	4115	2.0	...
235	2	Limestone	610	55°N/58°W	2260	59°N/14°E	1230	Stalingrad	1230	59°N/14°E	1720	60°N/44°W	1180	4115	2.0	...
324	1	Limestone	450	52°N/59°W	2420	59°N/14°E	1450	Batumi	1450	59°N/14°E	2320	53°N/57°W	550	4320	2.5	...
325	1	Limestone	450	52°N/59°W	2420	59°N/14°E	1490	Groznyy	1490	59°N/14°E	2320	53°N/57°W	550	4360	2.5	...
325	1	Limestone	450	52°N/59°W	2420	59°N/14°E	1555	Makhachkala	1555	59°N/14°E	1720	60°N/44°W	1180	4440	3.0	...
325	1	Limestone	450	52°N/59°W	2420	59°N/14°E	1560	Rustavi	1560	59°N/14°E	1720	60°N/44°W	1180	4445	3.0	...
325	3	Limestone	450	52°N/59°W	2420	59°N/14°E	1760	Baku	1760	59°N/14°E	1720	60°N/44°W	1180	4645	3.0	...
326	1	Limestone	700	55°N/54°W	2170	59°N/14°E	1935	Krasnovodsk	1935	59°N/14°E	1500	66°N/37°W	1500	4870	...	1.5
153	3	Limestone	610	55°N/58°W	2400	66°N/26°E	340	Leningrad	340	66°N/26°E	....	....	3010	3350	1.0	...
153	1	Limestone	610	55°N/58°W	2400	66°N/26°E	360	Kolpino	360	66°N/26°E	....	....	3010	3370	1.0	...
154	1	Limestone	610	55°N/58°W	2400	66°N/26°E	550	Shcherbakov	550	66°N/26°E	2530	55°N/60°W	550	3600	1.5	...
154	1	Limestone	610	55°N/58°W	2400	66°N/26°E	565	Konstant-inovskiy	565	66°N/26°E	2530	55°N/60°W	550	3610	1.5	...
154	1	Limestone	610	55°N/58°W	2400	66°N/26°E	590	Yaroslavl	590	66°N/26°E	2530	55°N/60°W	550	3640	1.5	...
167	6	Limestone	610	55°N/58°W	2400	66°N/26°E	650	Moscow	650	66°N/26°E	2530	55°N/60°W	550	3700	1.5	...
167	1	Limestone	610	55°N/58°W	2400	66°N/26°E	665	Noginsk	665	66°N/26°E	2530	55°N/60°W	550	3710	1.5	...
167	2	Limestone	610	55°N/58°W	2400	66°N/26°E	700	Kolomna	700	66°N/26°E	2530	55°N/60°W	550	3740	1.5	...
154	2	Limestone	610	55°N/58°W	2400	66°N/26°E	715	Dzerzhinsk	715	66°N/26°E	2530	55°N/60°W	550	3760	1.5	...
154	3	Limestone	610	55°N/58°W	2400	66°N/26°E	730	Gorkiy	730	66°N/26°E	2530	55°N/60°W	550	3775	1.5	...
155	1	Limestone	610	55°N/58°W	2400	66°N/26°E	755	Kirov	755	66°N/26°E	2530	55°N/60°W	550	3800	1.5	...
165	1	Limestone	610	55°N/58°W	2400	66°N/26°E	865	Kazan	865	66°N/26°E	1830	60°N/44°W	1180	3875	2.0	...
165	1	Limestone	610	55°N/58°W	2400	66°N/26°E	910	Ulyanovsk	910	66°N/26°E	1830	60°N/44°W	1180	3920	2.0	...
165	1	Limestone	610	55°N/58°W	2400	66°N/26°E	955	Syzran	955	66°N/26°E	1830	60°N/44°W	1180	3965	2.0	...
235	1	Limestone	610	55°N/58°W	2400	66°N/26°E	1000	Saratov	1000	66°N/26°E	1830	60°N/44°W	1180	4010	2.0	...
165	2	Limestone	610	55°N/58°W	2400	66°N/26°E	1010	Kuybyshev	1010	66°N/26°E	1830	60°N/44°W	1180	4020	2.0	...
165	3	Limestone	700	58°N/63°W	2310	66°N/26°E	1060	Ufa	1060	66°N/26°E	....	....	3010	4070	1.0	...
247	1	Limestone	450	53°N/61°W	2560	66°N/26°E	1335	Guryev	1335	66°N/26°E	2530	55°N/60°W	550	4380	2.5	...
204	2	Spokane	450	53°N/127°W	3390	44°N/139°E	420	Komsomolsk	420	44°N/139°E	3290	54°N/129°W	550	4260	2.5	...
328	1							Begovat[b]								

[a] World Aeronautical Charts, *Bombing Encyclopedia Manual and Code Book*, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.
[b] Target cannot be reached.

Table 16b

SUMMARY OF MINIMUM-TANKER PATHS FOR AIR-REFUELED B-52 AIRCRAFT[a]

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
					Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
57°N/111°E	450	1.04	4050	9.40	360	360	360	0.84	0.84	0.84	4410	4410	4410	10.23	10.23	10.23
62°N/90°E	450	1.04	4250	9.86	325	325	325	0.75	0.75	0.75	4575	4575	4575	10.61	10.61	10.61
60°N/77°E	450	1.04	4250	9.86	500	450	425	1.16	1.04	0.99	4750	4700	4675	11.02	10.90	10.85
63°N/65°E	450	1.04	3870	8.98	530	530	530	1.23	1.23	1.23	4400	4400	4400	10.21	10.21	10.21
64°N/53°E	647	1.50	3629	8.42	805	558	330	1.87	1.29	0.77	4434	4187	3959	10.29	9.71	9.18
59°N/14°E	580	1.35	2870	6.66	1935	1178	540	4.49	2.73	1.25	4805	4048	3410	11.15	9.39	7.91
66°N/26°E	613	1.42	3010	6.98	1335	740	340	3.10	1.72	0.79	4345	3750	3350	10.08	8.70	7.77
44°N/139°E	450	1.04	3840	8.91	420	420	420	0.97	0.97	0.97	4260	4260	4260	9.88	9.88	9.88

[a] These averages would, in some cases, be increased if we included the target Begovat, which cannot be reached at all, and if we measured from the actual multiplicity of ZI-base locations instead of from the two points of Limestone and Spokane.

evaluated in connection with their bombing use, they may be able to bomb visually with greater accuracy than high-altitude medium and heavy bombers and so may accomplish greater damage with a given quantity of fissile material, particularly in a summer campaign. Aside from their smaller weight, lower probability of being intercepted, and lower procurement cost, such airplanes as the F-101 can be easily dispersed and evacuated from their primary bases, are equipped as all-weather interceptors, and can defend their own bases. Whether the escorts programmed for 1956 are used as bombers, as escort fighters, or as decoys, their strategic use appears practicable only from an advanced primary-based system or from a more distant primary-based system with overseas ground-refueling facilities. The preference for ground-refueling over air-refueling would be greatly increased if these components of the programmed force were taken into account.

SUMMARY: THE EFFECTS OF DISTANCE FROM BASE TO ENEMY TARGET

One principal outcome of the analysis in the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, is that, so far as the effects of increasing target radius are concerned, radius-extension costs increase very sharply if we remove all ground-base functions to extreme distances from targets; and, by comparison, they increase quite moderately if we remove substantially all the functions associated with the storage and transfer of fuel. We have also seen that, at moderate combat radii (considerably less than intercontinental combat radii), the costs of aerial refueling are moderate and do not increase too sharply with small increases in distance.

These effects have been reflected in campaign costs. Campaigns have been examined for very wide ranges of parameters, and the results have been shown to be insensitive to such variations. However, we have not analyzed, so far, the costs of defending the overseas refueling function. And we have not considered the logistics costs and defense requirements of leaving all operating-base functions forward, or in some intermediate overseas position. Before considering these matters, we shall deal with the question of the relation of the base systems to the choice of alternative paths through enemy defenses.

Table 17a

MINIMUM-TANKER PATHS FOR GROUND-REFUELED B-52 AIRCRAFT

WAC No.*	RGZ's	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	320	Berezniki	320	63°N/65°E	2260	77°N/67°W	1800	4380	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	325	Gubakha	325	63°N/65°E	2260	77°N/67°W	1800	4385	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	325	Alapayevsk	325	63°N/65°E	2260	77°N/67°W	1800	4385	...	...
156	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	360	Nizhniy Tagil	360	63°N/65°E	2260	77°N/67°W	1800	4420	...	...
156	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	400	Sverdlovsk	400	63°N/65°E	2260	77°N/67°W	1800	4460	...	...
156	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	410	Molotov	410	63°N/65°E	2260	77°N/67°W	1800	4470	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	420	Polevskoy	420	63°N/65°E	2260	77°N/67°W	1800	4480	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	430	Severskiy	430	63°N/65°E	2260	77°N/67°W	1800	4490	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	465	Sarana	465	63°N/65°E	2260	77°N/67°W	1800	4525	...	...
155	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	480	Votkinsk	480	63°N/65°E	2260	77°N/67°W	1800	4540	...	...
164	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	490	Chelyabinsk	490	63°N/65°E	2260	77°N/67°W	1800	4550	...	...
164	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	510	Zlatoust	510	63°N/65°E	2260	77°N/67°W	1800	4570	...	...
164	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	510	Miass	510	63°N/65°E	2260	77°N/67°W	1800	4570	...	...
153	3	Limestone	2000	64°N/19°W	1100	66°N/26°E	340	Leningrad	340	66°N/26°E	1100	64°N/19°W	2000	3440	...	...
153	1	Limestone	2000	64°N/19°W	1100	66°N/26°E	360	Kolpino	360	66°N/26°E	1100	64°N/19°W	2000	3460	...	...
168	1	Limestone	2000	64°N/19°W	1020	59°N/14°E	540	Minsk	540	59°N/14°E	1020	64°N/19°W	2000	3560	...	...
249	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	375	Krasnodar	375	39°N/35°E	1980	34°N/8°W	2800	5155	...	...
249	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	470	Zhdanov	470	39°N/35°E	1980	34°N/8°W	2800	5250	...	...
249	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	480	Zaporozhye	480	39°N/35°E	1980	34°N/8°W	2800	5260	...	...
250	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	490	Krivoy Rog	490	39°N/35°E	1980	34°N/8°W	2800	5270	...	...
234	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	500	Dneprod-zerzhinsk	500	39°N/35°E	1980	34°N/8°W	2800	5280	...	...
234	3	Limestone	2800	34°N/8°W	1980	39°N/35°E	500	Dneprop-etrovsk	500	39°N/35°E	1980	34°N/8°W	2800	5280	...	...
249	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	500	Taganrog	500	39°N/35°E	1980	34°N/8°W	2800	5280	...	...
249	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	530	Stalino	530	39°N/35°E	1980	34°N/8°W	2800	5310	...	...
234	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	530	Makeyevka	530	39°N/35°E	1980	34°N/8°W	2800	5310	...	...
325	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	540	Dzaudzhikau	540	39°N/35°E	1980	34°N/8°W	2800	5320	...	...
234	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	550	Konstant-inovka	550	39°N/35°E	1980	34°N/8°W	2800	5330	...	...
234	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	560	Gorlovka	560	39°N/35°E	1980	34°N/8°W	2800	5340	...	...
249	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	565	Krasnyy Sulin	565	39°N/35°E	1980	34°N/8°W	2800	5345	...	...

234	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	570	Kramatorsk	570	39°N/35°E	1980	34°N/8°W	2800	5350	...	...
156	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	575	Kamensk	575	39°N/35°E	1980	34°N/8°W	2800	5355	...	...
234	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	600	Lisichansk	600	39°N/35°E	1980	34°N/8°W	2800	5380	...	...
235	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	680	Stalingrad	680	39°N/35°E	1980	34°N/8°W	2800	5460	...	...
235	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	850	Saratov	850	39°N/35°E	1980	34°N/8°W	2800	5630	...	...
167	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	900	Stalinogorsk	900	39°N/35°E	1980	34°N/8°W	2800	5680	...	...
167	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	960	Kolomna	960	39°N/35°E	1980	34°N/8°W	2800	5740	...	...
167	6	Limestone	2800	34°N/8°W	1980	39°N/35°E	980	Moscow	980	39°N/35°E	1980	34°N/8°W	2800	5760	...	...
165	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	990	Syzran	990	39°N/35°E	1980	34°N/8°W	2800	5770	...	...
167	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	1000	Noginsk	1000	39°N/35°E	1980	34°N/8°W	2800	5780	...	...
165	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	1030	Kuybyshev	1030	39°N/35°E	1980	34°N/8°W	2800	5810	...	...
154	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	1060	Dzerzhinsk	1060	39°N/35°E	1980	34°N/8°W	2800	5840	...	...
154	3	Limestone	2800	34°N/8°W	1980	39°N/35°E	1070	Gorkiy	1070	39°N/35°E	1980	34°N/8°W	2800	5850	...	...
165	1	Limestone	3130	37°N/3°E	1430	39°N/35°E	1090	Ulyanovsk	1090	39°N/35°E	1430	37°N/3°E	3130	5650	...	...
154	1	Limestone	3130	37°N/3°E	1430	39°N/35°E	1120	Shcherbakov	1120	39°N/35°E	1430	37°N/3°E	3130	5680	...	...
154	1	Limestone	3130	37°N/3°E	1430	39°N/35°E	1120	Konstant-inovskiy	1120	39°N/35°E	1430	37°N/3°E	3130	5680	...	...
154	1	Limestone	3130	37°N/3°E	1430	39°N/35°E	1120	Yaroslavl	1120	39°N/35°E	1430	37°N/3°E	3130	5680	...	...
165	1	Limestone	3130	37°N/3°E	1430	39°N/35°E	1125	Kazan	1125	39°N/35°E	1430	37°N/3°E	3130	5685	...	...
155	1	Limestone	3130	37°N/3°E	1430	39°N/35°E	1270	Kirov	1270	39°N/35°E	1430	37°N/3°E	3130	5830	...	...
324	1	Limestone	3130	37°N/3°E	1820	38°N/40°E	230	Batumi	230	38°N/40°E	1820	37°N/3°E	3130	5180	...	...
325	1	Limestone	3130	37°N/3°E	1820	38°N/40°E	280	Rustavi	280	38°N/40°E	1820	37°N/3°E	3130	5230	...	...
325	1	Limestone	3130	37°N/3°E	1820	38°N/40°E	360	Groznyy	360	38°N/40°E	1820	37°N/3°E	3130	5310	...	...
325	1	Limestone	3130	37°N/3°E	1820	38°N/40°E	420	Makhachkala	420	38°N/40°E	1820	37°N/3°E	3130	5370	...	...
325	3	Limestone	3130	37°N/3°E	1820	38°N/40°E	430	Baku	430	38°N/40°E	1820	37°N/3°E	3130	5380	...	...
326	1	Limestone	3130	37°N/3°E	1820	38°N/40°E	600	Krasnovodsk	600	38°N/40°E	1820	37°N/3°E	3130	5550	...	...
247	1	Limestone	3130	37°N/3°E	1820	38°N/40°E	750	Guryev	750	38°N/40°E	1820	37°N/3°E	3130	5700	...	...
236	3	Limestone	3130	37°N/3°E	1820	38°N/40°E	1090	Orsk	1090	38°N/40°E	1820	37°N/3°E	3130	6040	...	...
165	3	Limestone	3130	37°N/3°E	1820	38°N/40°E	1150	Ufa	1150	38°N/40°E	1820	37°N/3°E	3130	6100	...	...
164	2	Limestone	3130	37°N/3°E	1820	38°N/40°E	1170	Magnitogorsk	1170	38°N/40°E	1820	37°N/3°E	3130	6120	...	...
164	1	Limestone	3130	37°N/3°E	1820	38°N/40°E	1200	Beloretsk	1200	38°N/40°E	1820	37°N/3°E	3130	6150	...	...
328	1	Limestone	5420	26°N/50°E	1000	34°N/68°E	350	Begovat	350	34°N/68°E	1000	26°N/50°E	5420	6770	...	...
163	2	Limestone	5420	26°N/50°E	1000	34°N/68°E	1250	Omsk	1250	34°N/68°E	1000	26°N/50°E	5420	7670	...	...
161	1	Spokane	4240	36°N/140°E	2360	49°N/90°E	310	Stalinsk	310	49°N/90°E	2360	36°N/140°E	4240	6910	...	...
161	2	Spokane	4240	36°N/140°E	2360	49°N/90°E	400	Kemerovo	400	49°N/90°E	2360	36°N/140°E	4240	7000	...	...
159	1	Spokane	4240	36°N/140°E	2360	49°N/90°E	450	Krasnoyarsk	450	49°N/90°E	2360	36°N/140°E	4240	7050	...	...
166	1	Spokane	4240	36°N/140°E	575	47°N/113°E	330	Petrovsk	330	47°N/113°E	575	36°N/140°E	4240	5145	...	...
204	2	Spokane	4240	36°N/140°E	1490	44°N/139°E	420	Komsomolsk	420	44°N/139°E	1490	36°N/140°E	4240	6150	...	...

* World Aeronautical Charts, *Bombing Encyclopedia Manual and Code Book*, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.

from S.

Over the pole

Table 17b

SUMMARY OF MINIMUM-TANKER PATHS FOR GROUND-REFUELED B-52 AIRCRAFT

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
					Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
63°N/65°E	1800	4.18	4060	9.42	510	423	320	1.18	0.98	0.74	4570	4483	4380	10.60	10.40	10.16
66°N/26°E	2000	4.64	3100	7.19	360	345	340	0.84	0.80	0.79	3460	3445	3440	8.03	7.99	7.98
59°N/14°E	2000	4.64	3020	7.00	540	540	540	1.25	1.25	1.25	3560	3560	3560	8.26	8.26	8.26
39°N/35°E	2840	6.59	4753	11.03	1270	786	375	2.95	1.82	0.87	6023	5539	5128	13.97	12.85	11.90
38°N/40°E	3130	7.26	4950	11.48	1200	788	230	2.78	1.83	0.53	6150	5738	5180	14.27	13.31	12.02
34°N/68°E	5420	12.57	6420	14.89	1250	950	350	2.90	2.20	0.81	7670	7370	6770	17.79	17.10	15.71
49°N/90°E	4240	9.84	6600	15.31	450	390	310	1.04	0.90	0.72	7050	6990	6910	16.36	16.22	16.03
47°N/113°E	4240	9.84	5815	13.49	330	330	330	0.77	0.77	0.77	6145	6145	6145	14.26	14.26	14.26
44°N/139°E	4240	9.84	5730	13.29	420	420	420	0.97	0.97	0.97	6150	6150	6150	14.27	14.27	14.27

Table 18

INTERCONTINENTAL AIR- VERSUS GROUND-REFUELING FOR HEAVY BOMBERS

Air-refueled System Costs and Requirements To Destroy Russian Industry Targets Are Presented as a Percentage of Ground-refueled System Costs and Requirements

	B-52[a] (%)	B-36[a] (%)
Number of strikes	125	100
Total number of bombers	144	147
Number of bombers in operating force	84	99
Three-year cost of bomber force	144	148
Three-year cost of radius extension	439	358
THREE-YEAR TOTAL SYSTEMS COST, NEW	174	174
Inheritance	171	98
THREE-YEAR TOTAL SYSTEMS COST, INCREMENTAL	175	190

[a] Air-refueled systems use reserve tactics; ground-refueled systems use impact tactics.

C. Bases, Targets, and Penetration Paths

OFFENSE AND DEFENSE FLEXIBILITY AND PENETRATION CHOICE

The relation of a base system to various points of entry into and exits from enemy-defended territory can strongly affect both our attrition and our support costs in a strategic campaign. Base systems differ greatly in the choice that they permit among alternative routes, speeds, and altitudes of penetration through enemy defenses. By the same token, they differ in the choices they leave open to the enemy as to the deployment and commitment of his defense.

We have seen that some base systems entail very high average unit radius-extension costs to attack a specified defended target system, even when routes calculated to reduce the unit radius-extension costs for the operating force are used. The subject of this section concerns the campaign consequences of the fact that a base system may also involve (1) large differences in the average unit radius-extension costs it requires to follow alternative paths to the same targets, and (2) a large dispersion about these averages in the costs to reach individual targets. The degree of such inequalities in our effectiveness or costs contrasts markedly for differing offense base systems. But such inequalities may be exploited by the enemy. Therefore, to evaluate alternative offense base systems it is important to examine the penetration and defense tactics they permit.

Both the offensive tactics illustrated in the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, and the defense tactics which oppose them can be significantly improved. It appears doubtful that analytic "optima" are precisely definable in so complex a situation. However, several decisive improvements over the tactics examined can be defined and illustrated. These offense and defense tactics are examined in campaigns for the destruction of the basic 100-point industry-target system, and also for the distinction of expanded and nonuniform-valued target systems.

ATTRITION AND PENETRATION

As a mass formation of bombers penetrates more deeply into an area having roughly uniform fighter coverage, attrition inbound tends to increase because

(1) the track comes within the combat radius of a growing number of fighters, (2) the proportion of those fighters within range which are available for commitment becomes larger with the time after warning, and (3) the proportion of fighters available which the base commander can afford to commit, without excessive risks from feints and time-staggered attacks, grows as the bomber formation advances for an increasing distance inside the early-warning perimeter. Outbound attrition increases not only because the area within which the fighters are stirred up by the deeper penetrations is greater, but also because, where cells withdraw separately from widely separated targets along the same track, the number of opportunities to recycle individual fighters increases. For areas with a uniform density of equally effective fighters, this means a steady, more than proportional increase in attrition.* For nonuniform defense distributions, the relation of attrition to increasing penetration is not steady but depends on the region penetrated and on the specific tracks. The area-defense distribution described in the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, was nonuniform in the density of fighters employed above and below the Fiftieth Parallel. We shall consider other defense distributions involving, among other things, denser concentrations of fighters. First, however, we shall deal with the choice of alternative routes by the offense and the campaign costs involved against a defense distribution of the sort already described.

ROUTE CHOICE

Doglegging

Depending on the relationship between the base, the target, and the intervening boundary of fighter-covered territory, the distance penetrated through enemy defenses to a given target may be reduced by doglegs. Then, by increasing the base-to-entry-point leg of the mission, the entry-point-to-target leg is shortened. In the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, the routes adopted for specific bomber base combinations took advantage of such doglegs only so long as they did not involve an increase in total mission radius large enough to require extra tankers. These were minimum-tanker routes, and they minimized penetration subject to this condition. Penetration distances can be further reduced, if we relax this requirement. This

*More exactly, monotonic nondecreasing, with more than proportional increases for intervals of sufficient size.

means in effect that we are trading tankers in order to reduce penetration, i.e., to save bombers. The price we pay depends on the particular combination of bases and bombers we employ. It is clear that, if we have an operating base system located in the ZI, routes minimizing penetration to South Russian targets, such as Baku, involve very extended total mission radii. If, furthermore, our means of radius extension are limited principally to tankers, the cost of the extra radius to come up from the south is likely to be very large, since air-refueling requirements increase at an accelerating rate as mission radius is increased.

Alternative Routes

We distinguish three broadly different kinds of routes involving penetration and withdrawal along the same track. The first is the relatively direct type of route already described. These routes minimize penetration subject to the constraint that tanker costs are at a minimum. They therefore follow comparatively short paths from the last ground stop to the target. Since the minimum number of tankers required to visit the target system depends on the location of our bases, these minimum-tanker routes will differ for different base and bomber systems, both in the approach and penetration segments. Figure 43 shows the minimum-tanker routes for the ground-refueled intercontinental B-47 system to the points of entry into the SU radar net. Figure 33 (page 101) presented the penetration segments of the ground-refueled minimum-tanker routes. The minimum-tanker paths for an intercontinental air-refueled B-47 system are shown in Fig. 44 (page 139); their penetration segments were shown in Fig. 34 (page 102).

The second route type minimizes penetration through enemy defenses. The penetration segments of these routes are substantially the same for the various base systems. The approach segments vary with the base and bomber system. Figure 45 (page 140) presents the penetration segment of the minimum-penetration routes.

The approach segments to the point of entry into the SU radar net for an intercontinental air-refueled and for an intercontinental ground-refueled B-47 system are presented in Figs. 46 (page 141) and 47 (page 142), respectively.

A third type of route might be chosen to take the greatest advantage of darkness in a summer campaign. About two-thirds of the Russian target system is situated above the Fiftieth Parallel of latitude, and the rest is situated below it. In summer, day fighters could be employed effectively at an altitude of about

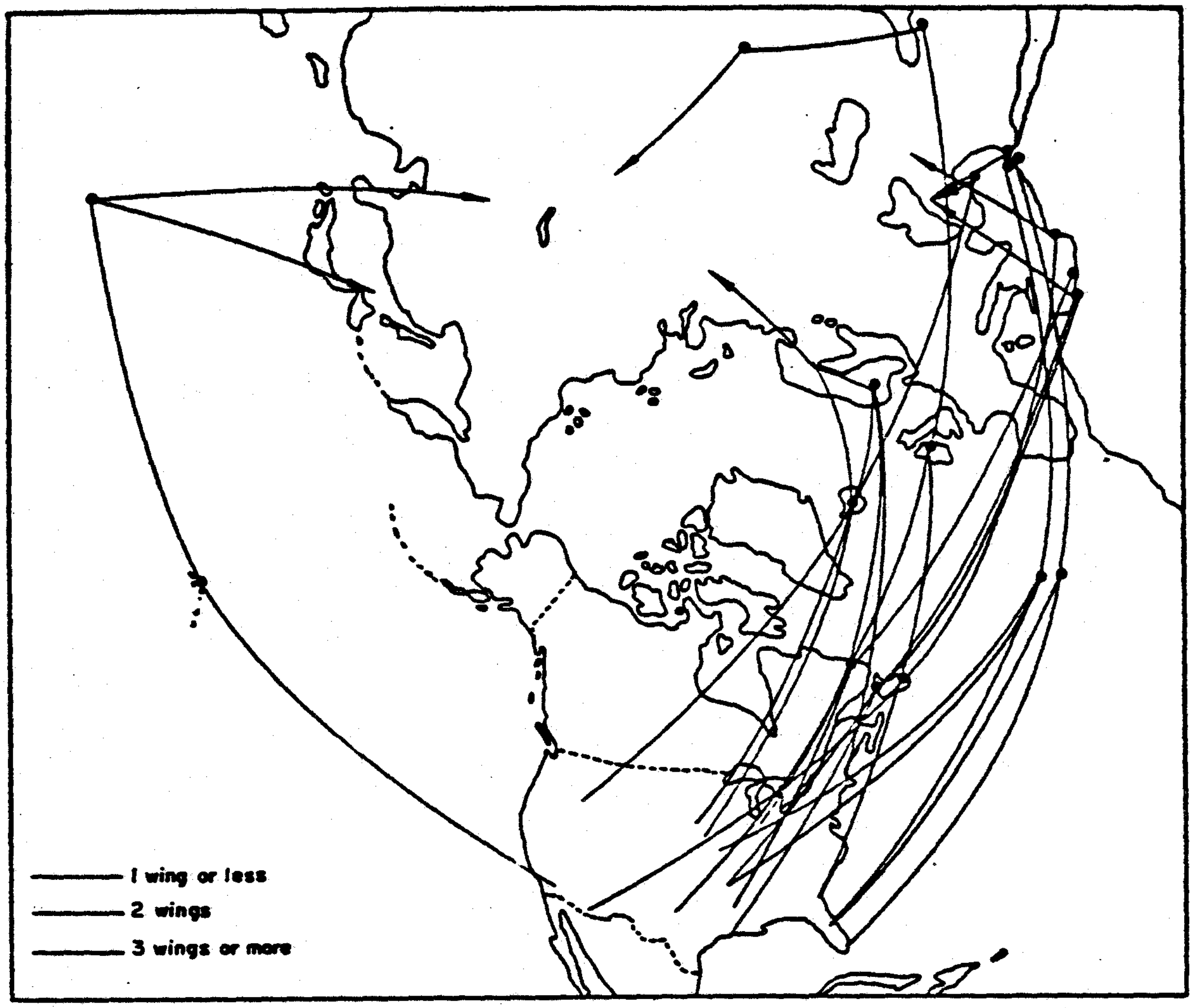

Fig. 43—Minimum-tanker approach routes: B-47 ground-refueled system (1750-n-mi radius)

40,000 ft or more above points north of the Fiftieth Parallel. The Russians are expected to have more day fighters than night fighters for some time to come. We have assumed in effect a 3.5 to 1 ratio (following previous RAND studies*). Moreover, a Russian night fighter's individual probability of intercepting and killing one of our bombers at night is expected to be very much smaller than that of a Russian day fighter under conditions of good visibility. (The analysis of air battles that was conducted at RAND indicates a more than two-fold difference for the B-47.) As a result, the probability of bomber losses in 100 mi of penetration through area defenses below the Fiftieth Parallel can be expected

*W. E. Gasich, *An Estimation of Soviet Interceptor Defenses through 1960*, The RAND Corporation, Research Memorandum RM-826, May 22, 1951 (Secret).

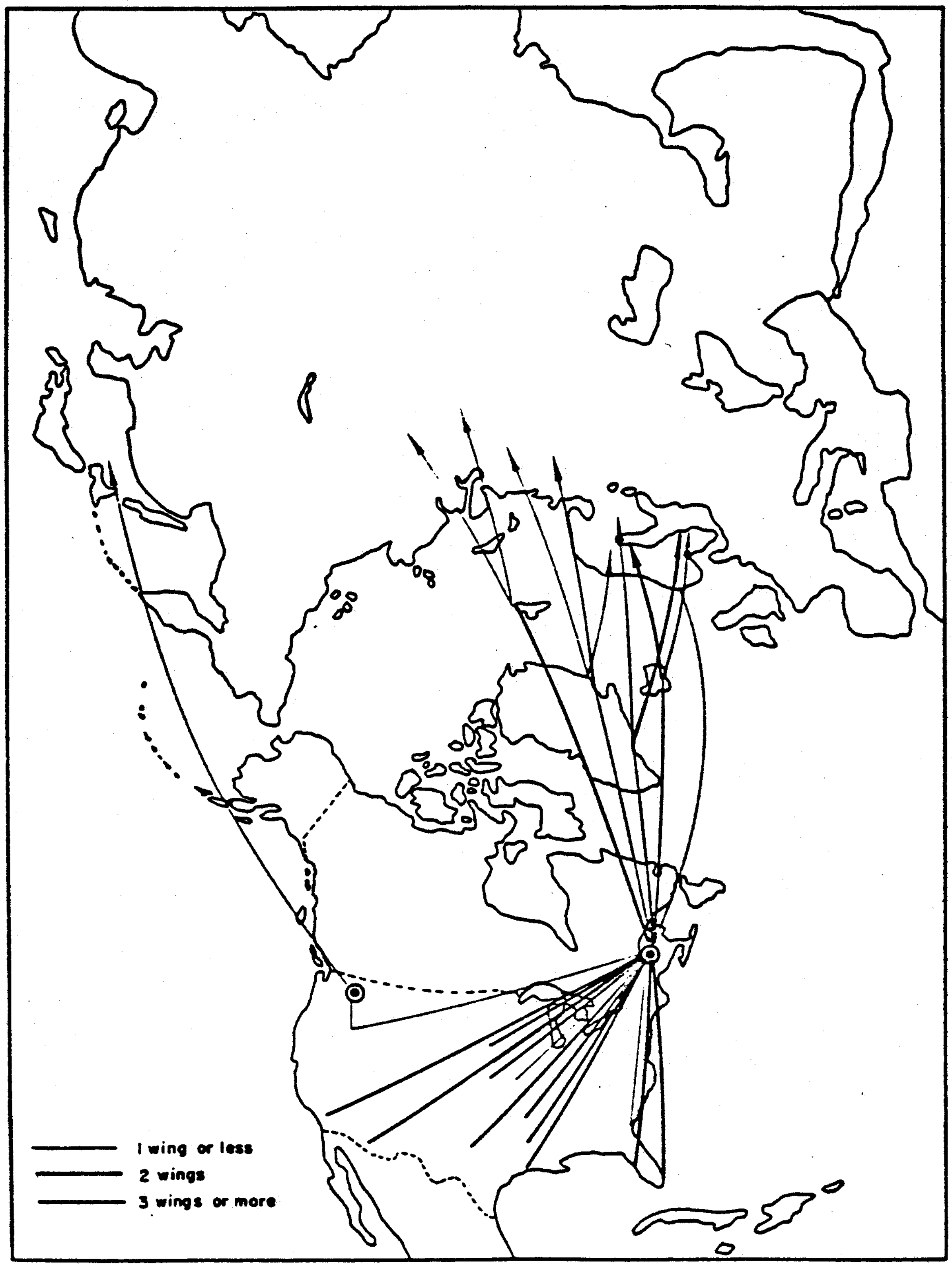

Fig. 44—Minimum-tanker approach routes: B-47 air-refueled system (1750-n-mi radius)

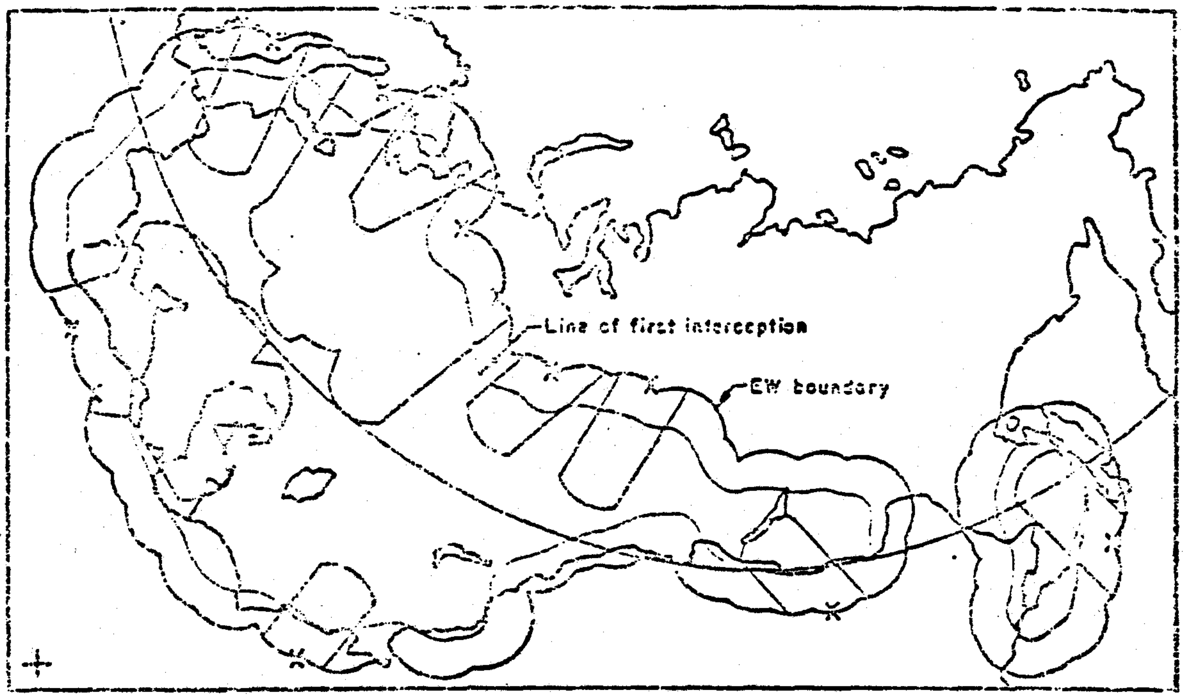

Fig. 45—Fighter areas swept out: minimum-penetration routes

to be very much lower than for a similar distance in the north during the summer. To minimize attrition, then, bombers would do well to trade a given number of miles of penetration in daylight for a larger number of miles of penetration in darkness. The penetration segment of such a route is illustrated in Fig. 48 (page 143).

The shaded fighter-corridor areas for the various penetration paths shown in Fig. 45 are a measure of the proportion of fighters within radius on the inbound trip. As was explained in the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, outbound losses of bombers on the way back along the same tracks are affected by the essentially separate withdrawals of cells dispatched to targets separated by more than the distance the bombers can travel in half a fighter cycle. Fighters near the point of exit, then, depending on the length of the bomber penetration and the distribution of targets in the track, may have the opportunity to be cycled several times. Outbound attrition is of greater importance in the case of Russian defenses than it appears to be in the case of the defense of the United States. This is so for several reasons. First, our target cities are for the most part reachable with shallower penetrations. Second, as long as the Russian stockpile of bombs is small in relation to the Russian stockpile of bombers, attriting bombs is more important than attriting bombers; the critical point in the defense is on the

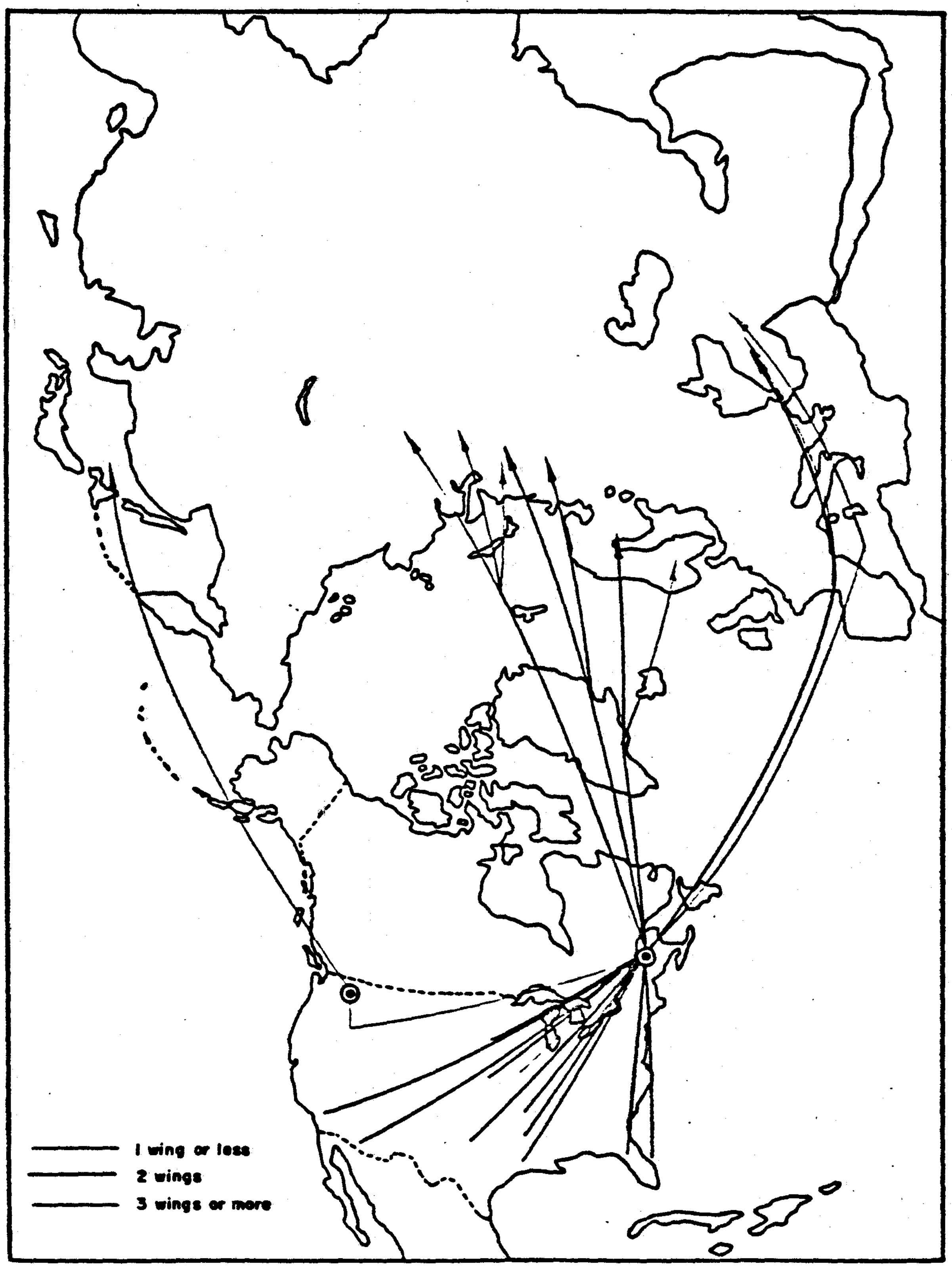

Fig. 46—Minimum-penetration approach routes: B-47 air-refueled system (1750-n-mi radius)

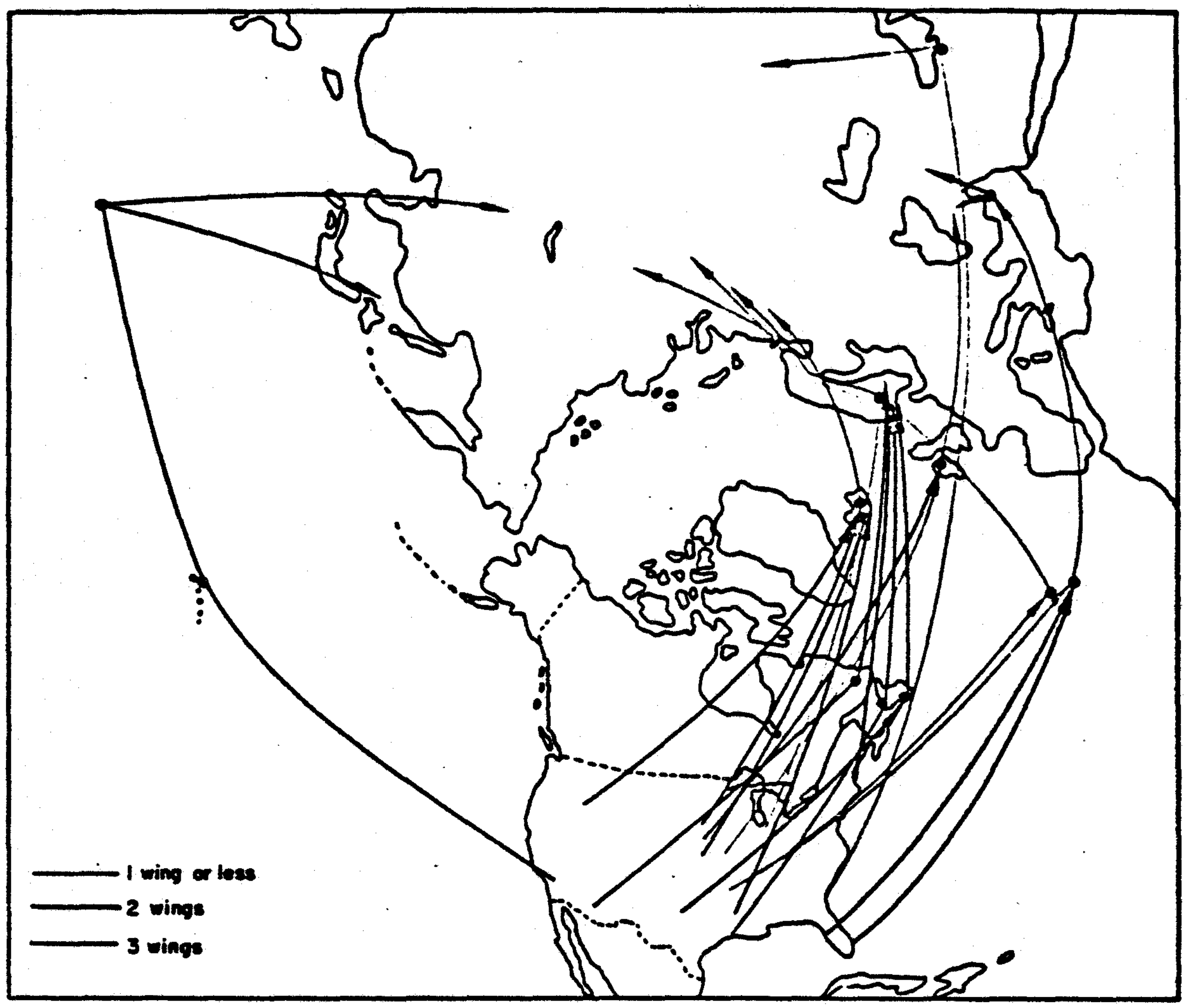

Fig. 47—Minimum-penetration approach routes: B-47 ground-refueled system (1750-n-mi radius)

target-bound leg. Third, with the range limitations of the Soviet bomber force, one-way missions are in general needed, so that in any case the bombers do not have to be shot down to prevent their being re-used for a later strike. In the case of our campaigns against Russia, however, the significance of outbound attrition is not reduced for any of these reasons. And for some combinations of routes and enemy defense deployments its significance is quite large. One of several tactics which may reduce outbound attrition for deep penetrations involves going in on one side of Russia on the way to the targets and coming out on the other side. This may involve stirring up new fighters, but maintains the benefits of saturation by keeping the cells together on the outbound trip. Figure 49 (page 144) presents the penetration segment of one set of routes to targets which enters the defenses on one side and exits on the other. For systems

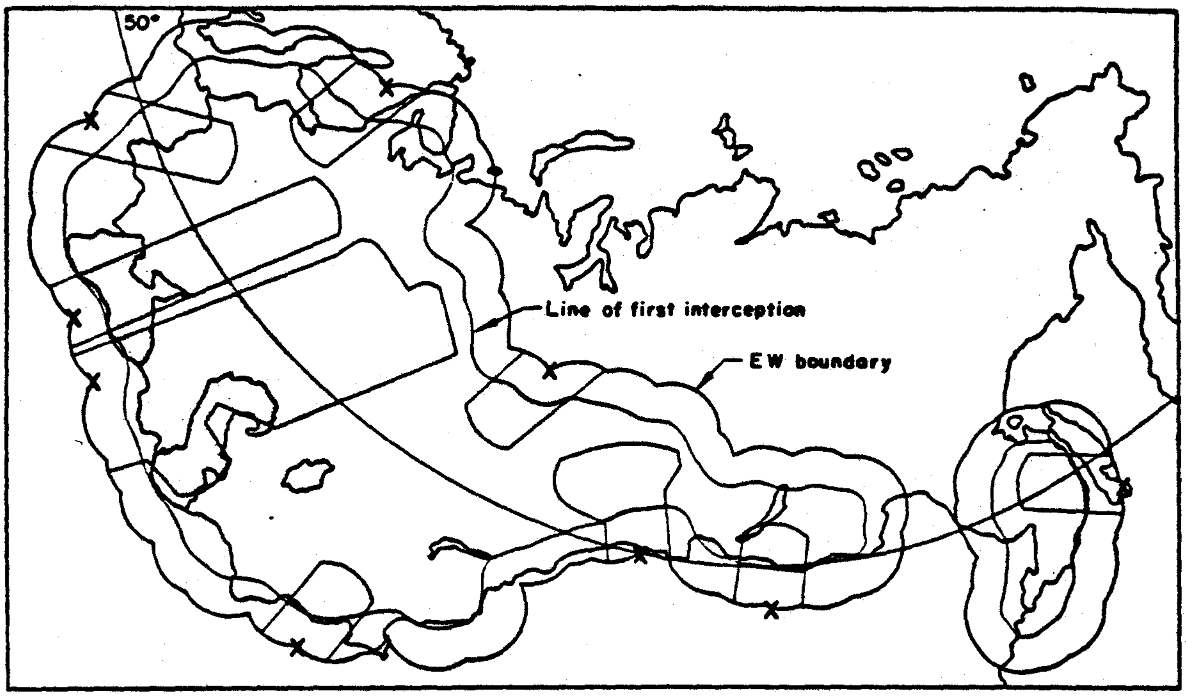

Fig. 48—Fighter areas swept out: minimum summer attrition routes for intercontinental ground-refueled strikes

which do not include bases around the periphery of Russia, the radius-extension costs of such routes are very large.

Bomber Losses for Alternative Routes: Defense Distribution I

If we take the enemy defense distribution and commitment policy which we have labeled Defense I and described in the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, large differences may be noted in the attrition suffered by use of alternative routes. Table 19 and Fig. 50 (page 145) present the area attrition for each of the routes described in a single strike against the 100-target points.

The absolute magnitude of bomber kills in each case depends on the level of fighter effectiveness assumed. The probability of interception and kill parameters used here assume no countermeasures. They are the high figures presented earlier in the section just referred to. The relative differences for the various routes are not affected by degradation of the probability of interception and kill parameters.

Several points may be observed from Table 19. First, attrition in the air-refueled case is very much higher when minimum-tanker routes are followed than it is when the minimum-penetration paths are followed: i.e., 46 per cent

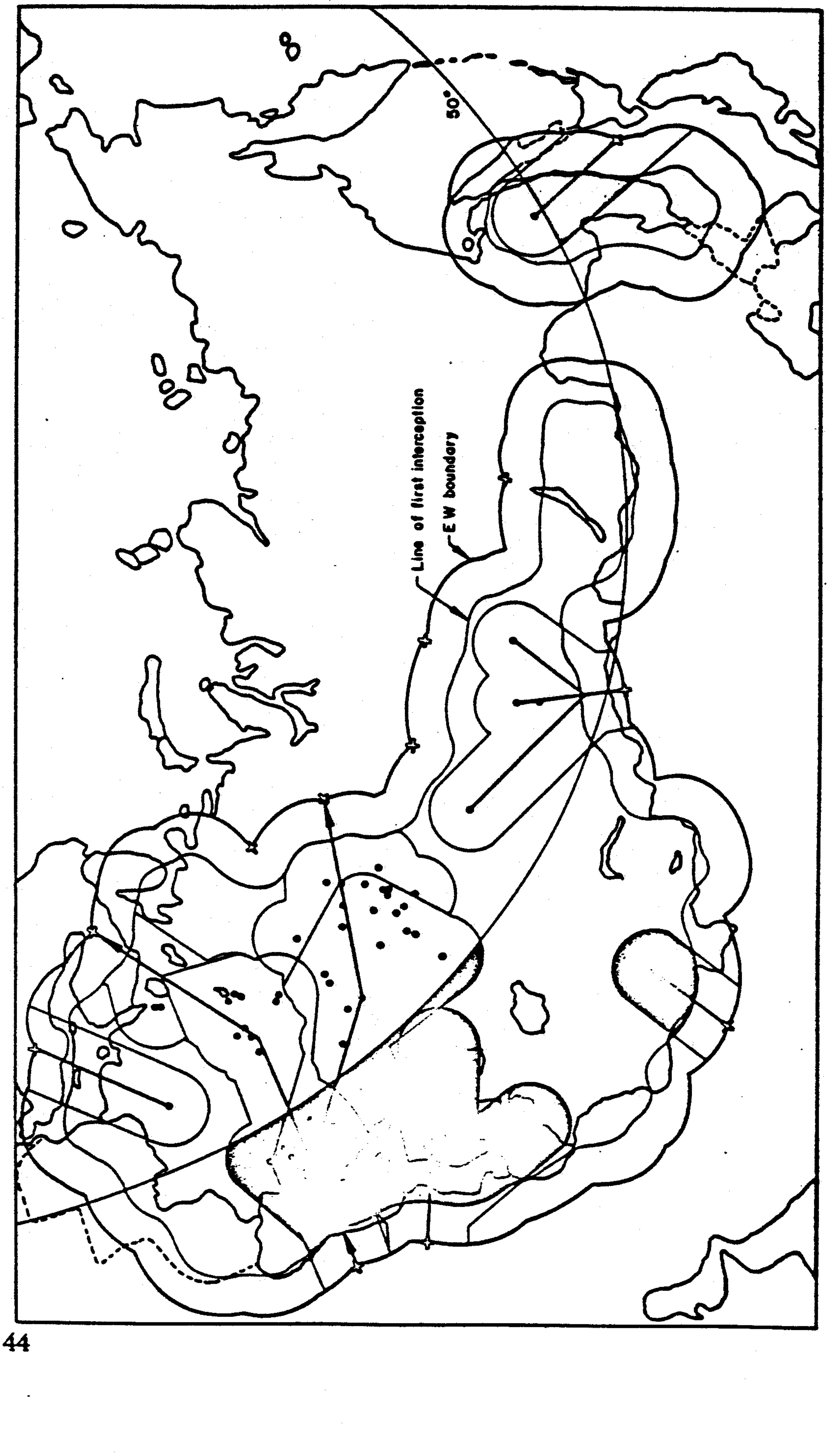

Fig. 49—Fighter areas swept out; shuttle routes

Table 19

SINGLE-STRIKE LOSSES TO AREA DEFENSES

(Simultaneous Entry into SU-defended Areas)

Quadrant[a]	Air-refueled System — Minimum-tanker Routes	Ground-refueled System — Minimum-tanker Routes	Air- and Ground-refueled Systems — Minimum-penetration Routes
NW	97	62	61
SW	4	6	4
NE	19	25	17
SE	0	3	0
TOTAL	120	96	82

[a] See p. 167*f* for a description of the quadrants.

higher. Second, for the ground-refueled system, the relatively direct routes minimizing tankers are also comparatively low-attrition routes, attrition being about 17 per cent higher than for the minimum-penetration routes. This is

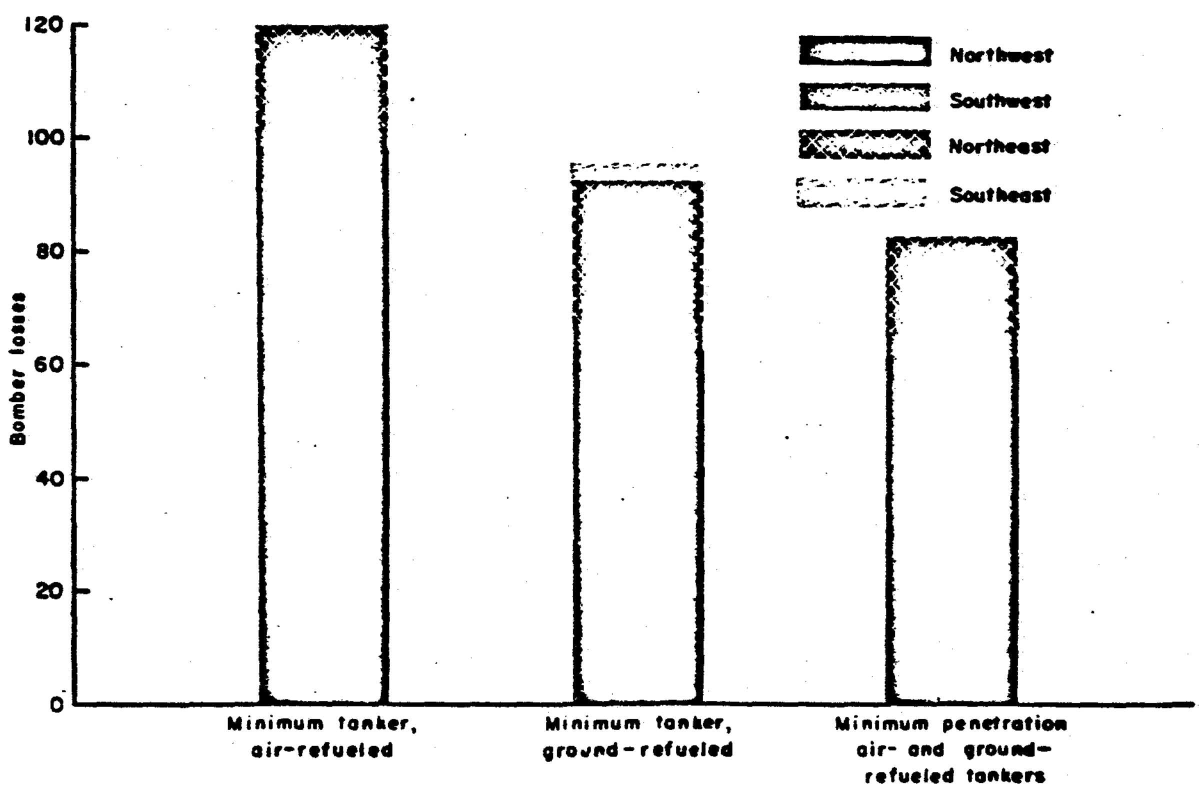

Fig. 50—Single-strike losses to area defenses

because routes minimizing tankers enter enemy territory largely from the south —some three-quarters of the individual paths, as compared with just one-third in the minimum-penetration cases. These southern routes benefit from darkness in a summer campaign. For the ground-refueled system, the minimum-tanker path is not very much inferior, as far as attrition is concerned, to the paths described above, which are designed to minimize attrition by taking maximum advantage of darkness. For some of the defense distributions and policies considered later, it in fact involves smaller losses than the minimum-penetration paths. For the air-refueled case, on the other hand, some 98 per cent of the minimum-tanker paths enter from the north. For this reason, among others, the air-refueled minimum-tanker paths are comparatively high-attrition paths.

Radius-extension Requirements for Alternative Routes

Measurements of distances along each element of the base-to-target paths, and tanker requirements and costs, were given for the minimum-tanker air-refueled and ground-refueled B-47 cases in Tables 4 and 5, pages 82–84, 86–88. Analogous measurements for minimum-penetration routes are given in Tables 20 (pages 148–150) and 21 (pages 152–154).* For the ground-refueled case or an overseas operating base system with similar locations, the tanker-bomber requirements to follow minimum-penetration routes with the B-47 amount to 0.15 B-36's and 0.2 KC-97's per B-47 in the operating force. This means a tanker cost of $3.1 million per operating bomber on a 3-year basis. For the air-refueled system, the tanker requirements for the minimum-penetration paths exceed by a very large amount its tanker requirements when following minimum-tanker paths. In the minimum-penetration case, 2.2 KB-36's and 0.55 KC-97's are needed, with a total radius-extension cost of $32.2 million per operating bomber on a 3-year basis. This is $7.6 million more per bomber than the unit radius-extension cost of the minimum-tanker path. In fact, some 6 per cent of the target system cannot be reached at all with the B-47 in an intercontinental air-refueled operation following minimum-penetration paths.† For the system having

* Here, as in the base target measurements presented earlier, air-refueling points are limited to identifiable regions no closer than 500 mi to enemy boundaries. The overseas bases are limited to areas included in the present Air Force program, but the precise locations of the programmed bases have been avoided to make the measurements generally usable without Top Secret clearance; further, no bases within 1000 n mi of enemy territory have been used for the purpose of determining tanker requirements.

† These have been treated as being reachable with the tanker-bomber requirements of the next most difficult targets to reach.

peripheral overseas bases (staging or operating), the differences both in attrition and in tanker cost are moderate. For the exclusively air-refueled system, the choice between minimum-penetration and minimum-tanker routes involves accepting a large increment either in radius-extension costs or in bomber losses.

The radius-extension costs involved in the other types of routes described above (routes taking maximum advantage of darkness and those going in on one side of the country and out on the other) have not been studied in the same detail as those for the minimum-penetration and minimum-tanker paths. It is clear, however, that an exclusively air-refueled intercontinental system will have a particular disadvantage in attempting to use such routes, for they involve a high proportion of entry and exit points from the south.

The intercontinental air-refueled system has a high average radius-extension cost on both the minimum-tanker and minimum-penetration paths; and there is a sizeable difference between the averages for each type of path. Also, there is a large dispersion about these averages in the radius-extension costs to reach individual targets. This is illustrated in Fig. 51 (below) and in Fig. 52 (page 151), which show, for the air-refueled system, the distribution of targets versus tanker costs per bomber for minimum-tanker and minimum-penetration paths.

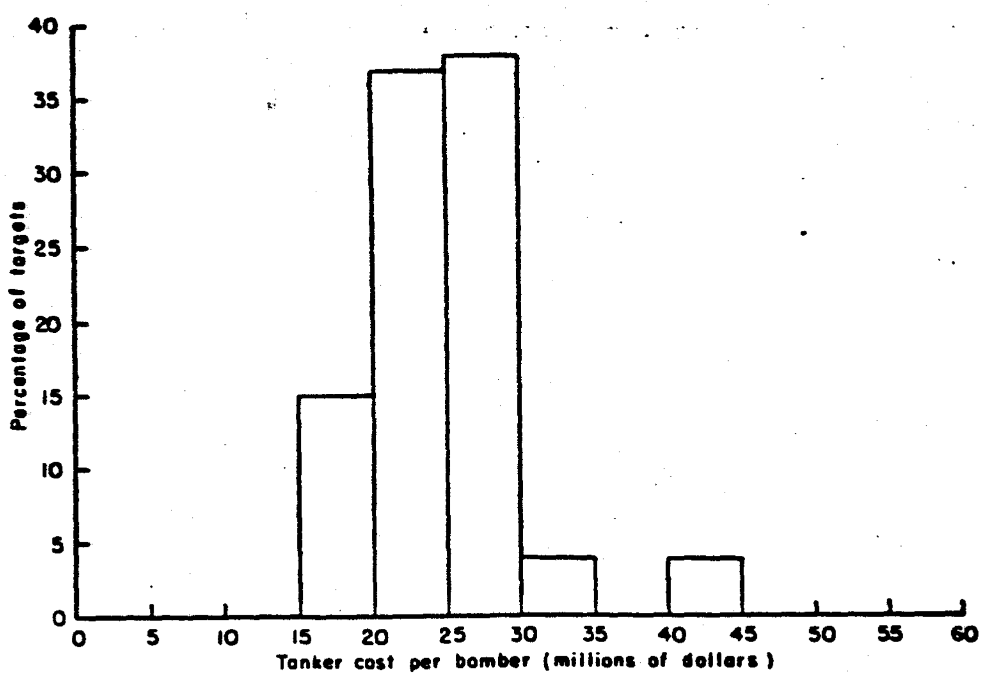

Fig. 51—Frequency distribution of targets by tanker cost: air-refueled minimum tanker

Table 20a

MINIMUM-PENETRATION PATHS FOR AIR-REFUELED B-47 AIRCRAFT

WAC No.*	RGZ's	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
159	1	Limestone	2800	80°N/38°E	1460	62°N/90°E	325	Krasnoyarsk	325	62°N/90°E	2300	74°N/22°W	2000	4605	...	2.5
161	2	Limestone	2800	80°N/38°E	1460	62°N/90°E	410	Kemerovo	410	62°N/90°E	2300	74°N/22°W	2000	4690	...	2.5
161	1	Limestone	2800	80°N/38°E	1460	62°N/90°E	480	Stalinsk	480	62°N/90°E	1700	78°N/15°E	2600	4760	...	3.0
163	2	Limestone	2800	80°N/38°E	1380	60°N/77°E	325	Omsk	325	60°N/77°E	2160	74°N/22°W	2000	4495	...	2.5
156	1	Limestone	1970	73°N/22°W	1840	63°N/65°E	325	Alapay	325	63°N/65°E	1860	74°N/22°W	2000	4160	...	1.5
156	2	Limestone	1970	73°N/22°W	1840	63°N/65°E	360	Nizhiniy Tagil	360	63°N/65°E	1275	78°N/15°E	2600	4200	...	2.0
156	2	Limestone	1970	73°N/22°W	1840	63°N/65°E	400	Sverdlovsk	400	63°N/65°E	1275	78°N/15°E	2600	4240	...	2.0
156	1	Limestone	1970	73°N/22°W	1840	63°N/65°E	415	Polevskoy	415	63°N/65°E	1275	78°N/15°E	2600	4255	...	2.0
156	1	Limestone	1970	73°N/22°W	1840	63°N/65°E	425	Severskiy	425	63°N/65°E	1275	78°N/15°E	2600	4265	...	2.0
156	1	Limestone	1970	73°N/22°W	1840	63°N/65°E	460	Sarana	460	63°N/65°E	1275	78°N/15°E	2600	4300	...	2.0
164	2	Limestone	1970	73°N/22°W	1840	63°N/65°E	490	Chelyabinsk	490	63°N/65°E	1275	78°N/15°E	2600	4330	...	2.0
164	2	Limestone	1970	73°N/22°W	1840	63°N/65°E	510	Zlatoust	510	63°N/65°E	1275	78°N/15°E	2600	4350	...	2.0
164	1	Limestone	1970	73°N/22°W	1840	63°N/65°E	510	Miass	510	63°N/65°E	1275	78°N/15°E	2600	4350	...	2.0
164	1	Limestone	1970	73°N/22°W	1840	63°N/65°E	580	Beloretsk	580	63°N/65°E	1275	78°N/15°E	2600	4420	...	2.0
165	3	Limestone	1970	73°N/22°W	1840	63°N/65°E	580	Ufa	580	63°N/65°E	1275	78°N/15°E	2600	4420	...	2.0
164	2	Limestone	1970	73°N/22°W	1840	63°N/65°E	620	Magnitogorsk	620	63°N/65°E	1275	78°N/15°E	2600	4460	...	2.0
236	3	Limestone	2800	80°N/38°E	1100	63°N/65°E	740	Orsk	740	63°N/65°E	1860	74°N/22°W	2000	4620	...	2.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	300	Berezniki	300	64°N/53°E	1650	74°N/22°W	2000	3950	...	1.5
156	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	360	Gubakha	360	64°N/53°E	1650	74°N/22°W	2000	4010	...	1.5
155	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	380	Kirov	380	64°N/53°E	1650	74°N/22°W	2000	4030	...	1.5
156	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	400	Molotov	400	64°N/53°E	1650	74°N/22°W	2000	4050	...	1.5
155	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	450	Votkinsk	450	64°N/53°E	1650	74°N/22°W	2000	4100	...	1.5
165	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	560	Kazan	560	64°N/53°E	1080	78°N/15°E	2600	4225	...	2.0
154	3	Limestone	1970	73°N/22°W	1680	64°N/53°E	580	Gorkiy	580	64°N/53°E	1080	78°N/15°E	2600	4245	...	2.0
165	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	590	Ulyanovsk	590	64°N/53°E	1080	78°N/15°E	2600	4255	...	2.0
154	2	Limestone	1970	73°N/22°W	1680	64°N/53°E	600	Dzerzhinsk	600	64°N/53°E	1080	78°N/15°E	2600	4265	...	2.0
165	2	Lim-stone	1970	73°N/22°W	1680	64°N/53°E	690	Kuybyshev	690	64°N/53°E	1080	78°N/15°E	2600	4335	...	2.0
165	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	700	Syzran	700	64°N/53°E	1080	78°N/15°E	2600	4365	...	2.0
235	1	Limestone	1970	73°N/22°W	1680	64°N/53°E	820	Saratov	820	64°N/53°E	1080	78°N/15°E	2600	4485	...	2.0
155	3	Limestone	1470	66°N/37°W	1620	66°N/26°E	370	Leningrad	370	66°N/26°E	1990	66°N/46°W	1100	3460	2.5	...
155	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	380	Kolpino	380	66°N/26°E	1990	66°N/46°W	1100	3470	2.5	...
154	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	370	Shcherbakov	370	66°N/26°E	1470	68°N/32°W	1620	3660	3.0	...

154	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	580	Konstant-inovskiy	580	66°N/26°E	1470	68°N/32°W	1620	3670	3.0	...
154	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	605	Yaroslavl	605	66°N/26°E	1470	68°N/32°W	1620	3695	3.0	...
167	6	Limestone	1470	66°N/37°W	1620	66°N/26°E	675	Moscow	675	66°N/26°E	1470	68°N/32°W	1620	3765	3.0	...
167	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	680	Noginsk	680	66°N/26°E	1470	68°N/32°W	1620	3770	3.0	...
167	2	Limestone	1470	66°N/37°W	1620	66°N/26°E	715	Kolomna	715	66°N/26°E	1010	65°N/10°W	2080	3805	4.0	...
167	1	Limestone	1470	66°N/37°W	1620	66°N/26°E	775	Stalinogorsk	775	66°N/26°E	1010	65°N/10°W	2080	3865	4.0	...
168	1	Limestone	1470	66°N/37°W	1480	59°N/14°E	560	Minsk	560	59°N/14°E	1850	66°N/46°W	1100	3510	2.5	...
249	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	375	Krasnodar	375	39°N/35°E	1650	48°N/3°W	2600	4650	...	3.0
249	2	Limestone	2800	44°N/1°E	1500	39°N/35°E	475	Zhdanov	475	39°N/35°E	1650	48°N/3°W	2600	4750	...	3.0
249	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	485	Zaporozhye	485	39°N/35°E	1650	48°N/3°W	2600	4760	...	3.0
249	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	500	Taganrog	500	39°N/35°E	1650	48°N/3°W	2600	4775	...	3.0
250	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	525	Krivoy Rog	525	39°N/35°E	1650	48°N/3°W	2600	4800	...	3.0
234	2	Limestone	2800	44°N/1°E	1500	39°N/35°E	525	Dnprod-zershinsk	525	39°N/35°E	1650	48°N/3°W	2600	4800	...	3.0
234	3	Limestone	2800	44°N/1°E	1500	39°N/35°E	525	Dneprop-etrovsk	525	39°N/35°E	1650	48°N/3°W	2600	4800	...	3.0
249	2	Limestone	2800	44°N/1°E	1500	39°N/35°E	530	Stalino	530	39°N/35°E	1650	48°N/3°W	2600	4805	...	3.0
234	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	530	Makeyevka	530	39°N/35°E	1650	48°N/3°W	2600	4805	...	3.0
325	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	540	Dzaudzhikau	540	39°N/35°E	1650	48°N/3°W	2600	4815	...	3.0
234	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	550	Konstant-inovka	550	39°N/35°E	1650	48°N/3°W	2600	4825	...	3.0
234	2	Limestone	2800	44°N/1°E	1500	39°N/35°E	560	Gorlovka	560	39°N/35°E	1650	48°N/3°W	2600	4835	...	3.0
234	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	570	Kramatorsk	570	39°N/35°E	1650	48°N/3°W	2600	4845	...	3.0
249	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	570	Krasnyy Sulin	570	39°N/35°E	1650	48°N/3°W	2600	4845	...	3.0
156	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	580	Kamensk	580	39°N/35°E	1650	48°N/3°W	2600	4855	...	3.0
234	1	Limestone	2800	44°N/1°E	1500	39°N/35°E	600	Lisichansk	600	39°N/35°E	1650	48°N/3°W	2600	4875	...	3.0
324	1	Limestone	2800	44°N/1°E	1900	38°N/40°E	230	Batumi	230	38°N/40°E	1700	40°N/5°E	3100	4980	...	4.0
325	1	Limestone	2800	44°N/1°E	1900	38°N/40°E	280	Rustavi	280	38°N/40°E	1700	40°N/5°E	3100	5030	...	4.0
325	1	Limestone	2800	44°N/1°E	1900	38°N/40°E	370	Groznyy	370	38°N/40°E	1700	40°N/5°E	3100	5120	...	4.0
325	1	Limestone	3100	40°N/5°E	1700	38°N/40°E	425	Makhachkala	425	38°N/40°E	1700	40°N/5°E	3100	5225	...	5.0
325	3	Limestone	3100	40°N/5°E	1700	38°N/40°E	440	Baku	440	38°N/40°E	1700	40°N/5°E	3100	5240	...	5.0
204	2	Spokane	1970	58°N/172°W	1880	44°N/139°E	420	Komsomolsk	420	40°N/139°E	1250	55°N/172°E	2600	4260	...	2.0
166								Petrovsk[b]								
247								Guryev[b]								
235								Stalingrad[b]								
326								Krasnovodsk[b]								
328								Begovat[b]								

[a] World Aeronautical Charts, ***Bombing Encyclopedia Manual and Code Book***, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.
[b] Target cannot be reached.

Table 20b

SUMMARY OF MINIMUM-PENETRATION PATHS FOR AIR-REFUELED B-47 AIRCRAFT[a]

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
					Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
62°N/90°E	1800	6.50	4260	9.88	480	406	325	1.11	0.94	0.75	4740	4666	4585	11.00	10.83	10.64
60°N/77°E	2800	6.50	4180	9.70	325	325	325	0.75	0.75	0.75	4505	4505	4505	10.45	10.45	10.45
63°N/65°E	2083	4.83	3822	8.87	740	520	325	1.72	1.21	0.75	4562	4342	4147	10.58	10.07	9.62
64°N/53°E	1970	4.57	3650	8.47	820	546	300	1.90	1.27	0.70	4470	4196	3950	10.37	9.73	9.16
66°N/26°E	1470	3.41	3090	7.17	775	599	370	1.80	1.39	0.86	3865	3689	3460	8.97	8.56	8.03
59°N/14°E	1470	3.41	2950	6.84	560	560	560	1.30	1.30	1.30	3510	3510	3510	8.14	8.14	8.14
39°N/35°E	2800	6.50	4300	9.98	600	526	375	1.39	1.22	0.87	4900	4826	4675	11.37	11.20	10.85
38°N/40°E	2971	6.89	4757	11.04	440	375	230	1.02	0.87	0.53	5197	5132	4987	12.06	11.91	11.57
44°N/139°E	1970	4.57	3850	8.93	420	420	420	0.97	0.97	0.97	4270	4270	4270	9.91	9.91	9.91

[a]These averages would, in some cases, be increased if we included the five targets, Petrovsk, Guryev, Stalingrad, Krasnovodsk, and Begovat, which cannot be reached at all, and if we measured from the actual multiplicity of ZI-base locations instead of from the two points of Limestone and Spokane.

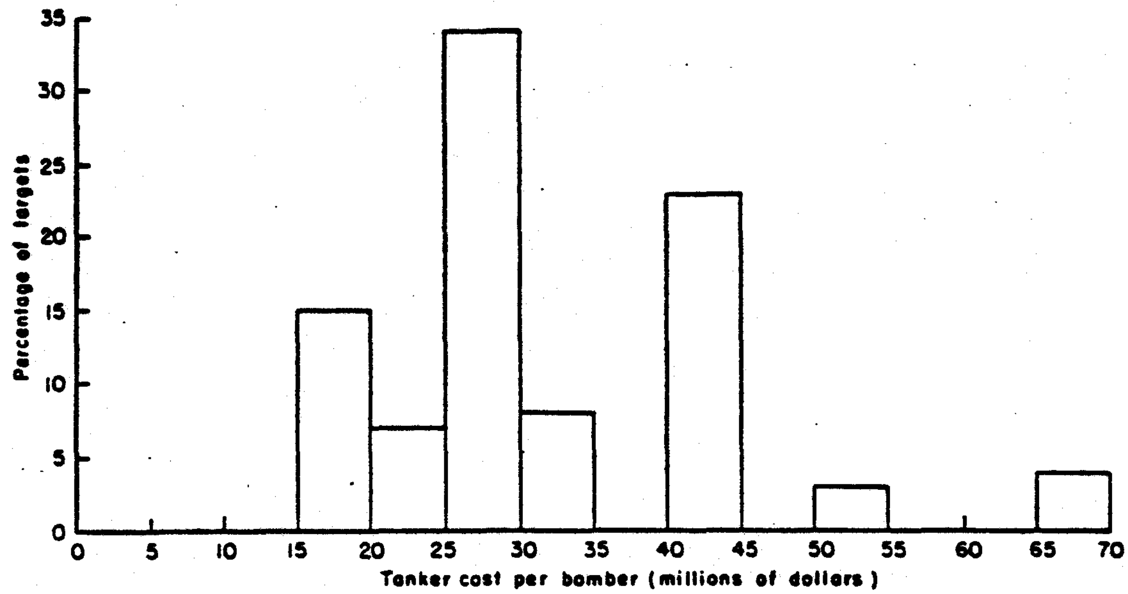

Fig. 52—Frequency distribution of targets by tanker cost: air-refueled minimum penetration

Flexibility in the Small and in the Large

It is a familiar fact that air-refueling provides a considerable amount of flexibility in the choice of routes and places to refuel. This is clearly the case in the sense that the specific refueling location does not involve a large fixed installation. And, within any given region, the number of spots at which it is possible to rendezvous with a tanker far exceeds in general the number of ground bases. This flexibility of choice within any given region might be designated "a flexibility in the small." However, this useful flexibility in the small, the foregoing measurements suggest, accompanies a distinct inflexibility in the large. This is to say that, for an air-refueled intercontinental operation based in the North American continent, the broad choice between refueling points in the north or in the south, for example, is far from being a matter of indifference as far as refueling requirements are concerned. There are large differences in radius-extension costs. A fixed force of tankers will support smaller strikes when the strike pattern involves coming up from the south. Such a system is very unequally effective along varied routes. It is also very unequally effective against various individual target points inside Russia.

CHOICE OF ALTITUDE AND SPEED OF PENETRATION

Flexibility in the choice of routes is related to a corresponding freedom in selecting the speed and profile of penetration. A bomber with fixed perform-

Table 21a

MINIMUM-PENETRATION PATHS FOR GROUND-REFUELED B-47 AIRCRAFT

WAC No.*	RGZs	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
159	1	Limestone	1800	77°N/67°W	2550	62°N/90°E	325	Krasnoyarsk	325	62°N/90°E	2550	77°N/67°W	1800	4675	0.5+	0.5
161	2	Limestone	1800	77°N/67°W	2550	62°N/90°E	410	Kemerovo	410	62°N/90°E	2550	77°N/67°W	1800	4760	0.5+	0.5
161	1	Limestone	1800	77°N/67°W	2550	62°N/90°E	480	Stalinsk	480	62°N/90°E	2550	77°N/67°W	1800	4830	0.5+	0.5
163	2	Limestone	1800	77°N/67°W	2600	60°N/77°E	325	Omsk	325	60°N/77°E	2600	77°N/67°W	1800	4725	0.5+	0.5
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	325	Alapayevsk	325	63°N/65°E	2100	64°N/19°W	2000	4425	...	0.5
156	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	360	Nizhiniy Tagil	360	63°N/65°E	2100	64°N/19°W	2000	4460	...	0.5
156	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	400	Sverdlovsk	400	63°N/65°E	2100	64°N/19°W	2000	4500	...	0.5
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	415	Polevskoy	415	63°N/65°E	2100	64°N/19°W	2000	4515	...	0.5
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	425	Severskiy	425	63°N/65°E	2100	64°N/19°W	2000	4525	...	0.5
156	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	460	Sarana	460	63°N/65°E	2100	64°N/19°W	2000	4560	...	0.5
164	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	490	Chelyabinsk	490	63°N/65°E	2100	64°N/19°W	2000	4590	...	0.5
164	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	510	Zlatoust	510	63°N/65°E	2100	64°N/19°W	2000	4610	...	0.5
164	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	510	Miass	510	63°N/65°E	2100	64°N/19°W	2000	4610	...	0.5
164	1	Limestone	2000	64°N/19°W	2100	63°N/65°E	580	Beloretsk	580	63°N/65°E	2100	64°N/19°W	2000	4680	...	0.5
165	3	Limestone	2000	64°N/19°W	2100	63°N/65°E	580	Ufa	580	63°N/65°E	2100	64°N/19°W	2000	4680	...	0.5
164	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	620	Magnitogorsk	620	63°N/65°E	2100	64°N/19°W	2000	4720	0.5+	0.5
236	3	Limestone	2000	64°N/19°W	2100	63°N/65°E	740	Orsk	740	63°N/65°E	2100	64°N/19°W	2000	4840	0.5+	0.5
156	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	300	Berezniki	300	64°N/53°E	1900	64°N/19°W	2000	4200	0.5	...
156	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	360	Gubakha	360	64°N/53°E	1900	64°N/19°W	2000	4260	0.5	...
155	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	380	Kirov	380	64°N/53°E	1900	64°N/19°W	2000	4280	0.5	...
156	2	Limestone	2000	64°N/19°W	1900	64°N/53°E	400	Molotov	400	64°N/53°E	1900	64°N/19°W	2000	4300	0.5	...
155	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	450	Votkinsk	450	64°N/53°E	1900	64°N/19°W	2000	4350	...	0.5
165	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	560	Kazan	560	64°N/53°E	1900	64°N/19°W	2000	4460	...	0.5
154	3	Limestone	2000	64°N/19°W	1900	64°N/53°E	580	Gorkiy	580	64°N/53°E	1900	64°N/19°W	2000	4480	...	0.5
165	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	590	Ulyanovsk	590	64°N/53°E	1900	64°N/19°W	2000	4490	...	0.5
154	2	Limestone	2000	64°N/19°W	1900	64°N/53°E	600	Dzerzhinsk	600	64°N/53°E	1900	64°N/19°W	2000	4500	...	0.5
165	2	Limestone	2000	64°N/19°W	1900	64°N/53°E	690	Kuybyshev	690	64°N/53°E	1900	64°N/19°W	2000	4590	0.5+	0.5
165	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	700	Syzran	700	64°N/53°E	1900	64°N/19°W	2000	4600	0.5+	0.5
235	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	820	Saratov	820	64°N/53°E	1900	64°N/19°W	2000	4720	0.5+	0.5
155	3	Limestone	2650	55°N/2°W	1150	66°N/26°E	370	Leningrad	370	66°N/26°E	1150	55°N/2°W	2650	4170	...	...
155	1	Limestone	2650	55°N/2°W	1150	66°N/26°E	380	Kolpino	380	66°N/26°E	1150	55°N/2°W	2650	4180	...	...
154	1	Limestone	2650	55°N/2°W	1150	66°N/26°E	370	Shcherbakov	370	66°N/26°E	1150	55°N/2°W	2650	4370	...	...

154	1	Limestone	2650	53°N/2°W	1150	66°N/26°E	580	Konstant-inovskiy	580	66°N/26°E	1150	53°N/2°W	2650	4380	...	...
154	1	Limestone	2650	53°N/2°W	1150	66°N/26°E	605	Yaroslavl	605	66°N/26°E	1150	53°N/2°W	2650	4405	...	...
167	6	Limestone	2650	53°N/2°W	1150	66°N/26°E	675	Moscow	675	66°N/26°E	1150	53°N/2°W	2650	4475	0.5	...
167	1	Limestone	2650	53°N/2°W	1150	66°N/26°E	680	Noginsk	680	66°N/26°E	1150	53°N/2°W	2650	4480	0.5	...
167	2	Limestone	2000	64°N/19°W	1100	66°N/26°E	715	Kolomna	715	66°N/26°E	1100	64°N/19°W	2000	3815	0.5	...
167	1	Limestone	2000	64°N/19°W	1100	66°N/26°E	775	Stalinogorsk	775	66°N/26°E	1100	64°N/19°W	2000	3875	0.5	...
168	1	Limestone	2650	53°N/2°W	640	59°N/14°E	560	Minsk	560	59°N/14°E	640	53°N/2°W	2650	3850	...	...
249	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	375	Krasnodar	375	39°N/35°E	1070	33°N/13°E	3660	5105	...	...
249	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	475	Zhdanov	475	39°N/35°E	1070	33°N/13°E	3660	5205	...	...
249	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	485	Zaporozhye	485	39°N/35°E	1070	33°N/13°E	3660	5215	...	...
249	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	500	Taganrog	500	39°N/35°E	1070	33°N/13°E	3660	5230	...	...
250	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	525	Krivoy Rog	525	39°N/35°E	1070	33°N/13°E	3660	5255	...	...
234	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	525	Dnprod-zershinsk	525	39°N/35°E	1070	33°N/13°E	3660	5255	...	...
234	3	Limestone	3660	33°N/13°E	1070	39°N/35°E	525	Dneprop-etrovsk	525	39°N/35°E	1070	33°N/13°E	3660	5255	...	...
249	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	530	Stalino	530	39°N/35°E	1070	33°N/13°E	3660	5260	...	...
234	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	530	Makeyevka	530	39°N/35°E	1070	33°N/13°E	3660	5260	...	...
325	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	540	Dzaudzhikau	540	39°N/35°E	1070	33°N/13°E	3660	5270	...	...
234	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	550	Konstan-tinovka	550	39°N/35°E	1070	33°N/13°E	3660	5280	...	...
234	2	Limestone	3660	33°N/13°E	1070	39°N/35°E	560	Gorlovka	560	39°N/35°E	1070	33°N/13°E	3660	5290	...	...
234	1	Limestone	3660	33°N/13°E	1070	39°N/35°E	570	Kramatorsk	570	39°N/35°E	1070	33°N/13°E	3660	5300	...	...
249	1	Limestone	4520	30°N/32°E	630	39°N/35°E	570	Krasnyy Sulin	570	39°N/35°E	630	30°N/32°E	4520	5720	...	...
136	1	Limestone	4520	30°N/32°E	630	39°N/35°E	580	Kamensk	580	39°N/35°E	630	30°N/32°E	4520	5730	...	...
234	1	Limestone	4520	30°N/32°E	630	39°N/35°E	600	Lisichansk	600	39°N/35°E	630	30°N/32°E	4520	5750	...	...
324	1	Limestone	4520	30°N/32°E	740	38°N/40°E	230	Batumi	230	38°N/40°E	740	30°N/32°E	4520	5490	...	...
325	1	Limestone	4520	30°N/32°E	740	38°N/40°E	280	Rustavi	280	38°N/40°E	740	30°N/32°E	4520	5540	...	...
325	1	Limestone	4520	30°N/32°E	740	38°N/40°E	370	Groznyy	370	38°N/40°E	740	30°N/32°E	4520	5630	...	...
325	1	Limestone	4520	30°N/32°E	740	38°N/40°E	425	Makhachkala	425	38°N/40°E	740	30°N/32°E	4520	5685	...	...
325	3	Limestone	4520	30°N/32°E	740	38°N/40°E	440	Baku	440	38°N/40°E	740	30°N/32°E	4520	5700	...	...
247	1	Limestone	4520	30°N/32°E	740	38°N/40°E	750	Guryev	750	38°N/40°E	740	30°N/32°E	4520	6010	...	...
235	2	Limestone	4520	30°N/32°E	740	38°N/40°E	650	Stalingrad	650	38°N/40°E	740	30°N/32°E	4520	5910	...	...
326	1	Limestone	4520	30°N/32°E	740	38°N/40°E	600	Krasnovodsk	600	38°N/40°E	740	30°N/32°E	4520	5860	...	...
328	1	Limestone	5420	26°N/50°E	1000	34°N/68°E	340	Begovat	340	34°N/68°E	1000	26°N/50°E	5420	6760	...	...
166	1	Spokane	4240	36°N/140°E	1490	47°N/113°E	340	Petrovsk	340	47°N/113°E	1490	36°N/140°E	4240	6070	...	...
204	2	Spokane	4240	36°N/140°E	575	44°N/139°E	420	Komsomolsk	420	44°N/139°E	575	36°N/140°E	4240	5235	...	...

*World Aeronautical Charts, *Bombing Encyclopedia Manual and Code Book*, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.

same as earlier case

/ (x) /

Table 21b

SUMMARY OF MINIMUM-PENETRATION PATHS FOR GROUND-REFUELED B-47 AIRCRAFT

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
					Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
62°N/90°E	1800	4.18	4350	10.09	480	406	325	1.13	0.94	0.75	4830	4756	4675	11.21	11.03	10.85
60°N/77°E	1800	4.18	4400	10.21	325	325	325	0.75	0.75	0.75	4725	4725	4725	10.96	10.96	10.96
63°N/65°E	2000	4.64	4100	9.51	740	520	325	1.72	1.21	0.75	4840	4620	4425	11.23	10.72	10.27
64°N/53°E	2000	4.64	3900	9.05	820	546	300	1.90	1.27	0.70	4720	4446	4200	10.95	10.31	9.74
66°N/26°E	2535	5.88	3676	8.53	775	599	370	1.80	1.39	0.86	4451	4275	4046	10.33	9.92	9.39
59°N/14°E	2650	6.15	3290	7.63	560	560	560	1.30	1.30	1.30	3850	3850	3850	8.93	8.93	8.93
39°N/35°E	3777	8.76	4787	11.11	600	526	375	1.32	1.22	0.87	5387	5313	5162	12.50	12.33	11.98
38°N/40°E	4520	10.49	5260	12.20	750	480	230	1.74	1.11	0.53	6010	5740	5490	13.94	13.32	12.74
34°N/68°E	5420	12.57	6420	14.89	340	340	340	0.79	0.79	0.79	6760	6760	6760	15.68	15.68	15.68
47°N/113°E	4240	9.84	5730	13.29	340	340	340	0.79	0.79	0.79	6070	6070	6070	14.08	14.08	14.08
44°N/139°E	4240	9.84	4815	11.17	420	420	420	0.97	0.97	0.97	5235	5235	5235	12.15	12.15	12.15

ance characteristics can trade some of its unrefueled radius for extra speed and extra altitude, and this choice presents itself in the selection of the last locations for refueling before entering enemy defenses and of the first refueling locations on the way home. By using refueling points near enemy boundaries, the bombers can fly greater distances at high speeds or at very high or very low altitudes. And a refueling location near minimum-penetration paths permits a large fraction of the total penetration to be traveled at high performance. Since the rate of exchange between the high-performance and the low-performance radius may be three or four to one, this is a critical matter for the bombing systems of the future, designed for supersonic or low-altitude use. But it is also significant for the possible low-altitude use of bombers of the current generation. And in the case of the heavy bombers of the current generation, it appears to be fruitful for the exploitation of their advantages at very high altitudes. The speed margin of the MiG's versus the B-47 or the B-52 makes a trade of radius for speed less than critical, but trading radius for altitude does appear quite important.

In fact, SAC assigns a good deal of value to the use of poststrike staging to optimize on the profile and penetration paths of such bombers as the B-52. The B-52 has a considerable amount of radius and fuel weight to trade. Picking up fuel near enemy territory on the way home permits it to fly at lighter weight over enemy territory. This reduces the probability of interception by enabling high-altitude flight, and it reduces the physical vulnerability because of smaller fuel volume and possibly diminished probability of fuel fires at high altitudes. The exact form of this diminution in the probability of interception and kill depends on the performance characteristics of the MiG's and the mixture of the various models in the total Russian interceptor force. The RD-45-powered MiG-15 cannot fight effectively above about 44,000 ft. We have assumed that a very limited number of these are included in the force which is composed half of MiG-15's of the VK-1 type and the rest of Type 38 day fighters. Above an altitude of about 49,000 ft, it is estimated, only Type 38 day fighters will be able to reach the B-52. For all fighters, the lateral distance from the bomber track from which they can reach the bomber diminishes with altitude, as do the probabilities of detection. The point of earliest interception is farther back. Gross errors of the fighters are more likely, and so on. We have not attempted to trace these effects target by target for each bomber-base combination, following the various alternative routes. However, we can illustrate their importance in a comparison of air-refueled and ground-refueled B-52 systems.

Take as an example a single mission starting at Limestone, which includes a 700-n-mi penetration to Moscow. The mission is accomplished in one case by means of prestrike air-refueling, and in the other, by using a poststrike staging base in the United Kingdom. At about 660 n mi out from Limestone, the prestrike air-refueled B-52 takes on enough fuel to get it to target and back to Limestone. The entry, target, and exit altitudes and the gross weights are respectively 41,000 ft, 42,500 ft, and 44,000 ft; and 307,000 lb, 283,000 lb, and 256,000 lb. The corresponding altitudes for the poststrike ground-refueled B-52 are about 6000 ft higher, and the weights, about 57,000 lb lower. These profiles are presented in Fig. 53; and the relative attrition per mile of penetration versus altitude is estimated in Fig. 54.* If all fighters in the Russian interceptor force are Type 38 day fighters, attrition for the prestrike air-refueled B-52 will double that of the poststrike ground-refueled B-52. If only half have this performance, and the other half are the VK-1 type, the relative differences are increased: the losses for the prestrike air-refueled case will be three times as great as for the poststrike ground-refueled system.

Target distances and tanker requirements for the B-52 air-refueled and ground-refueled system following minimum-penetration paths are shown in Tables 22 (pages 160–162) and 23 (pages 164–166).

The results of a B-52 campaign, in which flight profile differences are included in estimation of attrition from the 50 per cent MiG-15, 50 per cent Type 28 Soviet fighter defense of Fig. 54, are presented in Table 24 (page 167). Consideration of poststrike refueling near enemy territory increases the difference between the air- and ground-refueled case by 40 per cent.

Estimates of probability of interception and kill as a function of altitude have large areas of uncertainty. However, it is evident that a flexibility in the choice of routes and fueling points, which brings with it a wide choice of flight profiles, will be a significant asset for the prospective employment of such carriers as the B-52.

In the various campaigns comparing overseas operating or staging base systems with an exclusively air-refueled system, we have treated all systems as if they had equal flexibility in choice of flight profile. The actual inflexibility of the air-refueled system worsens its performance by comparison with the peripheral base system.

*These attrition estimates as a function of altitude were made by George Gompf, of the RAND Aircraft Division.

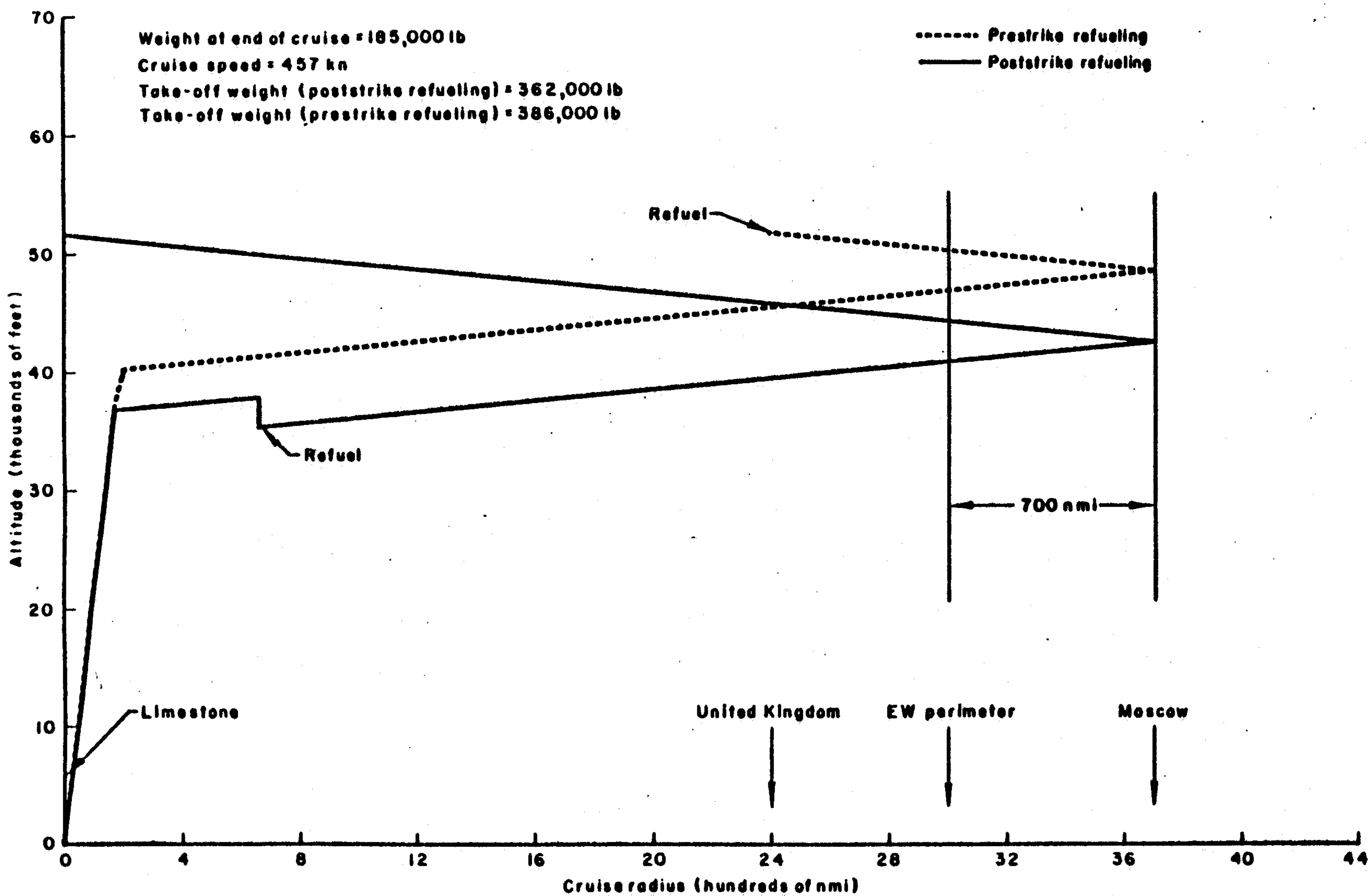

Fig. 53—B-52 flight profile: mission from Limestone to Moscow (prestrike vs poststrike refueling)

/ 1 2

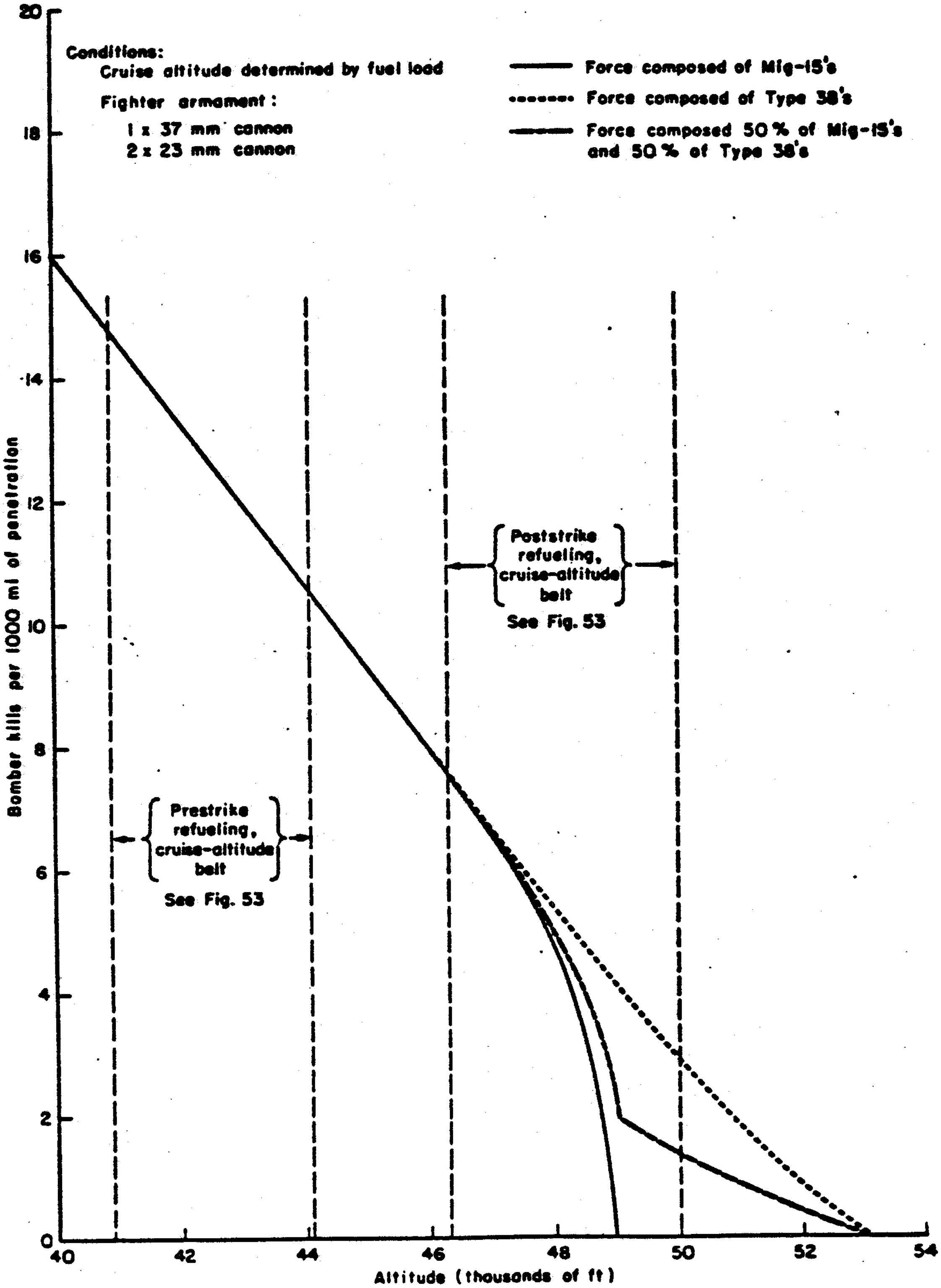

Fig. 54—Bomber kills per 1000 mi of penetration vs B-52 flight altitude

ENEMY CHOICE OF DEFENSE DEPLOYMENT AND COMMITMENT

The enemy can better the deployment and commitment tactics we have assumed so far. As for deployment, one well-established principle suggests concentrating in regions having a predominant number and value of targets; and another guiding principle, less familiar, suggests redistribution of defense in recognition of inequalities in the offense's radius capability. With such reorientation and with a better commitment policy, Russian defenses can exact a higher attrition from all the base-bomber systems we have examined. However, they can gain particular advantage against the exclusively air-refueled system because of its comparative inflexibility.

Fighter Deployment

Limitations in Allocating Area Defense to Targets. In deploying fighters for the protection of various segments of his industry, the enemy must work within many constraints. He is limited in the number and performance characteristics of his fighters, and in the number of airborne and ground radars available. For 1956 and thereabouts, not the least of these limitations, according to RAND's estimate, will lie in the number and quality of the airborne radars available. Limitations of this sort reduce his ability to defend all targets in the winter, and to defend South Russian targets or South Russian routes to all targets in the summer. Resource constraints can be expected to force some lopsidedness in defense of his target system.

Even operating within such resource constraints, there are limits to the precision with which it is possible to allocate area defense to targets. So long as there are targets of widely differing value within radius of the same fighter base, the less valuable targets come in under the umbrella spread for the more valuable targets. They receive some defense as a by-product of the protection given the more valuable targets. And if these latter are adequately defended, the former are overdefended.

In a similar way, the fighter defense of the shallow targets near the periphery automatically provides some defense for the targets deeper in. Since bomber penetrations must start at the periphery, then if fighter coverage is spread uniformly over a large area, as in Defense Distribution I, even assuming that the targets are all of equal value, the deep interior targets are very greatly overdefended. This overdefense is emphasized by the increase, referred to earlier,

Table 22a

MINIMUM-PENETRATION PATHS FOR AIR-REFUELED B-52 AIRCRAFT

WAC No.*	RGZ's	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
166	1	Spokane	450	55°N/123°W	3600	57°N/111°E	340	Petrovsk	340	57°N/111°E	3500	56°N/127°W	550	4430	2.5	...
159	1	Limestone	450	54°N/64°W	3800	62°N/90°E	325	Krasnoyarsk	325	62°N/90°E	3070	66°N/53°W	1180	4575	3.0	...
161	2	Limestone	450	54°N/64°W	3800	62°N/90°E	410	Kemerovo	410	62°N/90°E	3070	66°N/53°W	1180	4660	3.0	...
161	1	Limestone	450	54°N/64°W	3800	62°N/90°E	480	Stalinsk	480	62°N/90°E	3070	66°N/53°W	1180	4730	3.0	...
163	2	Limestone	450	54°N/64°W	3800	60°N/77°E	325	Omsk	325	60°N/77°E	3070	66°N/53°W	1180	4575	3.0	...
156	1	Limestone	450	54°N/63°W	3420	63°N/65°E	325	Alapayevsk	325	63°N/65°E	3320	55°N/62°W	550	4195	2.5	...
156	2	Limestone	450	54°N/63°W	3420	63°N/65°E	360	Nizhiniy Tagil	360	63°N/65°E	3320	55°N/62°W	550	4230	2.5	...
156	2	Limestone	450	54°N/63°W	3420	63°N/65°E	400	Sverdlovsk	400	63°N/65°E	3320	55°N/62°W	550	4270	2.5	...
156	1	Limestone	450	54°N/63°W	3420	63°N/65°E	415	Polevskoy	415	63°N/65°E	3320	55°N/62°W	550	4285	2.5	...
156	1	Limestone	450	54°N/63°W	3420	63°N/65°E	425	Severskiy	425	63°N/65°E	3320	55°N/62°W	550	4295	2.5	...
156	1	Limestone	450	54°N/63°W	3420	63°N/65°E	460	Sarana	460	63°N/65°E	3320	55°N/62°W	550	4330	2.5	...
164	2	Limestone	450	54°N/63°W	3420	63°N/65°E	490	Chelyabinsk	490	63°N/65°E	3320	55°N/62°W	550	4360	2.5	...
164	2	Limestone	450	54°N/63°W	3420	63°N/65°E	510	Zlatoust	510	63°N/65°E	3320	55°N/62°W	550	4380	2.5	...
164	1	Limestone	450	54°N/63°W	3420	63°N/65°E	510	Miass	510	63°N/65°E	3320	55°N/62°W	550	4380	2.5	...
164	1	Limestone	450	54°N/63°W	3420	63°N/65°E	580	Beloretsk	580	63°N/65°E	2690	60°N/44°W	1180	4450	3.0	...
165	3	Limestone	450	54°N/63°W	3420	63°N/65°E	580	Ufa	580	63°N/65°E	2690	60°N/44°W	1180	4450	3.0	...
164	2	Limestone	450	54°N/63°W	3420	63°N/65°E	620	Magnitogorsk	620	63°N/65°E	2690	66°N/53°W	1180	4490	3.0	...
236	3	Limestone	450	54°N/63°W	3420	63°N/65°E	740	Orsk	740	63°N/65°E	2690	66°N/53°W	1180	4610	3.0	...
156	1	Limestone	610	55°N/58°W	3020	64°N/53°E	300	Berezniki	300	64°N/53°E	2450	60°N/44°W	1180	3930	2.0	...
156	1	Limestone	610	55°N/58°W	3020	64°N/53°E	360	Gubakha	360	64°N/53°E	2450	60°N/44°W	1180	3990	2.0	...
155	1	Limestone	610	55°N/58°W	3020	64°N/53°E	380	Kirov	380	64°N/53°E	2450	60°N/44°W	1180	4010	2.0	...
156	2	Limestone	610	55°N/58°W	3020	64°N/53°E	400	Molotov	400	64°N/53°E	2450	60°N/44°W	1180	4030	2.0	...
155	1	Limestone	610	55°N/58°W	3020	64°N/53°E	450	Votkinsk	450	64°N/53°E	2450	60°N/44°W	1180	4080	2.0	...
165	1	Limestone	450	54°N/63°W	3180	64°N/53°E	560	Kazan	560	64°N/53°E	3080	55°N/62°W	550	4190	2.5	...
154	3	Limestone	450	54°N/63°W	3180	64°N/53°E	580	Gorkiy	580	64°N/53°E	3080	55°N/62°W	550	4210	2.5	...
165	1	Limestone	450	54°N/63°W	3180	64°N/53°E	590	Ulanovsk	590	64°N/53°E	3080	55°N/62°W	550	4220	2.5	...
154	2	Limestone	450	54°N/63°W	3180	64°N/53°E	600	Dzerzhinsk	600	64°N/53°E	3080	55°N/62°W	550	4230	2.5	...
165	2	Limestone	450	54°N/63°W	3180	64°N/53°E	690	Kuybyshev	690	64°N/53°E	3080	55°N/62°W	550	4320	2.5	...
165	1	Limestone	450	54°N/63°W	3180	64°N/53°E	700	Syzran	700	64°N/53°E	3080	55°N/62°W	550	4330	2.5	...
235	1	Limestone	450	54°N/63°W	3180	64°N/53°E	820	Saratov	820	64°N/53°E	2450	60°N/44°W	1180	4450	3.0	...
153	3	Limestone	610	55°N/58°W	2400	66°N/26°E	370	Leningrad	370	66°N/26°E	....	....	3010	3380	1.0	...
153	1	Limestone	610	55°N/58°W	2400	66°N/26°E	380	Kolpino	380	66°N/26°E	....	....	3010	3390	1.0	...

154	1	Limestone	610	55°N/58°W	2400	66°N/26°E	570	Shcherbakov	570	66°N/26°E	2530	55°N/60°W	550	3615	1.5	...
154	1	Limestone	610	55°N/58°W	2400	66°N/26°E	580	Konstant-inovskiy	580	66°N/26°E	2530	55°N/60°W	550	3625	1.5	...
154	1	Limestone	610	55°N/58°W	2400	66°N/26°E	605	Yaroslavl	605	66°N/26°E	2530	55°N/60°W	550	3650	1.5	...
167	6	Limestone	610	55°N/58°W	2400	66°N/26°E	675	Moscow	675	66°N/26°E	2530	55°N/60°W	550	3720	1.5	...
167	1	Limestone	610	55°N/58°W	2400	66°N/26°E	680	Noginsk	680	66°N/26°E	2530	55°N/60°W	550	3725	1.5	...
167	2	Limestone	610	55°N/58°W	2400	66°N/26°E	715	Kolomna	715	66°N/26°E	2530	55°N/60°W	550	3760	1.5	...
167	1	Limestone	610	55°N/58°W	2400	66°N/26°E	775	Stalinogorsk	775	66°N/26°E	2530	55°N/60°W	550	3820	1.5	...
168	1	Limestone	610	55°N/58°W	2260	59°N/14°E	560	Minsk	560	59°N/14°E	....	....	2870	3430	1.0	...
249	1	Limestone	700	49°N/52°W	3550	39°N/35°E	375	Krasnodar	375	39°N/35°E	1930	44°N/9°W	2420	4675	...	2.0
249	2	Limestone	700	49°N/52°W	3550	39°N/35°E	475	Zhdanov	475	39°N/35°E	1930	44°N/9°W	2420	4775	...	2.0
249	1	Limestone	700	49°N/52°W	3550	39°N/35°E	485	Zaporozhye	485	39°N/35°E	1930	44°N/9°W	2420	4785	...	2.0
249	1	Limestone	700	49°N/52°W	3550	39°N/35°E	500	Taganrog	500	39°N/35°E	1930	44°N/9°W	2420	4800	...	2.0
250	1	Limestone	700	49°N/52°W	3550	39°N/35°E	525	Krivoy Rog	525	39°N/35°E	1930	44°N/9°W	2420	4825	...	2.0
234	2	Limestone	700	49°N/52°W	3550	39°N/35°E	525	Dnprod-zershinsk	525	39°N/35°E	1930	44°N/9°W	2420	4825	...	2.0
234	3	Limestone	700	49°N/52°W	3550	39°N/35°E	525	Dneprop-etrovsk	525	39°N/35°E	1930	44°N/9°W	2420	4825	...	2.0
249	2	Limestone	700	49°N/52°W	3550	39°N/35°E	530	Stalino	530	39°N/35°E	1930	44°N/9°W	2420	4830	...	2.0
234	1	Limestone	700	49°N/52°W	3550	39°N/35°E	530	Makeyevka	530	39°N/35°E	1930	44°N/9°W	2420	4830	...	2.0
325	1	Limestone	700	49°N/52°W	3550	39°N/35°E	540	Dzaudzhikau	540	39°N/35°E	1930	44°N/9°W	2420	4840	...	2.0
234	1	Limestone	700	49°N/52°W	3550	39°N/35°E	550	Konstant-inovka	550	39°N/35°E	1930	44°N/9°W	2420	4850	...	2.0
234	2	Limestone	700	49°N/52°W	3550	39°N/35°E	560	Gorlovka	560	39°N/35°E	1930	44°N/9°W	2420	4860	...	2.0
234	1	Limestone	700	49°N/52°W	3550	39°N/35°E	570	Kramatorsk	570	39°N/35°E	1930	44°N/9°W	2420	4870	...	2.0
249	1	Limestone	700	49°N/52°W	3550	39°N/35°E	570	Krasnyy Sulin	570	39°N/35°E	1930	44°N/9°W	2420	4870	...	2.0
156	1	Limestone	700	49°N/52°W	3550	39°N/35°E	580	Kamensk	580	39°N/35°E	1930	44°N/9°W	2420	4880	...	2.0
234	1	Limestone	700	49°N/52°W	3550	39°N/35°E	600	Lisichansk	600	39°N/35°E	1930	44°N/9°W	2420	4900	...	2.0
324	1	Limestone	700	49°N/52°W	3950	38°N/40°E	230	Batumi	230	38°N/40°E	2330	44°N/9°W	2420	4930	...	2.0
325	1	Limestone	700	49°N/52°W	3950	38°N/40°E	280	Rustavi	280	38°N/40°E	2330	44°N/9°W	2420	4980	...	2.0
325	1	Limestone	700	49°N/52°W	3950	38°N/40°E	370	Groznyy	370	38°N/40°E	2330	44°N/9°W	2420	5070	...	2.0
325	1	Limestone	700	49°N/52°W	3950	38°N/40°E	425	Makhachkala	425	38°N/40°E	2330	44°N/9°W	2420	5125	...	2.0
325	3	Limestone	700	49°N/52°W	3950	38°N/40°E	440	Baku	440	38°N/40°E	2330	44°N/9°W	2420	5140	...	2.0
326	1	Limestone	1800	38°N/28°W	3250	38°N/40°E	600	Krasnovodsk	600	38°N/40°E	2330	44°N/9°W	2420	5500	...	3.0
255	2	Limestone	1800	38°N/28°W	3250	38°N/40°E	650	Stalingrad	650	38°N/40°E	2330	44°N/9°W	2420	5550	...	3.0
247	1	Limestone	1800	38°N/28°W	3250	38°N/40°E	750	Guryev	750	38°N/40°E	2330	44°N/9°W	2420	5650	...	3.0
204	2	Spokane	450	53°N/127°W	3390	44°N/139°E	420	Komsomolsk	420	44°N/139°E	3290	54°N/129°W	550	4260	2.5	...
328								Begovat[b]								

[a] World Aeronautical Charts, *Bombing Encyclopedia Manual and Code Book*, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.
[b] Target cannot be reached.

Table 22b

SUMMARY OF MINIMUM-PENETRATION PATHS FOR AIR-REFUELED B-52 AIRCRAFT[a]

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
					Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
57°N/111°E	450	1.04	4050	9.40	340	340	340	0.79	0.79	0.79	4390	4390	4390	10.18	10.18	10.18
62°N/90°E	450	1.04	4250	9.86	480	406	325	1.11	0.94	0.75	4730	4656	4575	10.97	10.80	10.61
60°N/77°E	450	1.04	4250	9.86	325	325	325	0.75	0.75	0.75	4575	4575	4575	10.61	10.61	10.61
63°N/65°E	450	1.04	3870	8.98	740	520	325	1.72	1.21	0.75	4610	4390	4195	10.70	10.18	9.73
64°N/53°E	506	1.17	3630	8.42	820	546	300	1.90	1.27	0.70	4450	4176	3930	10.32	9.69	9.12
66°N/26°E	610	1.42	3010	6.98	775	599	370	1.80	1.39	0.86	3785	3609	3380	8.78	8.37	7.84
59°N/14°E	610	1.42	2870	6.66	560	560	560	1.30	1.30	1.30	3430	3430	3430	7.96	7.96	7.96
39°N/35°E	700	1.62	4250	9.86	600	526	375	1.39	1.22	0.87	4850	4776	4625	11.25	11.08	10.73
38°N/40°E	1100	2.55	4795	11.12	750	480	230	1.74	1.11	0.53	5545	5275	5025	12.86	12.24	11.66
44°N/139°E	450	1.04	3840	8.91	420	420	420	0.97	0.97	0.97	4260	4260	4260	9.88	9.88	9.88

[a] These averages would, in some cases, be increased if we included the target Begovat, which cannot be reached at all, and if we measured from the actual multiplicity of ZI-base locations instead of from the two points of Limestone and Spokane.

in the proportion of the fighters that are available for commitment, and by the increase in the fraction that may be committed with safety as the bomber track increases in distance from the early-warning barrier.

The problem, of course, is not merely to defend targets equally, but to have a high level of defense for the important targets. An ordering of fighters around the periphery would dilute area defense. The defending of all targets would result in a defense that was more or less equal, but equally poor. For even if the targets were of equal value, it would mean defending not only them, but also vast empty spaces. More significantly, it would permit the offense to undertake doglegged routes which would concentrate entry at a very few points in the periphery. By concentrating at these few points, the offense could saturate the defenses and then branch out in long penetrations through the undefended interior.

Some fairly subtle modifications to meet such problems of area defense distribution are possible. For example, instead of the simple ring arrangement or the simple uniform spread, the enemy might diminish fighter density as a function of distance from the early-warning perimeter in such a way as more nearly to equalize the offense's survival probabilities. Along short routes to target starting at numerous points on the periphery, the offense would meet a good many of the fighters based near the periphery and would encounter fewer in the interior. On long tracks starting at a few entry points, the offense would meet fewer of the fighters based near the perimeter, but more of the fighters in the interior. While we shall look at the effect on area defense distribution of inequalities in the offense's radius capability, for the most part we shall deal with two quite gross reallocations of the Russian fighter defenses, and with the joint assignment of local and area defense. The two broad reallocations of fighters, while not optimal, are demonstrably better than the uniform defense assumed so far—and by a considerable margin.

Matching Target Concentration in the West: Defense Distribution II. Defense Distribution I assumed a fighter coverage spread uniformly, without regard to differences in geographical concentration of industry. However, there are quite gross differences in concentration between widely separated areas of Russia. The most obvious difference is that between Western and Eastern Russia. If we draw a line through the east side of Lake Aral to about the intersection of the 65th longitude with the northern boundary of Russia, the area on the west includes the Ural complex (Chelyabinsk, Magnitogorsk, Nizhniy Tagil, etc.), Baku, and the Caucasus, as well as European Russia. This

Table 23a

MINIMUM-PENETRATION PATHS FOR GROUND-REFUELED B-52 AIRCRAFT

WAC No.*	RGZ's	ZI Base	Distance to Refuel Point (n mi)	Refuel Point	Distance to Entry Point (n mi)	Entry Point	Distance to Target (n mi)	Target	Distance to Exit Point (n mi)	Exit Point	Distance to Refuel Point (n mi)	Refuel Point	Distance to Base (n mi)	Mission Radius (n mi)	KC-97's per Bomber	B-36-type Tankers per Bomber
153	3	Limestone	1170	61°N/45°W	1790	66°N/26°E	370	Leningrad	370	66°N/26°E	1790	61°N/45°W	1170	3330	...	...
153	1	Limestone	1140	63°N/51°W	1930	66°N/26°E	380	Kolpino	380	66°N/26°E	1930	63°N/51°W	1140	3450	...	...
154	1	Limestone	1170	61°N/45°W	1790	66°N/26°E	570	Shcherbakov	570	66°N/26°E	1790	61°N/45°W	1170	3530	...	...
154	1	Limestone	1140	63°N/51°W	1930	66°N/26°E	580	Konstant-inovskiy	580	66°N/26°E	1930	63°N/51°W	1140	3650	...	...
154	1	Limestone	1140	63°N/51°W	1930	66°N/26°E	605	Yaroslavl	605	66°N/26°E	1930	63°N/51°W	1140	3675	...	...
167	6	Limestone	1170	61°N/45°W	1790	66°N/26°E	675	Moscow	675	66°N/26°E	1790	61°N/45°W	1170	3635	...	...
167	1	Limestone	1170	61°N/45°W	1790	66°N/26°E	680	Noginsk	680	66°N/26°E	1790	61°N/45°W	1170	3640	...	...
167	2	Limestone	1170	61°N/45°W	1790	66°N/26°E	715	Kolomna	715	66°N/26°E	1790	61°N/45°W	1170	3675	...	...
167	1	Limestone	1170	61°N/45°W	1790	66°N/26°E	775	Stalinogorsk	775	66°N/26°E	1790	61°N/45°W	1170	3735	...	...
168	1	Limestone	1170	61°N/45°W	1750	59°N/14°E	560	Minsk	560	59°N/14°E	1750	61°N/45°W	1170	3480	...	...
249	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	375	Krasnodar	375	39°N/35°E	1980	34°N/8°W	2800	5155	...	...
249	2	Limestone	2800	34°N/8°W	1980	39°N/35°E	475	Zhdanov	475	39°N/35°E	1980	34°N/8°W	2800	5255	...	...
249	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	485	Zaporozhye	485	39°N/35°E	1980	34°N/8°W	2800	5265	...	...
249	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	500	Taganrog	500	39°N/35°E	1980	34°N/8°W	2800	5280	...	...
250	1	Limestone	2800	34°N/8°W	1980	39°N/35°E	525	Krivoy Rog	525	39°N/35°E	1980	34°N/8°W	2800	5305	...	...
234	2	Limestone	2840	38°N/5°W	1740	39°N/35°E	525	Dnprod-zershinsk	525	39°N/35°E	1740	38°N/5°W	2840	5105	...	...
234	5	Limestone	2840	38°N/5°W	1740	39°N/35°E	525	Dneprop-etrovsk	525	39°N/35°E	1740	38°N/5°W	2840	5105	...	...
249	2	Limestone	2840	38°N/5°W	1740	39°N/35°E	530	Stalino	530	39°N/35°E	1740	38°N/5°W	2840	5110	...	...
234	1	Limestone	2840	38°N/5°W	1740	39°N/35°E	530	Makeyevka	530	39°N/35°E	1740	38°N/5°W	2840	5110	...	...
325	1	Limestone	2840	38°N/5°W	1740	39°N/35°E	540	Dzaudzhikau	540	39°N/35°E	1740	38°N/5°W	2840	5120	...	...
234	1	Limestone	2840	38°N/5°W	1740	39°N/35°E	550	Konstant-inovka	550	39°N/35°E	1740	38°N/5°W	2840	5130	...	...
234	2	Limestone	2840	38°N/5°W	1740	39°N/35°E	560	Gorlovka	560	39°N/35°E	1740	38°N/5°W	2840	5140	...	...
234	1	Limestone	2840	38°N/5°W	1740	39°N/35°E	570	Kramatorsk	570	39°N/35°E	1740	38°N/5°W	2840	5150	...	...
249	1	Limestone	2840	38°N/5°W	1740	39°N/35°E	570	Krasnyy Sulin	570	39°N/35°E	1740	38°N/5°W	2840	5150	...	...
156	1	Limestone	2840	38°N/5°W	1740	39°N/35°E	580	Kamensk	580	39°N/35°E	1740	38°N/5°W	2840	5160	...	...
234	1	Limestone	2840	38°N/5°W	1740	39°N/35°E	600	Lisichansk	600	39°N/35°E	1740	38°N/5°W	2840	5180	...	...
324	1	Limestone	2840	38°N/5°W	2140	38°N/40°E	230	Batumi	230	38°N/40°E	2140	38°N/5°W	2840	5210	...	...
325	1	Limestone	2840	38°N/5°W	2140	38°N/40°E	280	Rustavi	280	38°N/40°E	2140	38°N/5°W	2840	5260	...	...
325	1	Limestone	3130	37°N/5°E	1830	38°N/40°E	370	Groznyy	370	38°N/40°E	1830	37°N/5°E	3130	5330	...	...
139	1	Limestone	1800	77°N/67°W	2550	62°N/90°E	325	Krasnoyarsk	325	62°N/90°E	2550	77°N/67°W	1800	4675	...	...

161	2	Limestone	1800	77°N/67°W	2550	62°N/90°E	410	Kemerovo	410	62°N/90°E	2550	77°N/67°W	1800	4760	...	...
161	1	Limestone	1800	77°N/67°W	2550	62°N/90°E	480	Stalinsk	480	62°N/90°E	2550	77°N/67°W	1800	4830	...	...
163	2	Limestone	1800	77°N/67°W	2600	60°N/77°E	325	Omsk	325	60°N/77°E	2600	77°N/67°W	1800	4725	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	325	Alapayevsk	325	63°N/65°E	2260	77°N/67°W	1800	4385	...	...
156	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	360	Nizhiniy Tagil	360	63°N/65°E	2260	77°N/67°W	1800	4420	...	...
156	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	400	Sverdlovsk	400	63°N/65°E	2260	77°N/67°W	1800	4460	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	415	Polevskoy	415	63°N/65°E	2260	77°N/67°W	1800	4475	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	425	Severskiy	425	63°N/65°E	2260	77°N/67°W	1800	4485	...	...
156	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	460	Sarana	460	63°N/65°E	2260	77°N/67°W	1800	4520	...	...
164	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	490	Chelyabinsk	490	63°N/65°E	2260	77°N/67°W	1800	4550	...	...
164	2	Limestone	1800	77°N/67°W	2260	63°N/65°E	510	Zlatoust	510	63°N/65°E	2260	77°N/67°W	1800	4570	...	...
164	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	510	Miass	510	63°N/65°E	2260	77°N/67°W	1800	4570	...	...
164	1	Limestone	1800	77°N/67°W	2260	63°N/65°E	580	Beloretsk	580	63°N/65°E	2260	77°N/67°W	1800	4640	...	...
165	3	Limestone	2000	64°N/19°W	2100	63°N/65°E	580	Ufa	580	63°N/65°E	2100	64°N/19°W	2000	4680	...	...
164	2	Limestone	2000	64°N/19°W	2100	63°N/65°E	620	Magnitogorsk	620	63°N/65°E	2100	64°N/19°W	2000	4720	...	...
236	3	Limestone	2000	64°N/19°W	2100	63°N/65°E	740	Orsk	740	63°N/65°E	2100	64°N/19°W	2000	4840	...	...
156	1	Limestone	1140	63°N/51°W	2500	64°N/53°E	300	Berezniki	300	64°N/53°E	2500	63°N/51°W	1140	3940	...	...
156	1	Limestone	1140	63°N/51°W	2500	64°N/53°E	360	Gubakha	360	64°N/53°E	2500	63°N/51°W	1140	4000	...	...
155	1	Limestone	1270	67°N/50°W	1390	64°N/53°E	380	Kirov	380	64°N/53°E	1390	67°N/50°W	1270	3040	...	...
156	2	Limestone	1140	63°N/51°W	2500	64°N/53°E	400	Molotov	400	64°N/53°E	2500	63°N/51°W	1140	4040	...	...
155	1	Limestone	1270	67°N/50°W	1390	64°N/53°E	450	Votkinsk	450	64°N/53°E	1390	67°N/50°W	1270	3110	...	...
165	1	Limestone	1270	67°N/50°W	1390	64°N/53°E	560	Kazan	560	64°N/53°E	1390	67°N/50°W	1270	3220	...	...
154	3	Limestone	1140	63°N/51°W	2500	64°N/53°E	580	Gorkiy	580	64°N/53°E	2500	63°N/51°W	1140	4220	...	...
165	1	Limestone	1270	67°N/50°W	1390	64°N/53°E	590	Ulyanovsk	590	64°N/53°E	1390	67°N/50°W	1270	3250	...	...
154	2	Limestone	1140	63°N/51°W	2500	64°N/53°E	600	Dzerzhinsk	600	64°N/53°E	2500	63°N/51°W	1140	4240	...	...
165	2	Limestone	1270	67°N/50°W	1390	64°N/53°E	690	Kuybyshev	690	64°N/53°E	1390	67°N/50°W	1270	3350	...	...
165	1	Limestone	1270	67°N/50°W	1390	64°N/53°E	700	Syzran	700	64°N/53°E	1390	67°N/50°W	1270	3360	...	...
235	1	Limestone	2000	64°N/19°W	1900	64°N/53°E	820	Saratov	820	64°N/53°E	1900	64°N/19°W	2000	4720	...	...
325	1	Limestone	3130	37°N/3°E	1830	38°N/40°E	425	Makhachkala	425	38°N/40°E	1830	37°N/3°E	3130	5385	...	...
325	3	Limestone	3130	37°N/3°E	1830	38°N/40°E	440	Baku	440	38°N/40°E	1830	37°N/3°E	3130	5400	...	...
326	1	Limestone	3130	37°N/3°E	1830	38°N/40°E	600	Krasnovodsk	600	38°N/40°E	1830	37°N/3°E	3130	5560	...	...
235	2	Limestone	3130	37°N/3°E	1830	38°N/40°E	650	Stalingrad	650	38°N/40°E	1830	37°N/3°E	3130	5610	...	...
247	1	Limestone	3130	37°N/3°E	1830	38°N/40°E	750	Guryev	750	38°N/40°E	1830	37°N/3°E	3130	5710	...	...
328	1	Limestone	3660	33°N/13°E	2650	34°N/68°E	340	Begovat	340	34°N/68°E	2650	33°N/13°E	3660	6650	...	...
166	1	Spokane	4240	36°N/140°E	1490	47°N/113°E	340	Petrovsk	340	47°N/113°E	1490	36°N/140°E	4240	6070	...	...
204	2	Spokane	4240	36°N/140°E	575	44°N/139°E	420	Komsomolsk	420	44°N/139°E	575	36°N/140°E	4240	5235	...	...

*World Aeronautical Charts, *Bombing Encyclopedia Manual and Code Book*, Directorate of Intelligence, HqUSAF, Washington, D.C., September, 1950.

Table 23b

SUMMARY OF MINIMUM-PENETRATION PATHS FOR GROUND-REFUELED B-52 AIRCRAFT

Target Group	Refuel Point		Entry Point		Target Penetration						Radius Mission					
	Avg Distance (n mi)	Avg Time (hr)	Avg Distance (n mi)	Avg Time (hr)	Distance (n mi)			Time (hr)			Distance (n mi)			Time (hr)		
					Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
62°N/90°E	1800	4.18	4350	10.09	480	406	325	1.11	0.94	0.75	4830	4756	4675	11.21	11.03	10.85
60°N/77°E	1800	4.18	4400	10.21	325	325	325	0.75	0.75	0.75	4725	4725	4725	10.96	10.96	10.96
63°N/65°E	1873	4.35	4075	9.45	740	520	325	1.72	1.21	0.75	4815	4595	4400	11.17	10.66	10.21
64°N/53°E	1244	2.89	3252	7.54	820	546	300	1.90	1.27	0.70	4072	3798	3552	9.45	8.81	8.24
66°N/26°E	1165	2.70	2980	6.91	775	599	370	1.80	1.39	0.86	3755	3579	3350	8.71	8.30	7.77
59°N/14°E	1170	2.71	2920	6.77	560	560	560	1.30	1.30	1.30	3480	3480	3480	8.07	8.07	8.07
39°N/35°E	2829	6.56	4634	10.75	600	526	375	1.39	1.22	0.87	5234	5160	5009	12.14	11.97	11.62
38°N/40°E	3077	7.14	4963	11.51	750	480	230	1.74	1.11	0.53	5713	5443	5193	13.25	12.63	12.05
34°N/68°E	3660	8.49	6310	14.64	340	340	340	0.79	0.79	0.79	6650	6650	6650	15.43	15.43	15.43
47°N/113°E	4240	9.84	5730	13.29	340	340	340	0.79	0.79	0.79	6070	6070	6070	14.08	14.08	14.08
44°N/139°E	4240	9.84	4815	11.17	420	420	420	0.97	0.97	0.97	5235	5235	5235	12.15	12.15	12.15

Table 24

CAMPAIGN EFFECTS OF DIFFERENCES IN B-52 PROFILES[a]

Air-refueled System Costs and Requirements To Destroy Russian Industry Targets Are Presented as a Percentage of Ground-refueled System Costs and Requirements

(Costs and three-year costs)

	Including Flight-profile Difference (%)	Excluding Flight-profile Difference (%)
Number of strikes	100	125
Number of B-52's in operating force	151	112
Total number of B-52's	89	66
Cost of bomber force	151	112
Cost of radius extension[b]	682	518
New Cost of Complete System	205	151
Inheritance	164	164
Incremental Cost of Complete System	209	150

[a] The air-refueled system uses a reserve tactic; the ground-refueled system uses an impact tactic. The air-refueled system follows minimum-penetration routes; minimum-penetration and minimum-tanker routes are identical for the ground-refueled system. The SU fighter-force composition assumed is 50 per cent MiG-15, 50 per cent Type 38.

[b] Includes the cost of en route bases, refueling bases, and tankers.

western area contains about 90 per cent of the industry targets in our 100-point system.

This concentration in the west is not an arbitrary or peculiar feature of the specific industry-target system we have taken in our basic campaigns. And it is not changed when plausible value weights are attached to the various RGZ's in the 100-point system. RAND's target systems analysis group have prepared an aggregative industrial index* (AII) which is essentially a measure of capital investment with some adjustments for strategic importance. (Petroleum refineries, for example, are weighted somewhat more heavily in this index than their percentage contribution to the estimated total capital investment in Russian industry.) The exact nature of the weighting process used is not of particular importance here. As we have stressed earlier, we have not ourselves attempted

* Norman Dalkey, Olaf Helmer, and F. B. Thompson, *Report of a Preliminary Systems Analysis for Strategic Targets*, The RAND Corporation, Research Memorandum RM-1011, January 1, 1953 (Secret).

an analysis of targets for the purpose of target selection, and our use of these weights is illustrative. They have, however, the advantage (1) of having been selected independently of the geographical considerations that influence the outcome of our campaign analyses, (2) of having been selected independently of the 100-point system we have taken for the basic analyses, (3) of providing a criterion for expanding this 100-point system to an industrial-target system with a larger number of RGZ's, and (4) of insuring that this larger target system will have an economic significance contrasting with the 100-point system (the 100-point system is a vertical system concentrating on many large and some small plants in six industries; the additional targets in the larger target system are large plants drawn from seventeen broad industrial categories). The coincidence of results obtained using the unweighted 100-point system with results obtained using the same and a larger target system weighted by contributions to AII is therefore of some interest.

If we take the largest 50 plants of the 100-point system as measured by their contribution to the AII, then the second 50, then the next 50 largest contributors to the AII not already included in the 100-point system, then the next 50 largest, and the next, the distribution of these RGZ's, whether weighted or not as between the east and the west, is rather stable. The same is true if we take the division between the north and south made by the no-summer-darkness contour. This point is illustrated in Table 25.

Table 25

DISTRIBUTION OF TARGETS BY AII RANK AND BY GEOGRAPHIC LOCATION

AII Rank	NW Quadrant	SW Quadrant	NE Quadrant	SE Quadrant
1 to 50	17	29	3	1
51 to 100	43	4	3	..
101 to 150	19	20	11	..
151 to 200	28	11	6	5
201 to 250	43	6	..	1
TOTAL	150	70	23	7

We shall have occasion to test the effects of assuming nonuniform values and the effects of expanding the target system later, when we talk about local-defense allocation. At that point it will be evident that other parameters which are influenced by geography remain rather stable, as far as our results are concerned. Here, however, the illustration merely serves to confirm the fact that a fighter coverage which is uniform for east and west ignores a major feature of Russian industrial geography. The first gross reallocation of defense that might be tried, then, is a shift of area defense to the west, leaving the sparse targets in the east to be defended locally. This is Defense Distribution II.

Matching Radius Limitations of Offensive Base-bomber Systems. The uniformity of deployment in Defense Distribution I was based in part on the assumption that an attack from any angle was equally probable. The validity of this assumption depends on the base-bomber system of the offense. As the measurements presented earlier in Tables 4, 5, 20, and 21 demonstrate, it is by no means true for all systems that they are equally effective along any axis of penetration. For some base-aircraft combinations, some target points are out of reach altogether; others can be reached only by long penetrations over enemy territory. And there is a wide disparity in the cost to reach individual targets for various base-aircraft combinations.

Such inequalities in radius effectiveness can be exploited in distributing defense. First, if a target is beyond the offensive capability altogether, it may be left undefended. However, even where a target is beyond two-way-bomber refueled radius, the offense can muster sporadic attack, perhaps on a one-way mission basis. In this case, other things being equal, the smaller offensive capability calls for a proportionately smaller defense. And even where the offense can reach a given target region on a two-way mission, but requires for this purpose a very large number of tankers, the defense can exploit this fact. With a fixed force the offense will be able to muster smaller strikes against such remote regions. The defense needs a smaller bomber kill potential to reduce probability of bomber survival inbound to a given level. Regions which the offense can attack with comparatively little radius-extension cost, and where it can in consequence manage more massive raids, can be defended by a larger number of fighters.

Figure 55 shows contours of equal radius-extension cost for the air-refueled system. A defense tailored to match this bomber-base system would concentrate in the north to make up for this system's greater capability in that region.

Figure 56 shows contours of equal radius-extension cost for the ground-refueled B-47 system. Matching the capability of such a system clearly involves a more even spread of fighter defense, i.e., a dilution of fighter defense.

Russian night-fighter limitations for 1956 make it difficult to cope with a peripheral base system situated equally in the south and north. But area-defense

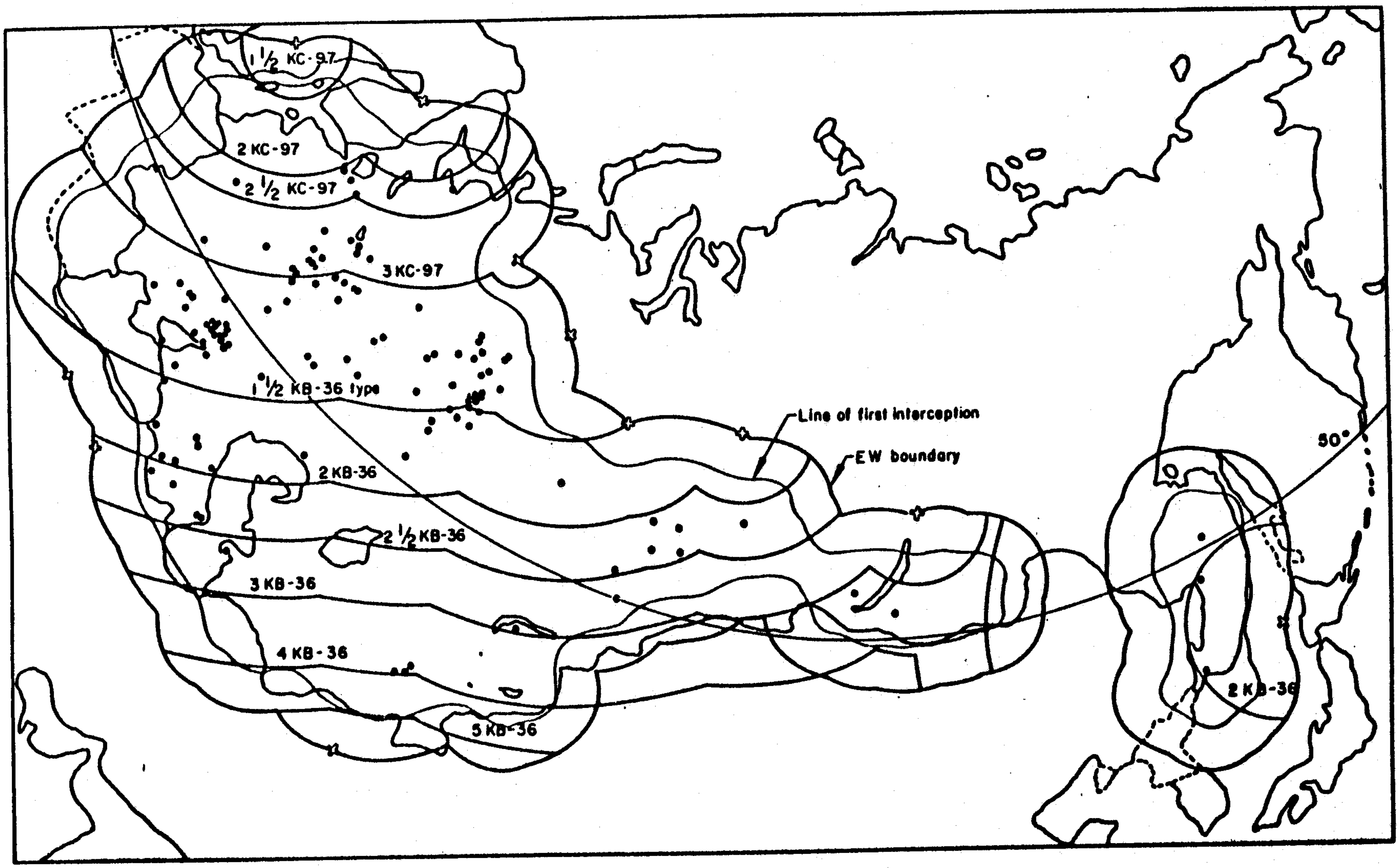

Fig. 55—Contours of equal radius-extension cost: intercontinental air-refueled system

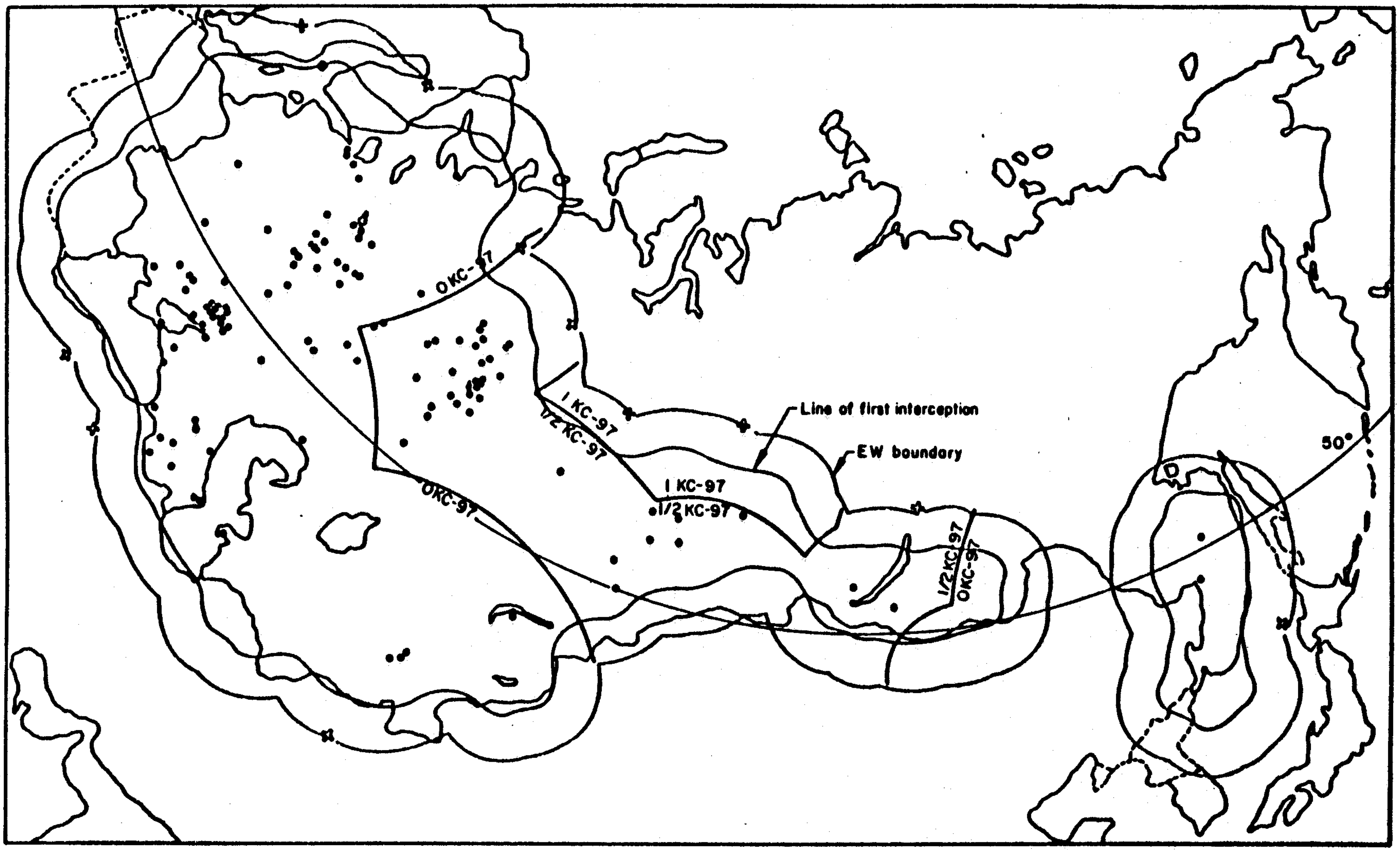

Fig. 56—Contours of equal radius-extension cost: ground-refueled system

limitations in the south in a rough way happen to match the air-refueled offense system's radius limitations in that area. This situation is underlined by the possibility of exploiting day fighters more fully. As a result, a rather gross rearrangement of fighters is suggested, much simpler in principle than the distribution of defense, so as to equalize costs to reach targets of a given value, considering both attrition and radius-extension costs. This simpler rearrangement accomplishes in some degree the objectives of the more complex rearrangement.

Making Maximum Use of Day Fighters in the North. Defense Distribution I assumed day fighters spread with uniform coverage over the GCI area both above and below the Fiftieth Parallel. Defense Distribution II shifted day and night fighters to the west, but did not alter the north-south division. However, so far as high-altitude attacks are concerned, the offense will suffer low attrition when it makes its penetrations below the Fiftieth Parallel at night, during a summer campaign. It should therefore, in general, attack under cover of darkness. This means in effect that, except for those day fighters which can be used along with night fighters on the buddy system, the day fighters below the Fiftieth Parallel will for the most part be unused. The defense can inflict higher losses during the day than it can at night, even without using these excess day fighters. This is true, since the probability that a fighter will intercept and kill a bomber is expected to be higher in daytime. Therefore, the moving of the excess day fighters north should not offer sufficient incentive for the offense to attack during the day. (These comments refer to high-altitude attack. We shall discuss low-altitude attacks later.)

For these summer campaigns, by moving substantially all day fighters not otherwise usable to points north of the Fiftieth Parallel, the enemy can make significantly better use of his fighter force. Area-defense losses for all the offensive base systems examined increase. However, the systems are not equally affected. The concentration of fighters in the north penalizes especially sharply those systems whose greatest capacity lies in approaches from that region, i.e., the exclusively air-refueled intercontinental system, in particular. Ninety-eight per cent of this system's minimum-tanker paths to targets enter from the north. For it, therefore, the choice between minimum-tanker and minimum-penetration paths favors the latter more than in Defense Distribution I. For a system with peripheral overseas bases located approximately as programmed, paths minimizing tanker needs approach largely from the south (over 75 per cent); for such a system the choice between minimum-penetration and minimum-tanker paths approaches indifference. The comparative advantage of the southern routes is emphasized by Defense Distribution III.

Defense Distribution III. Defense Distribution III combines the shift of fighters to the west in recognition of target concentration there, most day fighters being shifted to the north to obtain their maximum utilization. It means, specifically, given the force composition we have assumed, that there are 2700 day fighters in the northwest and a total of 600 fighters (300 day and 300 night) in the southwest. Targets in the east are defended by local-defense missiles.

The concentration of 2700 fighters in the northwest is not excessive from the standpoint of their control. This northwest area is a very large one. For the sort of semibroadcast control we have assumed throughout this report, the fighter density is quite easily handled by ground radar.*

Campaigns Using Defense Distribution III. Against enemy defenses distributed as in Defense Distribution III, campaigns using minimum-tanker and minimum-penetration paths for the air- and ground-refueled systems may be compared. The results of such a comparison are presented in Fig. 57 and in Table 26. Defense Distribution III raises the campaign costs of all offensive systems. This may be observed by referring to the corresponding campaigns against the same target system defended by Defense Distribution I. (These Defense Distribution I campaigns are presented in the section entitled "Base to Target: The Cost of Increasing Combat Radius," pages 61*ff*.) But Defense Distribution III raises, in particular, the costs of the air-refueled system. It makes the northern routes to targets especially unprofitable. Therefore, for the air-refueled system, the minimum-penetration paths are superior to the minimum-tanker paths. For the ground-refueled system, whose minimum-tanker paths are largely from the south, there is little difference between the two sets of routes.

For the intercontinental air-refueled system, paths chosen to reduce the tanker requirements per bomber sortied actually involve more tankers in total than the

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*Against bombers flying at low altitude, control-capacity limitations may become important (because of the short-sightedness of AI radars at low altitude). For a nonuniform *deployment* of *fighters*, such as Defense Distribution III, the effect of this limitation would be to return the distribution of *attrition* to one which was similar to Defense Distribution I (Tables 13 and 15); it is evident that consideration of the reduction in attrition achievable by low-altitude tactics does not seriously affect the comparison of an air-refueled and a ground-refueled system when both use low-altitude tactics. However, as indicated on pp. 151*ff*, above, the ground-refueled system provides a greater capability for low-altitude attacks.

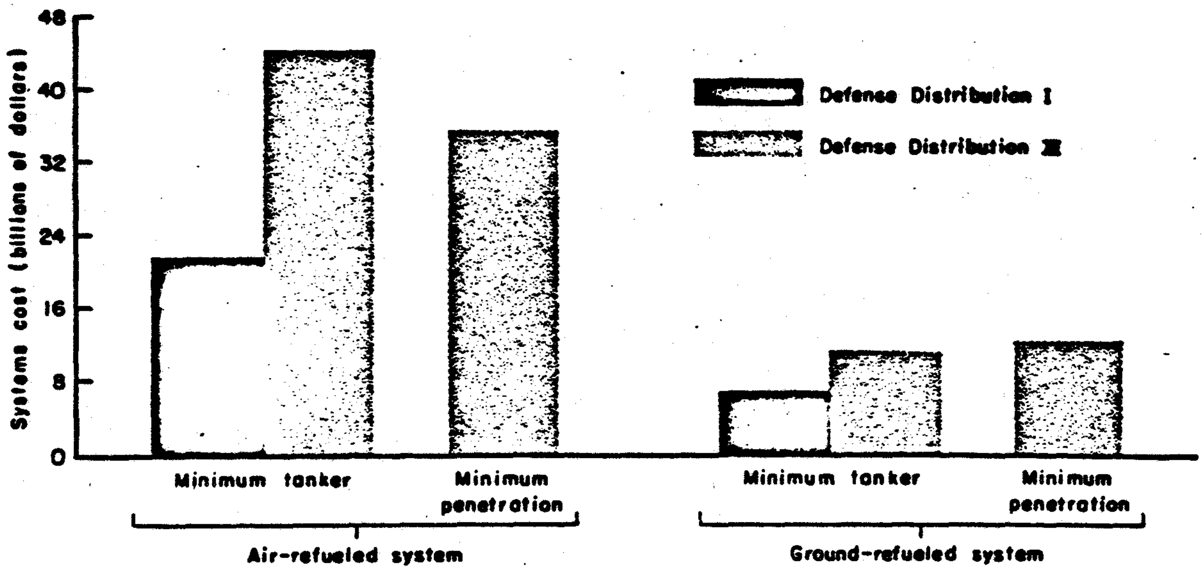


Fig. 57—Route choice and defense distribution: intercontinental B-47 campaigns (incremental 3-year cost)

minimum-penetration paths. This is so because the former routes involve high attrition and therefore large strike sizes to insure acceptable crew-survival probabilities; the larger strike size involves more tankers in total, even though fewer tankers per bomber are required than in the minimum-penetration case.

Fighter Commitment Policy

The lateral distance from a bomber track at which a base commander can commit his fighters with protection against feints is a function of the relative speeds of the fighter and the bomber, the time to land and rearm the interceptors, and the distance from the early-warning network. Since the alternative routes we have studied involve quite different depths of penetration inside the early-warning perimeter, it is important to consider the consequences of a systematic policy of feint-protected commitment. The possibility of feints and feint protection influences the effective fighter-corridor width. It is also important, therefore, in evaluation of attacks intended to isolate and saturate one or two regions at a time.

The commitment policy we have assumed so far has had several arbitrary elements. On the one hand, we have assumed that, though the MiG's will have an estimated combat radius of at least 250 mi against the B-47 at the altitudes of penetration considered (this makes a generous allowance for vectoring errors), nonetheless only MiG's within a 150-mi lateral distance from the

Table 26

ROUTE CHOICE AND DEFENSE DISTRIBUTION IN INTERCONTINENTAL B-47 CAMPAIGNS

(Three-year cost in billions of dollars)

	Air-refueled System		Ground-refueled System	
	Minimum-tanker Routes	Minimum-penetration Routes	Minimum-tanker Routes	Minimum-penetration Routes
Tactic	Reserve	Reserve	Impact	Impact
Number of strikes	5	6	3	3
Number of B-47's in operating force	1079	708	1230	1207
Number of B-47's in reserve for air attrition	984	892	0	0
Total number of B-47's	2063	1600	1230	1207
Number of B-36-type tankers	1400	1560	43	181
Number of KC-97's	1185	390	234	242
New cost of bomber force	20.2	15.7	12.1	11.8
New cost of radius extension[a]	28.0	23.9	3.3	5.5
NEW COST OF COMPLETE SYSTEM	48.2	39.6	15.4	17.3
Inheritance	4.1	4.1	3.8	4.8
INCREMENTAL COST OF COMPLETE SYSTEM	44.1	35.5	11.6	12.5

[a] Includes cost of en route bases, refueling bases, and tankers.

bomber track will be committed. On the other hand, within the 150-mi corridor half-width, we have assumed commitment of all fighters available. How are the comparisons we make affected by a systematic commitment policy designed to utilize more of the fighter radius, but also to insure feint protection? Such a policy might commit fighters only when there was enough radar coverage between the base and the early-warning network to give the interceptor time to return to a status equivalent to that existing before the first attack, even when a second attack might come with the interceptor in the worse situation for such recovery.

In RAND's *Air Defense Study*,* this worse situation for the defense is taken to occur when a second attack enters the radar detection system just after the interceptor has fired its load at a bomber in the first attack. Using a formula

*E. J. Barlow and J. F. Digby (eds.), *Air Defense Study*, The RAND Corporation, Report R-227, October 15, 1951 (Secret).

developed in the *Air Defense Study* for determining the radar coverage yielding feint protection,* we have tested the effect of such a commitment policy on the interceptor and kill potential of Defense Distribution III. For full commitment against a B-47 track at a 250-n-mi lateral distance, the interceptor base following this policy would have to be at least 550 n mi or so behind the early-warning boundary; against a track directly in line with the base, i.e., at a zero lateral distance, the available fighters would be committed only if the base were approximately 300 n mi behind the early-warning network. Short of these distances, a seven-tenths commitment is assumed.

The total result of this commitment policy, compared with the one assumed before this, is to increase B-47 losses along the minimum-penetration paths by 52 per cent; along routes minimizing tankers for a peripheral overseas system, by 23 per cent; and along routes minimizing tankers for an exclusively air-refueled intercontinental system, by 70 per cent. The minimum-tanker routes for the peripheral base system involve fewer losses as well as lower tanker costs than the minimum-penetration routes. For such a base system, then, this route choice can be made on grounds of dominance. For the intercontinental air-refueled system, preference for minimum-penetration paths, as far as they are feasible, becomes even more distinct than with the commitment policy assumed earlier—in spite of the high radius-extension cost of these paths. Finally, the contrast between intercontinental air-refueled and ground-refueled systems is even more marked, given Defense Distribution III and the feint-protected, wider-corridor commitment policy outlined.

Figure 58 and Table 27 present the campaign results, assuming this adjusted commitment policy, for the air-refueled system following both minimum-tanker and minimum-penetration paths and for the ground-refueled system following minimum-tanker paths only.

The revision in commitment policy has effects worthy of note other than those described. These additional effects characterize a campaign including strikes against many regions simultaneously. The increase in corridor width with the revised commitment policy results in a corresponding increase in the overlap among the corridors of fighters stirred up by adjacent tracks in a single raid. If these tracks are made simultaneously, the increase in overlap does not mean any extra attrition, since a fighter in the overlap area can be committed against one or another of two adjacent tracks, but not against both. In other words, this

Ibid., p. 303.

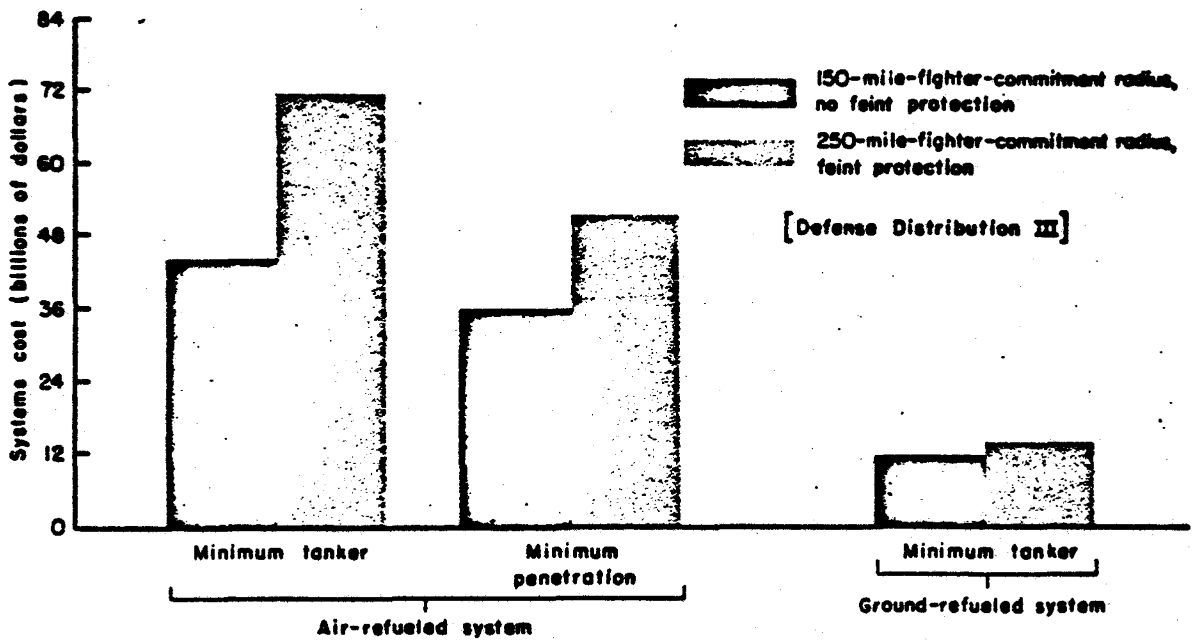


Fig. 58—Improved SU fighter-commitment policy: intercontinental B-47 system (incremental 3-year cost)

commitment policy increases the advantage of simultaneous raids on adjacent regions.

We shall consider, later in this section, the use of this adjusted commitment policy for Defense Distribution III in connection with a regional saturation. The final campaigns tested in Part III, which combine the effects of enemy bombing attacks on our bases along with the target-radius and route-choice alternatives we have examined so far, assume the commitment policy dealt with originally. If the revised commitment policy were to be incorporated in these campaigns, the conclusions drawn would be reinforced.

Local- and Area-defense Allocation for an Expanded Target System and for a Nonuniform Target System

The expanded target system referred to earlier adds 150 RGZ's. The predominant majority of these extra RGZ's fall within the same inbound fighter corridors stirred up by tracks to the 100-RGZ system. A moderate additional amount of outbound attrition is incurred in attacks against the enlarged system. On strikes against the whole of the larger system, cells withdraw in a more continuous stream over various segments of the tracks, and this permits some fighters to recycle that had no opportunity to do so in strikes against the 100-RGZ system. However, the total difference in area attrition is in all cases less than 10 per cent.

Table 27

COST OF INTERCONTINENTAL B-47 CAMPAIGNS ASSUMING IMPROVED SU FIGHTER COMMITMENT POLICY AND DEFENSE DISTRIBUTION III

(Three-year cost in billions of dollars)

	Air-refueled System		Ground-refueled System
	Minimum-tanker Routes	Minimum-penetration Routes	Minimum-tanker Routes
Tactic	Reserve	Reserve	Impact
Number of strikes	4	5	3
Number of B-47's in operating force	1779	1040	1416
Number of B-47's in reserve for air attrition	1176	1061	0
Total number of B-47's	2955	2101	1416
Number of B-36-type tankers	2310	2290	51
Number of KC-97's	1960	572	277
New cost of bomber force	29.0	20.6	13.9
New cost of radius extension[a]	46.2	34.9	3.8
NEW COST OF COMPLETE SYSTEM	75.2	55.5	17.7
Inheritance	4.1	4.1	4.0
INCREMENTAL COST OF COMPLETE SYSTEM	71.1	51.4	13.7

[a] Includes cost of en route bases, refueling bases, and tankers.

Local defense is tied more specifically to individual targets than is area defense. As compared with the fighter radius of 200 or 300 miles, the Wasserfall missile installation we have assumed will protect only those targets within a radius of about 20 mi. If we make the simplifying assumption, implicit in the earlier campaign calculations, of the divisibility of the local defenses and the separability of the targets, we may divide the fixed total of local-defense kill potential among the 250 RGZ's as we did in the case of the 100-point target system.

The campaign costs for destruction of 80 per cent of the 250 RGZ's may be calculated, using the local-defense attrition parameters obtained in this way, and using area attrition obtained by measurement. To obtain the other major inputs for campaigns against the larger target system, we have also measured the tanker-bomber requirements for the air-refueled and ground-refueled system to visit the expanded target system, using either minimum-penetration or minimum-tanker routes. The average radius-extension costs are roughly the same. The campaign comparisons made previously are not affected very much by this shift to a larger target system. This is indicated by the campaign costs presented in Fig. 59.

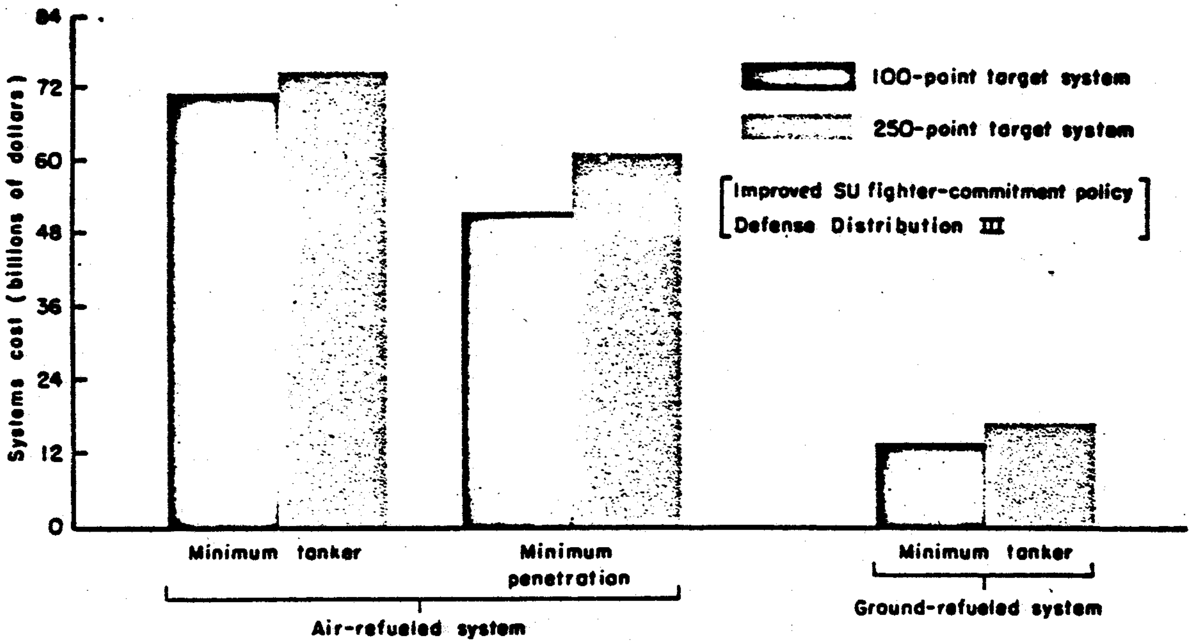


Fig. 59—Enlarged target system: intercontinental B-47 campaigns (incremental 3-year cost)

Similarly, the assignment to the target points of nonuniform values measured by contributions to the aggregate industrial index does not affect the comparisons significantly, if we assume each target point as being defended by a share of the local defense proportionate to its value, and take as the goal of the offense the destruction of 80 per cent of the target system by value. The assignment of AII values to the 250 points moderately reduces radius-extension costs for the air-fueled system because of the great weight of the Moscow-Leningrad area. The aggregative-industrial-index weighting of the 100-point system affects the radius-extension costs very little. (It increases them slightly for the air-refueled case.) Such campaigns against an AII-weighted target system with proportionate assignment of local defense are presented in Figs. 60 and 61.

Concentrations of Local Defense and Local Concentrations of Target Value

The simplifying assumption as to the isolability of individual targets and the divisibility of local-defense kill potential may be harmless as long as we con-

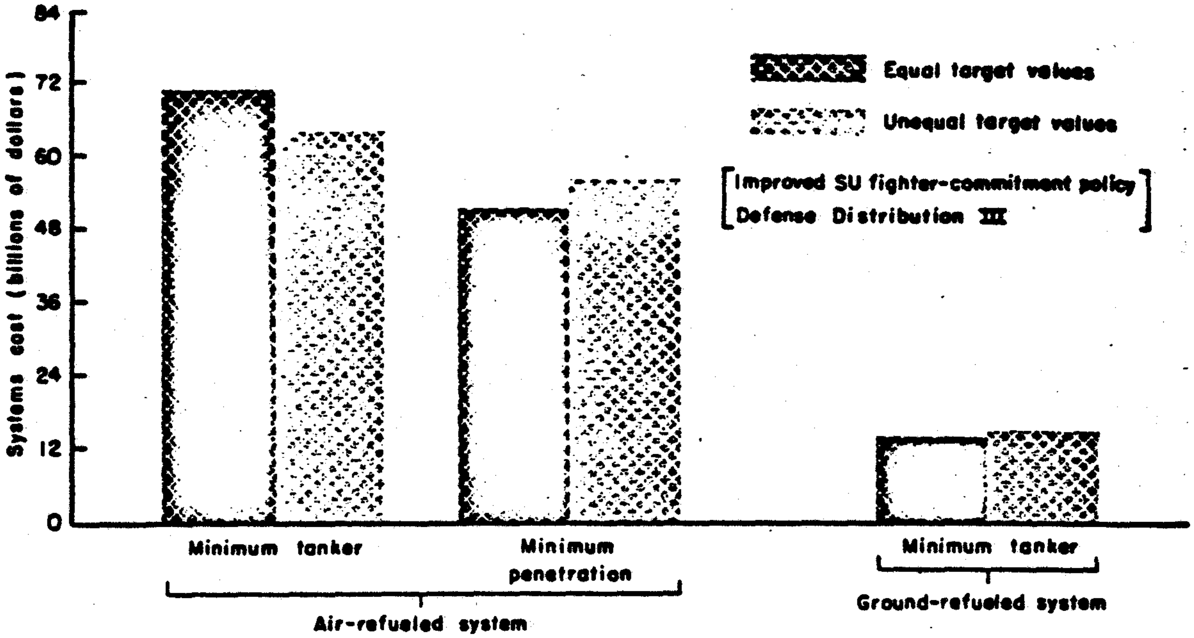


Fig. 60—Unequal target values for 100-point target system: intercontinental B-47 campaign (incremental 3-year cost)

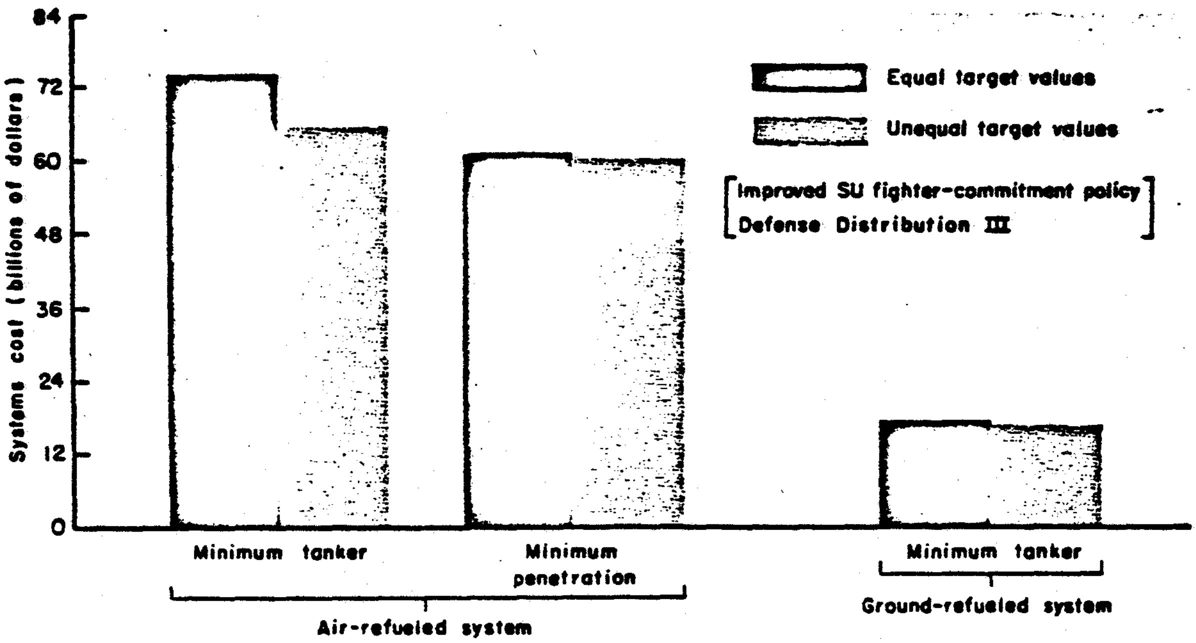


Fig. 61—Unequal target values for 250-point target system: intercontinental B-47 campaign (incremental 3-year cost)

sider strikes of sufficiently large size. However, while local defenses are tied more specifically to individual targets than is area defense, a single local-defense installation will in general defend several RGZ's. The 100 RGZ's are contained in some 66 cities; the 250 RGZ's, in 117 cities. Local concentrations of target values as distinct from numbers of targets are even greater.

Figure 62 presents Lorenz curves showing the percentage of total aggregate industrial value versus the percentage of cities. Over 80 per cent of the value of the 100-point target system is contained in a third of the target cities. Similarly, for the 250-RGZ system.

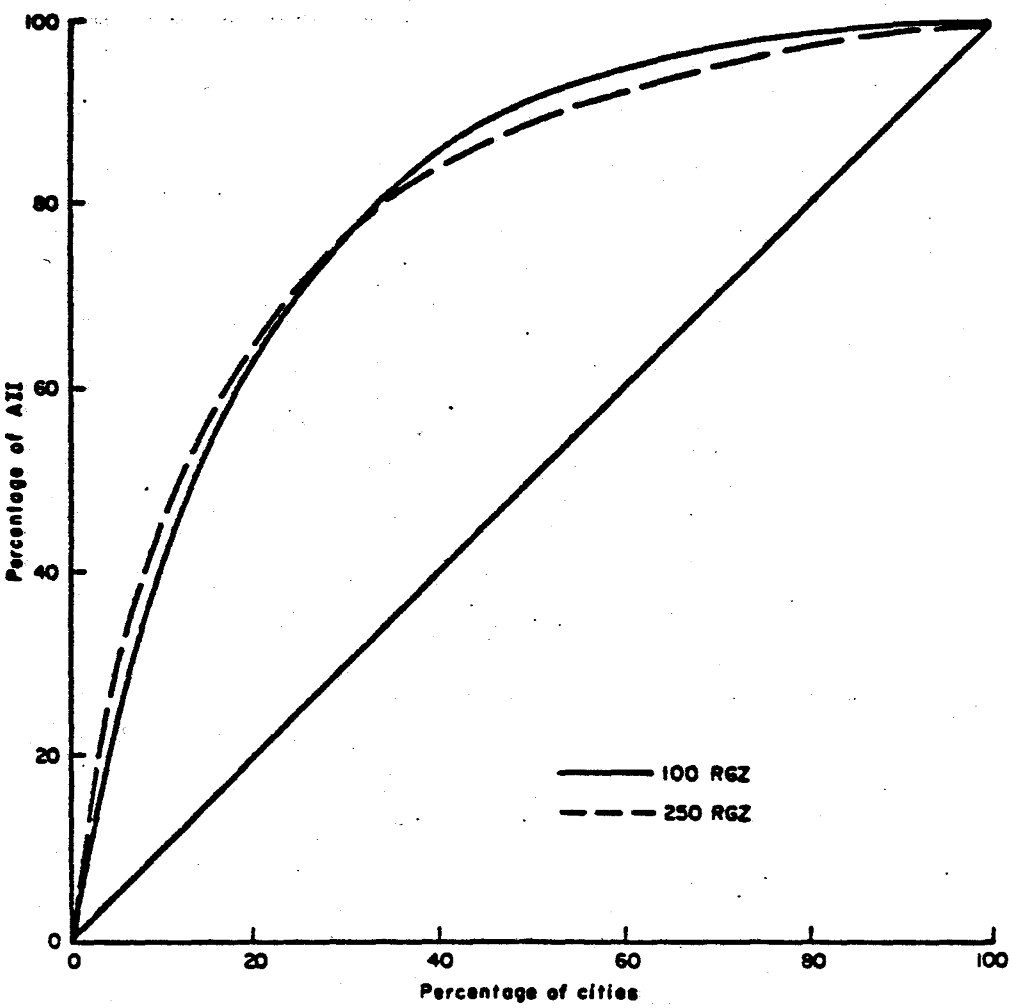


Fig. 62—Percentage of total aggregate industrial value vs percentage of cities

If we consider campaigns in which the target system is divided by the attacking force and attacked region by region in an attempt to reduce the size of the operating force, it is essential to examine the concentration of local defense in relation to target value. As in the case of the area defense, it is possible for the local defense to be distributed more effectively by use of the technique of concentration. One such distribution of defense might provide local defense in proportion to value for the Eastern targets which have, in Defense Distribution III, no area defense; and it might distribute the remainder of the local defense among the target cities which contain 80 per cent of the AII. Such a distribution of defense is a counteraction to any attempt by the offense to nibble at the target system bit by bit. (To discourage attempts to pick off the shallow targets, local defenses may be distributed in depth so as partially or wholly to compensate for the lower area kills involved in visits to the shallower portions of the system. This tends to equalize the losses per unit of target value destroyed.) Given this defense distribution, the offense gains nothing by attacking first either the eastern targets which have no area defense or the small western targets which have no local defense, for the offense would incur some losses by so doing. The eastern targets are defended locally, and the western targets are defended by area defense as a by-product of the defense of the larger targets. By incurring losses in attacking this less-defended part of the target system, the offense would lose some of the advantages of saturation in attacks against the more heavily defended part. Therefore it is best for the offense in this regional campaign to go early into the heavily defended area while it has its maximum force intact.

The results of a regional saturation campaign against a target system so defended are presented in Fig. 63 and Table 28.

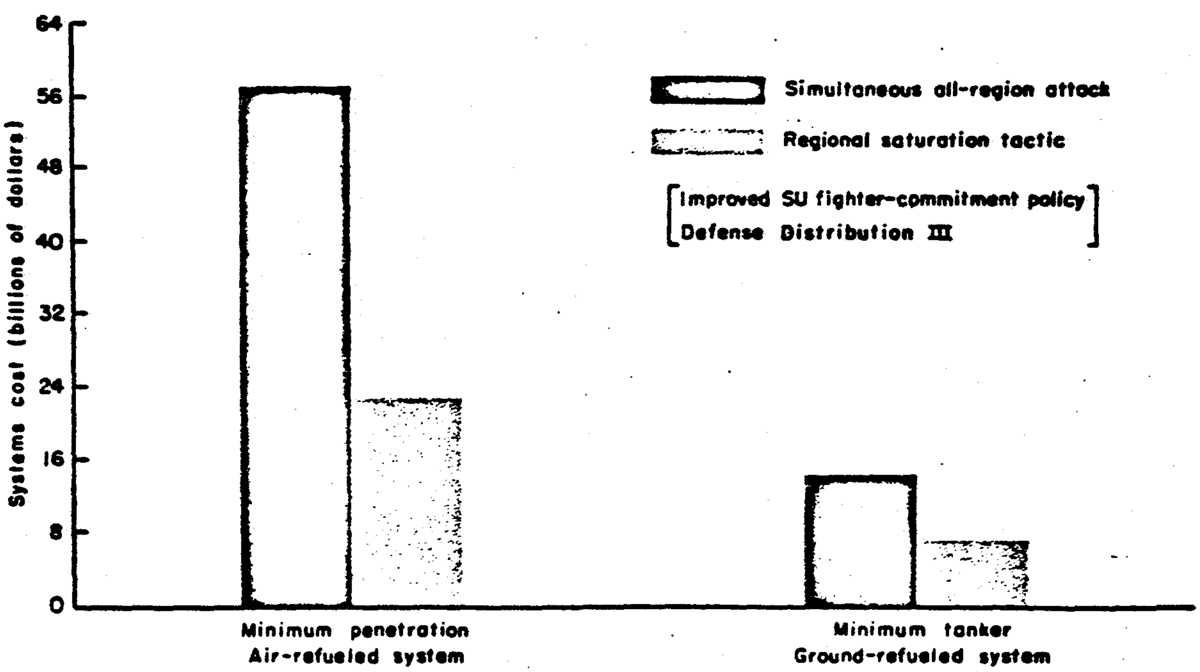


Fig. 63—Regional saturation tactic and unequal target values for 100-point target system: B-47 campaign (incremental 3-year cost)

Table 28

REGIONAL SATURATION TACTICS IN INTERCONTINENTAL B-47 CAMPAIGNS

	Air-refueled System	Ground-refueled System
Number of strikes	6	4
Total number of B-47's	790	875
Number of B-36-type tankers	1372	0
Number of KC-97's	0	210
New cost of bomber force	7.8	8.6
New cost of radius extension[a]	19.1	2.2
NEW COST OF COMPLETE SYSTEM	26.9	10.8
Inheritance	4.1	3.3
INCREMENTAL COST OF COMPLETE SYSTEM	22.8	7.5

[a] Includes cost of en route bases, refueling bases, and tankers.

In this campaign, the air-refueled system found it to its advantage to attack the two regions with highest total target value successively on its first two strikes, and after this to attack the smaller-valued regions several at a time for a total of six strikes. Minimum-penetration paths were employed throughout. The ground-refueled system used minimum-tanker paths for the most part, but found it economic in one case to go in on one side of the country and withdraw on the other.

The results of this campaign show once more the marked disadvantages of intercontinental air-refueling.

Local Defenses and Radius Capability

Local defenses may be distributed to make more nearly equal not only total offense bomber losses per unit of target value destroyed, but also total destruction costs to the offense, taking into account differences in radius-extension cost as well as differences in area kills. Local-defense kills may be made higher in regions of low fighter kills and low tanker requirements. As in the case of the area-defense redistributions we discuss, the enemy works within limitations here, too. There are limits first of all in the size of the local-defense kill potential available for such compensation.

Against the air-refueled system, the enemy could count on his high tanker costs in the south as making up in part for his present low night-fighter kill potential; and in the future, with increasing night-fighter kill potential in the south, the enemy could concentrate local defenses more heavily in the north to combat an exclusively air-refueled system. Against a peripheral overseas system, the total local- and area-defense kill potential would need, in the long run, to be diluted by more or less uniform spreading; and for the period in which his night-fighter potential would be relatively low, the south might draw a principal part of the local defenses to compensate. However, the total local-defense kill potential, even at the rather high levels assumed in this study, would not be enough, in 1956, to compensate for the estimated weaknesses of night-fighter defense. For this period the south will be a soft spot in the enemy's armor.

THE IMPORTANCE OF SOUTHERN BASES

To combat a base system having a larger offensive capability in the north, the Russians could in the future orient their defenses to accomplish what they are forced into now by night-fighter limitations: They could concentrate their kill potential in the north. A peripheral spread of bases is needed to minimize penetration distances to target and to compel dispersal of the defense. And, for the present, attacks from the south can expect an extra advantage because of deficiencies in the defense there. For the time being, then, as the attrition studies of the minimum-tanker paths for the ground-refueled system indicate, we can use even more bases in the south than in the north.

A comparison of base requirements and supply, assuming a peak strike of 1300 bombers, shows that the addition of as many as 20 bases to the south, preferably in Northeast Africa and the Arabian and Indian peninsulas, would be an important adjunct to our present base system. There has been Air Force interest in an expansion of the base program in this direction, and we should like to underscore its importance.

SUMMARY: THE EFFECTS OF ROUTE CHOICE

The implications of the analysis presented in this section may be stated as follows. First, it is important to develop a rounded capability for many-sided attack against the enemy target system. By doing this we force him to spread his defenses. This does not mean that on any one strike we need actually use a multiplicity of penetration paths starting from many sides. Having forced the dilution of his defense, we can concentrate on some portion of the target system and some few penetration paths to get the benefit of saturation. But the development of a rounded capability is a condition for concentration in its use. Second, the inferiority of the exclusively air-refueled intercontinental system which was evidenced by the cost and effectiveness versus radius studies of the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, is reinforced by an examination of the inflexibility this system imposes on the offense. The exclusively air-refueled system is less free than a peripheral overseas system in its choice of route, speed, and altitude of penetration. It permits corresponding concentration on the part of the defense. On the other hand, the analysis, while it has dissected the high costs of operating without an overseas base system, has not yet dealt explicitly with the logistics costs of operating with an overseas system. And, most important, it has not taken explicit account of the costs of defense and expected damage associated with the vulnerability of overseas bases.

D. Base to ZI: The Cost of Operations Outside the ZI

We have seen how difficult it is to operate without overseas bases. What are the difficulties of operating with them? So far the only overseas bases we have dealt with have been minimal overseas refueling bases. However, the formerly programmed 1956–1961 bombing force was designed in large part to operate from advanced overseas bases. In this section we examine the requirements and costs associated with our formerly programmed overseas operating base system and alternate operating base systems and with staging base systems.

The method of basing medium bombers on advanced overseas bases during wartime and of basing some overseas on rotation during peacetime was developed because (1) increasing bomber speed and altitude requirements have been gained at the expense of combat radius; (2) short missions offer an apparent advantage in increased sortie rates; and (3) there was a considerable heritage of bases from World War II in such advanced areas as the United Kingdom and Japan (many operating bases have been built overseas since then). It is important to assess these advantages in relation to the costs of operating a large part of our strategic force overseas, since a considerable part of the Air Force budget is directly or indirectly associated with this method of operation. In particular, it is important to discriminate among types of overseas base systems, since the cost and effectiveness of the entire strategic force depends largely on where systems functions are performed, how they are performed, and how they are protected against attack. There are wide variations in vulnerability as well as in construction, support, and operations costs.

COSTS OF PROCURING AND OPERATING BOMBERS IN THE ZI

When a wing of bombers or strategic fighters or a squadron of tankers is created, a direct investment in bases, personnel, stocks, and equipment is made, amounting to several million dollars per aircraft in addition to the cost of the aircraft itself. For every year during which the unit operates, costs are generated for maintenance and supplies, fuel, personnel pay and allowances, and replacement aircraft. The total cost of procuring and operating each of the aircraft types in the strategic force, as well as that of supporting aircraft, is presented in Table 29.

Table 29

THREE-YEAR SYSTEMS COSTS FOR VARIOUS AIRCRAFT[a]
Based in ZI

(Costs in millions of dollars)

	B-47		B-52		KC-97 Based with B-47's		KC-97 Separately Based	
	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual
Installations[b]								
Technical facilities	29.5	....	45.0	....	5.3	....	22.6	....
Personnel facilities	15.6	....	17.3	....	1.5	....	16.9	....
Maintenance	.....	2.2	.....	3.1	....	....	0.4	2.0
Major equipment[c]								
Mission aircraft	100.0	11.1	240.0	4.0	27.6	1.0	47.0	1.7
Support aircraft	10.0	....	24.0	....	2.8	....	4.7	....
Minor equipment[d]								
Organization equipment	6.5	0.4	9.2	0.6	0.7	0.1	4.5	0.2
Ground radar	0.6	0.1	0.6	0.1	....	....	0.6	0.1
Stocks[e]								
Initial stock level	2.5	....	3.4	....	0.5	....	1.3	....
Readiness reserve	2.2	....	4.6	....	2.3	....	3.2	....
Spares	47.2	....	115.2	....	12.5	....	18.0	....
Transportation[f]	0.9	1.1	1.1	1.4	0.1	0.1	0.5	0.5
Personnel[g]								
Training	22.8	5.7	23.8	6.0	2.6	0.6	14.0	3.5
Pay and allowances	.....	10.2	.....	13.2	....	1.7	.....	6.0
Travel	0.6	0.5	0.8	0.7	....	0.1	0.4	0.4
Maintenance[h]								
Mission aircraft	.....	8.6	.....	15.6	....	2.1	.....	4.5
Support aircraft	.....	0.6	.....	0.8	....	0.1	.....	0.4
POL[i]								
Mission aircraft	.....	4.8	.....	5.9	....	0.9	.....	1.6
Support aircraft	.....	0.3	.....	0.4	....	0.4	.....	0.2
Miscellaneous	.....	1.3	.....	1.7	....	0.2	.....	0.8
Service and Miscellaneous[j]	.....	0.4	.....	0.6	....	0.1	.....	0.2
Intermediate commands[k]	.....	3.0	.....	4.0	....	1.0	.....	2.1
Overhead[l]	.....	17.2	.....	19.4	....	2.9	.....	8.0
TOTAL	238.4	67.5	485.0	77.5	55.9	11.7	133.7	32.2
Number of aircraft per unit	45		30		20		36	
Cost per aircraft	5.3	1.5	16.0	2.6	2.8	0.6	3.7	0.9
TOTAL THREE-YEAR COST	9.8		23.8		4.6		6.4	

For footnotes, see pp. 190–193.

B-36-type Tanker		B-36 Wing		F-84F Wing		F-86D Wing		C-124C Group		C-97 Group	
Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual
31.8	....	35.9	....	18.3	....	13.6	....	25.0	....	38.0	1.9
21.8	....	27.4	....	16.7	....	11.5	....	12.0	....	.....	....
.....	2.7	.....	3.2	.....	1.8	....	1.3	.....	1.9	.....	....
100.2	3.7	121.2	4.4	27.4	2.7	23.7	5.0	60.2	1.7	45.4	4.5
10.0	....	12.1	....	2.7	....	2.4	....	6.0	....	4.5	....
5.2	0.3	8.7	0.5	4.0	0.2	4.0	0.2	5.7	0.3	4.5	0.2
0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1
2.6	....	2.9	....	1.2	....	1.1	....	1.7	....	1.3	....
2.0	....	3.4	....	0.5	....	0.7	....	2.2	....	2.2	....
37.0	....	58.7	....	22.0	....	10.4	....	30.0	....	22.0	....
1.0	1.2	1.1	1.4	0.5	0.7	0.5	0.6	0.6	0.7	0.7	1.0
18.2	4.5	23.8	6.0	8.3	2.1	8.2	2.1	14.0	3.5	14.0	3.5
.....	9.8	.....	13.2	.....	6.0	....	6.0	.....	7.0	.....	6.0
0.6	0.5	0.8	0.7	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.4
.....	12.0	.....	15.8	.....	3.2	....	6.1	.....	5.5	.....	4.5
.....	0.6	.....	0.7	.....	0.3	....	0.3	.....	0.4	.....	0.4
.....	4.6	.....	4.6	.....	0.9	....	1.4	.....	3.0	.....	1.6
.....	0.2	.....	0.3	.....	0.2	....	0.1	.....	0.2	.....	0.2
.....	1.5	.....	1.7	.....	0.8	.....	0.7	.....	0.9	.....	0.8
.....	0.4	.....	0.6	.....	0.2	....	0.2	.....	0.2	.....	0.2
.....	2.0	.....	3.8	.....	1.6	....	2.0	.....	2.1	.....	2.1
.....	14.6	.....	19.0	.....	7.0	....	8.8	.....	9.3	.....	9.1
231.0	58.7	296.6	76.0	102.6	28.1	77.1	35.2	158.4	37.2	133.6	36.5
30		30		75		75		36		36	
7.7	2.0	9.9	2.5	1.4	0.4	1.0	0.5	4.4	1.0	3.7	1.0
13.7		17.4		2.6		2.5		7.4		6.7	

Notes for Table 29

a. These costs are the peacetime costs incurred in the procurement and operation of each type of aircraft for a 3-year period. These are new costs and do not allow for any inheritance from previous periods or legacies to later ones.

(1) The 3-year cost for the B-52 is included, although this bomber is not scheduled to be in tactical units for that length of time prior to January, 1956, so that a comparison can be made on a comparable basis. Some specific assumptions are as follows: 4400 total personnel (peacetime manning); 2 C-47 and 19 B-26 MIT (minimum individual training) support aircraft; 50 flying hours per month for mission aircraft; aircraft cost based on production of 200 units.

(2) B-47 costs are based on: 3355 total personnel (readiness manning); 2 C-47 and 14 B-26 MIT support aircraft; 50 flying hours per month for mission aircraft, 75 for C-47's, and 41 for B-26's. Aircraft cost is based on production of 2000 units.

(3) B-36 costs are based on: 4403 total personnel (peacetime manning); 2 C-47 and 18 B-26 MIT support aircraft; 50 flying hours per month for mission aircraft.

(4) F-84F costs are based on: a fighter-bomber wing rather than a fighter-escort wing; 1909 total personnel (peacetime manning); 2 C-47, 12 F-51, and 6 T-33 support aircraft; 20 flying hours per month for mission aircraft.

(5) F-86D costs are based on: 1909 total personnel (peacetime manning); 2 C-47, 12 F-51 (2 tow target, 10 MIT), and 6 T-6 support aircraft; 28 flying hours per month per mission aircraft.

(6) Costs are developed for C-124 operation in a separately based Heavy Troop Carrier group. If the squadron is tenanted or other bases are considered, 3-year costs will be approximately $6.5 million per aircraft. With relatively small air logistics operations, the lower cost will apply; but with large numbers of aircraft engaged in air resupply, separate or augmented bases will be required. Specific assumptions are as follows: 2264 total personnel (peacetime manning); 2 C-47 and 9 B-26 support aircraft; 63 flying hours per month for C-124.

(7) The cost of the C-97 and KC-97 aircraft is displayed both in the 20-aircraft-squadron units, which are attached to medium-bomber wings, and as separate squadrons. Deployment of tanker squadrons to bomber bases permits economies of installations and personnel and is practicable with the bomber-tanker ratios programmed for the 1955–56 force. If a large number of tankers per bomber will be required, then the costs of separate tanker basing will be applicable.

b. Installations costs are based on *USAF Installations Facility Requirements*, 2d rev, April, 1952, Directorate of Installations, HqUSAF, and on *Cost Estimates for U.S. Air Force Construction*, April 1, 1952, Department of the Army, Office, Chief of Engineers.

Annual maintenance of installations is estimated at 5 per cent of construction cost. Included are the costs of materials and contractual services; labor is included under "Personnel." This factor was developed from an analysis of "Real Estate Facilities Management and Preservation Monthly Cost Reports" for selected Air Force Bases for FY 1950 and the first 4 months of FY 1951.

c. Major Equipment. The costs of the mission aircraft are from the latest USAF Airplane Program Budget Estimate. The estimated costs are for complete aircraft, including all government-furnished equipment. Aircraft spares and spare parts are included in the cost heading "Stocks."

An allowance of 10 per cent of the cost of the mission aircraft is added for command-support aircraft based on Air Force Letter 150-10, *Peacetime Planning Factors*, September 27, 1951, Department of the Air Force. Unit-support aircraft are assumed to be available from existing second-line stocks of aircraft; their cost is therefore excluded from the estimates.

Annual costs of mission aircraft reflect normal aircraft attrition. These attrition costs are computed on the basis of normal flying hours times the attrition per 100,000 flying hours as given in AFL 150-10, Table VII.

d. Minor Equipment. The *organizational-equipment* component of minor equipment includes such items as general- and special-purpose vehicles, construction equipment, materials-handling equipment, communications and test equipment, special flying clothing and similar individual equipment, and organization, base, and maintenance equipment.

Investment costs for organizational equipment are developed from the wartime cost columns of the USAF T/O & E Equipment Cost Reports as of 1950. Costs are available directly from the reports for some of the wings. For other wings, costs are interpolated on the basis of gross weight of the aircraft, the available costs of the most similar aircraft being used as bench marks. No T/A equipment is provided.

Cost of replacement of organizational equipment—the amount shown as annual cost—is estimated to be 6 per cent of the investment cost. Maintenance of organizational equipment is included in the amount for the "Services and Miscellaneous" element of wing cost.

The estimate for the investment cost of ground-controlled approach radar (assuming one installation per wing) is based on current budget estimates. The annual cost is based on an expected life of 6 years.

e. Stocks. For convenience of estimation and presentation, stock-level estimates are broken down into three components: (1) initial stock level, (2) readiness reserve, and (3) spares.

The estimate for *initial stock level* includes those supply costs which are occasioned by the aircraft wing but which do not appear as annual charges. This allowance was suggested by Headquarters, Air Materiel Command, and is the allowance suggested for most items in the FY 1953 budget guidance, *Secondary Program Guidance for Logistic and Material Budgetary FY 1953*, September 11, 1951, Department of the Air Force, DCS/Operations, Assistant for Programming. It provides for 6 months' procurement lead time and for 5.5 months' base and depot stock levels and pipelines. The allowance for all supplies other than fuel and lubes and aircraft spares and spare parts consists of 345 days of supplies at the annual consumption rate, i.e., 345/365 of the estimated annual supply costs.

The initial-stock-level allowance for aviation fuel and lubes is 75 days' supply at peacetime-consumption rates. Other fuels and lubes are included at 90 per cent of capacity of base-storage facilities.

Stock levels and lead time for aircraft-component spares and spare parts are included under the entry "Spares."

A 90-day *readiness-reserve* allowance is made for supplies used in installations, services, and for personnel. A readiness-reserve stock of aviation fuel and lubes is estimated at 75 days' supply at war-consumption rates. Other fuels and lubes are also estimated at 75 days' supply, but at peacetime-consumption rates.

The estimates for *spares* (including aircraft spare parts) are based on the following budget estimates for FY 1952 and FY 1953: Headquarters, Air Materiel Command, Director of Procurement and Production, WPAFB: (*a*) *USAF Airplane Budget Program Revised, 6828 Airplanes, FY 1952, Regular*, February 1, 1952; (*b*) *Budget Estimates USAF Airplane Program, 1163 Airplanes, FY 1952 Supplemental*, February 1, 1952; (*c*) *Budget Estimates USAF Airplane Program, 6410 Airplanes, FY 1953*, February 1, 1952. This figure includes stock-level and pipeline requirements, as well as readiness-reserve requirements in the form of flyaway kits, Table II's, and Table XVI's. It also includes engine requirements for the first-line life of the aircraft.

One adjustment is made to these budget estimates. The budgeted total includes, among other items, the estimated maintenance-material requirements for the first year's operation of the aircraft. Since this cost is included in the present study as an annual cost under the heading "Maintenance—Mission Aircraft," it was deducted from the budget estimate.

f. Transportation. Transportation costs are for an average shipping distance of 1000 mi. An estimated cost of $50.00 per ton, including packaging, was developed from tonnage data and cost obtained from the Traffic Division at Headquarters, Air Materiel Command. The tonnage to be transported (excluding petroleum, oil, and lubricants) is estimated from planning factors obtained from AFM 400-5. The cost of transportation POL is included in the estimated cost of the POL.

g. Personnel. The manpower figures of all wings represent estimates of "typical" authorized military and civilian strengths as of March, 1951. Total manpower authorizations include T/O, T/D-A, and civilians. The T/O portion was taken directly from T/O & E Branch, Manpower Requirements Division, DCS/Operations, Manpower and Organization, *Typical T/O Strengths—Wings and Separate Squadrons*, Director Statistical Services, AFASC-3D, DCS/Comptroller, March 1, 1951. Where T/O's were not available, the most analogous existing wing was used for which T/O's did exist. The T/D-A portion was estimated by applying to the T/O strengths an approximate ratio of total non-T/O to total T/O strength of the major command that is to operate the wing under study. The civilian portion included is 10 per cent of the total military strength of each wing.

The investment cost of training the manpower of each wing is based directly on formal training costs of wings as computed by Program Standards and Cost Control, Headquarters, U.S. Air Force. The annual training costs are included at 25 per cent of investment cost.

Annual personnel operating costs, including the cost of payroll, subsistence, clothing, TDY travel, and miscellaneous allowances for each wing, are based on an analysis of Form 320 cost data for May, 1951.

Travel. Costs per man were developed from information obtained at the Directorate of Transportation, HqUSAF. The average distance traveled in the ZI by military personnel is assumed to be 1000 miles. Allowances are included for the travel of dependents and for the shipment of household goods for officers and for the first three grades of airmen.

Annual costs are assumed to be 85 per cent of initial costs. This is for an estimated annual peacetime attrition rate of 25 per cent (for discharge, retirement, death, etc.) and an annual rate of 60 per cent for permanent change of station.

h. Maintenance. Maintenance costs for both mission and support aircraft were developed from two sets of average costs per flying hours: one computed and published by DCS/Comptroller, and the other based on SCOOP computations. For mission aircraft and MIT and tactical-unit support aircraft, the models and rates of utilization were obtained from Air Force peacetime planning factors.

i. POL. The estimated costs of POL (petroleum, oil, and lubricants) were obtained from DCS/Comptroller's estimated flying-hour costs, or from Air Force planning factors. For mission aircraft and support aircraft the number of flying hours per month were developed from Air Force planning factors.

Miscellaneous POL requirements include fuel for heating, cooking, and the motor pool. The physical requirements given in AFM 400-5 are the rates stated in "Program 121-8," Headquarters, Eastern Air Defense Force, December 19, 1950.

j. Service and Miscellaneous. The estimates for "service and miscellaneous" costs cover annual operating and maintenance costs reported on Forms 320 not included in the cost categories described above. This is costs of materials and supplies for such functions as administration, flight service, supply operations, medical service, food service, and operation and maintenance of organizational equipment. The estimated costs are based on an analysis of cost reports of combat wings and separate squadrons in SAC, TAC, and ADC for the months of May, June, and July, 1951.

k. Intermediate Commands. The intermediate-command estimate includes the costs of support given the wing by organizations at and below the major-command-headquarters level (i.e., HqSAC, HqTAC, or HqADC). The costs of major-command headquarters and other command headquarters above the wing level and below the major-command-headquarters level (e.g., air divisions and numbered air forces) are included here. The costs of organizations other than these headquarters that support the primary mission of the command but do not perform that mission themselves are included. Examples are radar-calibration units, statistical-service squadrons, liaison flights, etc. The estimates were based on an analysis of SAC, TAC, and ADC cost reports for the months of May, June, and July, 1951.

l. The overhead estimate consists of an allocation of the costs of major commands other than the one to which the unit belongs.

The major initial expenditure in the build-up of the force is for aircraft and bases. For medium-bomber wings, these items account for 46 and 19 per cent, respectively, of the total cost of creating a B-47 wing. The major annual costs generated are for maintenance and fuel, pay and allowances of personnel, and aircraft replacement. These account for 23, 15, and 16 per cent of the costs that recur every year for this aircraft type. The relation of each of the cost categories to total system cost, including both investment and annual costs, is shown in Table 30 over 3- and 8-year time periods. The relative importance of systems components changes with the time period examined, and an evaluation of the cost and effectiveness of measures affecting the strategic force should be examined for sensitivity to cost patterns. High initial base costs, for example, are followed by still higher aircraft operating costs over a period of years.

The total cost of building up the ZI component of the strategic force from its January, 1953, position to the 143-wing program goal and of operating it

Table 30

RELATION OF B-47 COST CATEGORIES TO TOTAL ZI SYSTEMS COST

	Three-year Period (%)	*Eight-year Period* (%)
Installations	12	8
Major equipment	33	25
Minor equipment	2	1
Stocks	12	7
Transportation	1	1
Personnel	16	20
Maintenance	6	9
POL	4	7
Service and miscellaneous	([a])	([a])
Intermediate commands	2	4
Overhead	12	18
TOTAL	100	100

[a] Less than 0.5 per cent.

until January, 1958, would be approximately $25.5 billion. The relatively small number of aircraft available for combat from this budget emphasizes the large differential between bomber procurement cost and total system cost per bomber operated. In the case of the B-47, it costs four times as much ($9.8 million) to have a combat-ready bomber on ZI bases over a 3-year period than it does to procure the bomber alone. Since the Air Force is following the policy of having no reserves of first-line aircraft, and since there will be hardly any opportunity for the production of aircraft during the atomic phase of the strategic air campaign, the force in being on D-day, procured from limited peacetime funds, is the force we shall have with which to fight the campaign.

REQUIREMENTS AND COSTS FOR OVERSEAS OPERATING BASES

Having the capability of rapidly deploying to overseas bases and commencing operations adds substantially to the cost of the strategic force. In addition, high costs are incurred for active defenses and for the procurement of aircraft likely to be killed on the ground during the campaign. The average additional cost of having an overseas operating capability, excluding en route bases, tanker costs, and any consideration of active defenses and ground attrition, comes to approximately 56 per cent of the ZI total 3-year cost. This is an average operating cost; and in the Arctic it may be as much as 144 per cent more than ZI costs. These substantial additional costs are incurred in spite of economies effected by the Mobility Plan type of operation. Although this carefully thought out plan acts to reduce peacetime costs of operation and initial-force vulnerability, as compared with alternatively maintaining the strategic force overseas in peacetime, we still have large base, airlift, logistics support, and personnel requirements. Major costs are shown in Table 31.

Bases

The overseas strategic base system as originally planned for the 143-wing Air Force program would cost ultimately $3.4 billion. Of this amount, approximately 1.4 billion dollars' worth of facilities were in place or committed in January, 1953. This sum would provide us with 26 operating bases for medium bombers and strategic fighters, 7 additional operating bases for tankers and strategic reconnaissance, and 10 additional staging bases for medium and heavy bombers and strategic fighters. Excluded from these totals were requirements for the basing of interceptors, radar stations intended primarily for the defense of SAC, depots contributing to SAC support, terminal pipeline, and medical facilities in overseas theaters.

Table 32 shows typical base costs overseas for operating staging bases. Rotational bases are built to ZI standards; bases for wartime operation are designed to a more austere standard. A staging base costs about 40 per cent as much as a rotational base, while a wartime operating base cost is intermediate. Figures 64 and 65 show two types of staging bases.

Costs of construction vary widely among base regions, depending on the existence of a construction industry, supply of labor, port and transportation facilities, climate, and terrain. These costs vary from 120 to 400 per cent of ZI costs as shown in Table 33 (page 200). In addition, there is a wide difference among base areas in the facilities already in existence upon which we can build. And, in general, there is a correlation between a high inheritance of facilities "free" and low costs of construction for a given base area. The United Kingdom and Japan are the most noteworthy in this regard. For example, the total cost of improving 10 United Kingdom bases to suitable standards approximately equals the cost of *one* base constructed in Alaska or Iceland.

Personnel, Equipment, Stocks, and Theater Support

After our forces deploy overseas, they must have available for use: vehicles; housekeeping, communications, maintenance, photographic, medical, and

Table 31

ADDITIONAL COST OF B-47 OVERSEAS OPERATIONS[a]

(Costs in millions of dollars)

	French Morocco		United Kingdom		Northern Greenland		Alaska		Iceland		Japan		Labrador-Newfoundland	
	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual
Installations														
Construction	68.1	....	58.0	....	250.0[b]	....	90.0	....	113.0	....	54.6	....	113.0	....
Maintenance	.....	3.4	.....	2.9	.....	12.5	.....	4.5	.....	3.6	.....	2.7	.....	3.7
Minor equipment														
Organizational	2.7	0.2	2.7	0.2	3.7	0.3	3.7	0.3	2.7	0.2	2.7	0.2	2.7	0.2
Ground radar	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.1
Stocks														
Initial	2.0	....	2.0	....	4.5	....	3.5	....	2.0	....	2.0	....	2.0	....
Readiness reserve	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
Spares	14.8	....	14.8	....	29.6	....	18.1	....	14.8	....	16.8	....	14.8	....
Transportation	0.1	0.1	0.1	0.1	0.4	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Personnel														
Training	1.5	0.4	1.5	0.4	6.8	1.7	6.8	1.7	1.5	0.4	1.5	0.4	1.5	0.4
Pay and allowances	.....	1.5	.....	1.5	.....	3.0	.....	7.0	.....	1.5	.....	1.5	.....	1.5
Travel	0.1	0.1	0.1	0.1	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Service and miscellaneous	.....	0.4	.....	0.4	.....	0.8	.....	0.6	.....	0.4	.....	0.4	.....	0.4
Intermediate commands	.....	1.0	.....	1.0	.....	1.0	.....	1.0	.....	1.0	.....	1.0	.....	1.0
Theater support	32.7	9.9	29.5	9.7	84.5	14.2	48.8	12.4	48.7	10.7	28.1	9.6	26.6	7.4
Airlift	31.0	8.0	31.0	8.0	31.0	8.0	31.0	8.0	31.0	8.0	31.0	8.0	15.5	4.0
TOTAL	153.5	25.0	142.5	24.4	409.7	42.5	192.9	31.9	214.5	28.1	141.7	24.1	175.9	20.9
Cost per bomber	3.4	0.6	3.2	0.5	9.1	0.9	4.3	0.7	4.8	0.6	3.2	0.5	3.9	0.5
Additional three-year cost per bomber	5.1		4.8		11.9[c]		6.4		6.7		4.8		5.3	
TOTAL THREE-YEAR COST (ZI and overseas)	14.9		14.6		21.7		16.2		16.5		14.6		15.1	

[a] Excluding costs of en route bases and tanker systems.

[b] This is a published initial estimate. Recent classified information indicated that to give this base capability as an operating base would cost an additional $100 million.

[c] If the higher installation cost is taken into account, the 3-year cost per operating bomber will rise to $14.1 million.

Table 32

FACILITIES COSTS FOR OVERSEAS MEDIUM BOMBER AIR BASES

(In millions of dollars, ZI prices)

	Rotational Base[a]—1 Runway	Wartime Operating Base[b]—1 Runway	Refueling Bases: 1 Runway, Underground Fuel	Refueling Bases: 1 Runway, Dispersed Fuel	Refueling Bases: 2 Runways, Underground Fuel
Airfield pavements					
Runway	2.91	2.91	2.91	2.91	5.82
Taxiway	1.39	1.39	1.39	1.39	2.78
Aprons	6.59	3.84	1.98	1.98	2.58
TOTAL	10.80	8.14	6.28	6.28	11.18
Fuel storage and distribution					
Bulk fuel storage	0.74	0.30	4.44	1.14	4.44
Hydrants and operating storage	2.02	2.02	2.76	2.76	2.76
Miscellaneous POL	0.03	0.01	0.02	0.02	0.02
TOTAL	2.79	2.33	7.22	3.92	7.22
Communications, Nav Aids, and airfield lighting	0.93	0.85	0.60	0.60	0.60
Operational facilities	1.34	0.82	0.22	0.22	0.22
Aircraft maintenance facilities	6.19	5.31	.....	.....	.....
Training facilities	0.69	0.47	.....	.....	.....
Troop housing	5.59	4.78	0.41	0.41	0.41
Family housing	.....	.....	.....	.....	.....
Administrative and community facilities	4.33	3.11	0.16	0.16	0.16
Utilities	3.34	2.91	1.19	1.19	1.19
Medical facilities	1.92	1.92	0.16	0.16	0.16
Storage facilities	1.75	1.85	0.08	0.08	0.08
Shops	0.52	0.91	0.02	0.02	0.02
TOTAL COST AT ZI PRICES	40.20	33.40	16.36	13.06	21.26
OVERSEAS COST (1.5 × ZI cost) (North Africa)	60.30	50.10	24.60	19.60	36.90

[a] As shown in *USAF Installations Facility Requirements*, 2d rev, April, 1952, Directorate of Installations, HqUSAF.
[b] As shown in *USAF Installations Facility Requirements*, 3d rev, February, 1953, Directorate of Installations, HqUSAF.

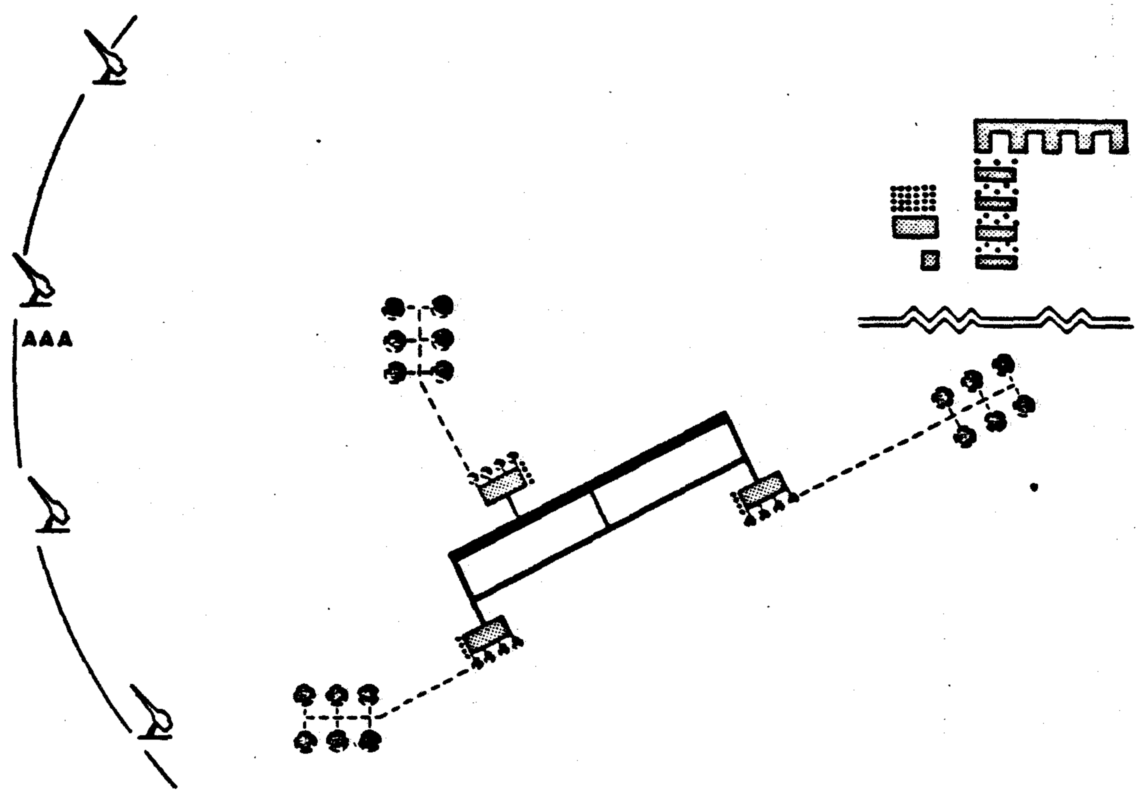


Fig. 64—One-runway refueling base (POL storage underground)

administrative equipment; and stocks of fuel, aircraft spares, oxygen, ammunition, rations, assist take-off units, chaff, etc. Not all this equipment need be duplicated on overseas bases, and the Air Force both pre-positions material overseas (Project Seaweed) and airlifts unit essential equipment and flying kits from ZI bases. In addition to these immediate requirements, which must be met on D-day, there is need for a continuing resupply throughout the campaign as flying kits and base supplies are exhausted. This necessity is being met by the establishment of depot stocks overseas and by plans for the continuation of airlift from the ZI. The support of the resupply activity has led to the development of theater depots. Other theater-supporting units include Aviation Field Depot Squadrons; Globecom units; Air Rescue and Air Weather Squadrons; medical, port pipeline, and transportation units; etc. An estimated 70,000 men, in addition to wing personnel, are required for the support of SAC overseas operations. The total initial cost per wing of the additional overseas base equipment and stocks and of facilities, personnel, equipment, and supplies for supporting units comes to $50.8 million, or 21 per cent of the ZI B-47 system initial cost.

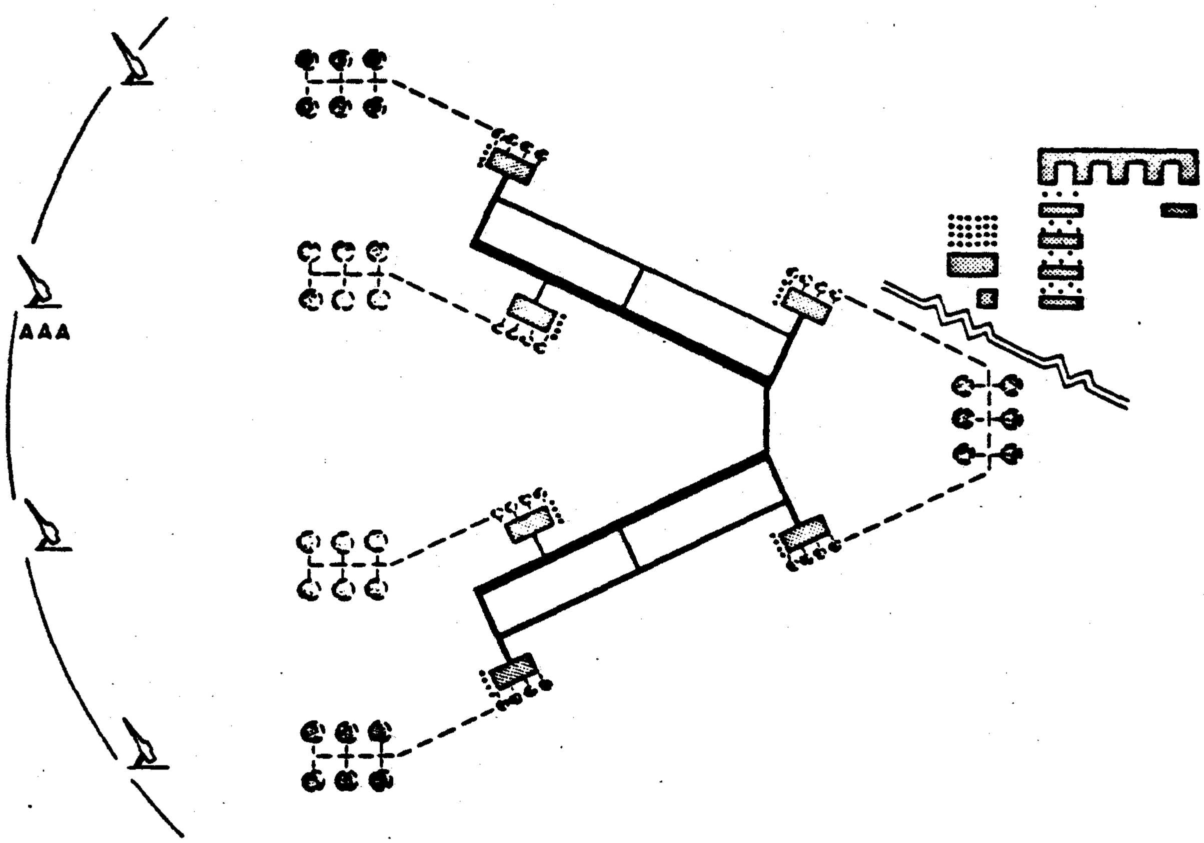


Fig. 65—Two-runway refueling base (POL storage underground)

Airlift

The deployment of a B-47 wing with air-refueling squadron means airlifting 621,000 lb of material and 2297 persons in three air echelons. Although unit aircraft provide most of this airlift, the first air echelon transport requirements (E to E + 5) is for 13 C-54 equivalent aircraft. This rises to 29 C-54 equivalent for the second air echelon (normally on E + 5 to E + 7). The continuing airlift requirement, largely aircraft engines, may occupy approximately 10 C-54 equivalent aircraft. However, if it is desired to operate for an indefinite period of time from overseas bases, as was contemplated under the formerly programmed system, and to operate under circumstances which make surface transport difficult, a continuing airlift requirement of 26 C-54 equivalents might be generated. This requirement would exclude air transport of POL, rations, and ammunition. The magnitude of the total SAC airlift requirement is indicated by the fact that the deployment of 4 heavy- and 20 medium-bomber and reconnaissance wings and 5 strategic fighter wings would require

Table 33

DEPARTMENT OF DEFENSE
CONSTRUCTION COST INDICES—OVERSEAS CONSTRUCTION
April 1, 1952

Atlantic	
Azores	1.5
Bermuda	1.4
Greenland—Grondal	2.5
Iceland	2.5
Labrador	2.5
Newfoundland (interior)	2.0
Argentia	1.8
Caribbean Area	
Bahama Islands	1.5
Canal Zone	1.4
Caribbean Area (general)	1.4
Mediterranean and North African Area	
Mediterranean Area (general)	1.3
French Morocco (general)	1.5
Liberia, Africa	1.6
Port Lyautey	1.3
Tripoli	2.0
Persian Gulf Area	
Iran	1.5
Dhahran, Saudi Arabia	2.0
Ceylon	1.5
European Area	
Denmark	2.0
England	1.3
France	1.2
Italy	1.2
Luxemburg	1.2
Norway	2.0
Spain	1.5
Pacific	
Admiralty Islands—Manus	2.0
Alaska	
Anchorage Area—Elmendorf	1.7
Adak	3.0
Attu	3.0
Dutch Harbor	2.5
Fairbanks Area—Eilson and Ladd	2.0
Kodiak	2.5
North of Alaska Range except Fairbanks Area	4.0
Bonin Islands—Iwo Jima	
Caroline Islands—Truk and Palau	1.7
Hawaii	1.6
Japan	1.2
Johnston Island	2.0
Marcus Island	2.6
Marianas Islands—Guam, Saipan, and Tinian	2.2
Marshall Islands—Eniwetok, Kwajalein, and Majuro	2.2
Midway	2.2
Palmyra	2.2
Philippine Islands	1.5
Ryukyu Islands—Okinawa	1.9
Samoa Islands—Tutuila	2.0
Wake Island	2.6

the use of *all* Military Air Transport Service (MATS) aircraft. After a period of weeks, some 300 C-54 equivalents from the Civil Air Fleet could be made available, but MATS and Strategic Support aircraft would have to support initial deployment. Although the cost of the airlift support received by SAC is reduced by the peacetime services performed by MATS, it nevertheless adds 12 per cent to the basic ZI 3-year systems costs.

En Route Bases

The movement overseas, simultaneously, of up to 2400 bombers, tankers, fighters, and transports generates a heavy traffic load on those intermediate bases used for fueling and crew rest between home and overseas bases. In deploying from the ZI to our scheduled forward operating bases, B-47's land an average of 0.7 times; and transports, 3.0 times. This traffic saturates the limited en route base facilities available and leads to slow deployment overseas, the arrival of medium bombers at overseas bases being spread over a time period as long as 3 days. While, as presently scheduled, en route bases add little to overseas costs of operation, the indirect effect of this systems component, through increased vulnerability of the striking force prior to the first strike, appears to be of considerable significance.

Active Defenses

So far we have dealt with the direct operating and support costs overseas. However, our overseas base system is to be defended by radar, antiaircraft artillery, fighters, and ground forces. Not all the defenses deployed in SAC base areas are intended for strategic base defense, and there is considerable "free" defense obtained in the United Kingdom, Japan, and Alaska, just as in the ZI. Nevertheless, many of the defenses located overseas can be charged to SAC. The estimated 3-year cost of defense weapons programmed for overseas strategic base defense comes to approximately $2 billion.

INTERMEDIATE OVERSEAS OPERATING BASES

There are other alternatives than the extreme ones of locating bombers either on advanced bases or back in the ZI. Intermediate locations might be expected to have some of the advantages of decreasing our own mission distance, as compared with that of ZI bases, and of decreasing our ground vulnerability, as compared with that of advanced bases. In the expansion, since 1950, of the overseas strategic base structure, there has been a pronounced tendency to develop base areas more remote from the Soviet Union than are the United Kingdom and Japan. French Morocco, Spain, Libya, and Iceland, unlike the United Kingdom and Japan, are beyond the combat radius of SU jet light bombers, although well within unrefueled TU-4 radius. Intermediate areas that might be expected to show a clearer difference are those beyond unrefueled TU-4 radius. Two intermediate base systems meeting this condition are (1) a system of operating bases confined solely to the North American continent, and (2) a system of operating bases around the periphery of the Soviet Union.

North American Bases

The usable base area in North America, north of the ZI, beyond unrefueled TU-4 radius is confined to Labrador, Newfoundland, and, possibly, the southwest coast of Greenland. Operation from this region would reduce mission length by 500 to 1200 n mi as compared with operation from Limestone. The effect of this reduction in mission length on tanker requirements per operating bomber is shown in Table 34. Along direct minimum-tanker routes, there is a significant reduction in tanker ratios as compared with ZI basing; but the reduction along more desirable minimum-penetration paths is slight, since operation from farther north does not benefit those aircraft approaching the Soviet Union from the south. (It should be noted that it is not possible to shorten significantly mission distances against most Eastern Siberian targets and meet the constraint of remaining beyond TU-4 unrefueled radius. Fairchild AFB itself is barely beyond TU-4 radius.) Moreover, the slight reduction effected in the *number* of tankers along minimum-penetration paths is more than offset by the increased cost of operating the tankers overseas as compared with operating them from the ZI; and even the more sizeable quantitative reduction effected for the more direct paths is almost obliterated by the higher cost of tanker operations overseas.

The cost of operation from the Labrador-Newfoundland area is presented in Table 31, page 196. As compared with most other overseas locations, we find that base costs are much higher; stocks and aircraft costs, lower. The total addition to ZI Force costs, excluding defenses, is approximately the same as for advanced overseas areas. However, the inheritance of bases we could obtain is small here in comparison with that in other overseas areas. Only Goose Bay, Harmon, Argentia, Pepperell, and a few other smaller bases exist as a nucleus for the build-up of an extensive base complex.

A Peripheral, Intermediate Base System

Moving back beyond SU medium-bomber radius would mean using existing bases and developing others in the ZI, Labrador, Newfoundland, the Azores, Central Africa, the Indian Peninsula, and the Pacific. Operation around the periphery of the Soviet Union, even from such remote locations, would permit relatively direct routes to targets with substantially reduced tanker requirements, as compared with operation from a system of North American bases alone (see Table 34). However, this intermediate system, like the previous

Table 34

COMPARATIVE COSTS OF ALTERNATIVE OPERATING-BASE SYSTEMS

(New three-year costs in millions of dollars)

	Zone of Interior				North America				North America, Central Africa, Pacific	Advanced Overseas	
	Minimum-penetration Routes		Minimum-tanker Routes		Minimum-penetration Routes		Minimum-tanker Routes		Minimum-penetration Routes	Minimum-penetration Routes	
	B-36-type Tanker	KC-97 Tanker	B-36-type Tanker	KC-97 Tanker	B-36-type Tanker	KC-97 Tanker	B-36-type Tanker	KC-97 Tanker	KC-97 Tanker	B-36-type Tanker	KC-97 Tanker
Average tanker-bomber ratio	2.2	0.55	1.3	1.1	1.5	1.2	0.31	1.8	1.7	0.03	0.2
Cost per tanker[a]	13.5	4.5	13.5	6.4	21.5	9.0	21.5	9.0	9.0	21.5	7.1
Radius extension cost per bomber[b]	32.9		25.3		43.0		22.9		15.3	2.1	
B-47 cost	10.5		10.5		15.1		15.1		15.1	16.5	
TOTAL BOMBER AND TANKER SYSTEMS COST	43.4		35.8		58.1		38.0		30.4	18.6	

[a] Includes the cost of operating the tankers in the ZI and of providing a capability for operating them outside the ZI where required.

[b] Includes the additional cost of providing a capability for operating the bombers outside the ZI and the cost of en route and staging bases.

one, would have a small inheritance to build on. And the extent to which vulnerability would be reduced has to be carefully assessed.

OVERSEAS REFUELING-BASE SYSTEMS

This method of operation for both medium and heavy bombers is essentially an extension of the method adopted by SAC, in an even earlier period of lesser Soviet danger, for the operation of its heavy bombers at intercontinental distances and for its medium bombers from some overseas bases. More recently, to meet the danger of increasing SU offensive capability, this extension of the method to medium bombers has been adopted. It makes use of minimal forward bases, rapid refueling of aircraft, and control and maintenance teams. An overseas refueling base adds 14 per cent (excluding tanker costs, defense costs, and ground attrition) to the cost of buying and operating bombers in the ZI. This increment is to be contrasted with the 59 per cent or more additional cost of having an overseas operating base system. The latter costs include the expense of a minimal number of en route bases determined by traffic, but exclude consideration of the costs of defense and ground attrition (see Tables 35, below, and 31, page 196).

The primary function of the refueling base is to provide fuel for aircraft

Table 35

ADDITIONAL COSTS OF B-47 STAGING OVERSEAS

(In millions of dollars)

	Initial	Annual
Installations	24.6	1.2
Equipment and stocks	3.0	...
Runway repair equipment	0.8	...
Personnel		
Training	0.3	0.1
Pay and allowances	....	0.3
Theatre support	5.8	2.6
Airlift	7.0	2.0
TOTAL	41.5	6.2
Cost per bomber	0.92	0.14
THREE-YEAR COST PER BOMBER	1.35	

within a restricted period of time. It may be thought of as a tanker performing at minimum altitude. Other functions which may be performed as matters of necessity or convenience are crew rest or exchange, briefing, feeding, and interrogation; aircraft inspections, servicing and decontamination, minor maintenance and repair; bomb replacement; and medical aid. However, it is the essence of the refueling-base method that both the extent and duration of the foregoing functions are explicitly constrained by the expectation of enemy attack. These functions generate requirements for facilities, personnel equipment, and strategic support as follows:

Installations

Table 32 (page 197) presents facilities and costs for three alternate refueling bases which are designed to handle simultaneously the available aircraft (two-thirds) of a wing of 45 B-47 bombers and 20 KC-97 tankers or a wing of 30 B-36 or B-52 bombers. On each base, the major costs are for airfield pavements and fuel systems. These make up about 85 per cent of total base cost. And while the functions performed on these bases are few, the facilities provided for these functions are not. In particular, extensive fueling facilities have been installed in order that bombers can be staged through rapidly. Costs given include passive defense measures described in detail in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225. Facilities presented do not include provisions for tenant missions often located on overseas strategic bases; but, neither do they take account of the possible economies of using bases developed principally for purposes other than SAC's.

Base Equipment and Stocks

The equipment and stock item includes a medium-bomber reconnaissance half-Station Set of the type presently being allocated to staging bases, augmented to permit more rapid servicing and maintenance of aircraft; a Housekeeping Set for the base complement; and fuel and other stocks. There is, in addition, a considerably enlarged list of heavy construction equipment for runway repair. The effect on recuperation time of this augmentation is shown in Table 48 on page 330. The major item of supply stored on base is fuel. Stocks of oxygen, carbon dioxide, and assist take-off units are also included.

Base Requirements

Figure 66*a* (page 210*f*) shows occupancy patterns at refueling bases for a case which places the maximum load on bases, crew, the number of landings and take-offs, and coordination and control facilities. This is a case in which—

1. B-47's are required to strike every type of SU target.
2. An impact tactic employing all aircraft is used (29 wings).
3. All target regions in the USSR—including areas such as the Far East and northwest USSR, whose defenses are relatively independent—are penetrated simultaneously.
4. Base use has been constrained on grounds of vulnerability by limits placed on the number of aircraft occupying the base simultaneously (30 aircraft), and by limits placed on the duration of the period of occupancy, according to proximity to enemy striking power (2 to 16 hr).

By using the range-extended B-47E, which will in any case be phased into the force, by assigning the long missions to the heavy bombers, by following a reserve strike tactic, and by employing regional saturation strike patterns of the kind described in the section entitled "Bases, Targets, and Penetration Paths," page 135, the loads shown can be drastically reduced. This would affect the abort rate, the crew fatigue problem, etc., as shown below. It would also reduce the number of bases and tankers required and other costs associated with the refueling operation. Some other occupancy patterns are presented in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225.

Mobile Control and Maintenance Teams

The functions of SAC staging teams are as follows:*

(1) Control Elements—.Command and control in accordance with SAC Reg. 55–16; weather, route, and intelligence briefing: Interrogation; Intelligence and Operations reporting.

(2) Maintenance Elements—.Specialized inspection and maintenance of aircraft, including limited emergency repair of battle damage; radiological decontamination of aircraft and matériel.

(3) Medical Elements—.Emergency medical care of crews of staging aircraft and of staging team personnel.

(4) Service Elements—.Assistance, as necessary, to base complements in handling increased work load in messing, motor transport, munitions handling, refueling and crash rescue, and security functions.

The Strategic Air Command has developed three teams to provide specialized staging support: Control and En Route Maintenance Teams (C and EMT's)

**SAC Mobility Planners Guide*, SAC Manual 400-1, HySAC, p. IVA-1.

for prestrike staging; Control and Maintenance Task Forces (C and MTF's) for poststrike staging; and Advance Echelons (ADVON's) for turn-around staging. These teams are designed to complete staging service within 24 hr for C and MTF's and C and EMT's and within 48 hr for ADVON's.

On vulnerability grounds, it appears that short periods of forward-base occupancy are essential. Within these safe periods—from 3 to 16 hr, depending on location—at least the functions of land, fueling, and take-off occur. Few maintenance functions can be performed within these short periods. In general, it appears better to accept a higher abort rate on overseas bases through reduced maintenance than to risk the destruction of a large part of the strategic force. The components requiring repair should be largely nonelectronic in character, since the K-bombing systems responsible for most aborts will not have to be operated on this leg of the mission. However, every attempt should be made to reduce aborts on forward bases by performing maintenance and repair functions *within* these restricted occupancy periods. In fact, it appears that B-47 and B-52 aborts on prestrike bases will be low. We distinguish between those aborts normally associated with combat missions: those occurring through a large increase in mission length, and those produced by the landing and take-off of aircraft. When we increase mission length by operating from the ZI as compared with operating from overseas bases, aborts, chiefly from engine failure, increase by about 3 per cent. With each landing and take-off, additional aborts occur. A total of 10 per cent additional aborts for each prestrike landing has been assumed in the campaign comparison. To be explicit, it had been assumed that 15 per cent of those taking off aborted before the first landing, 10 per cent of those remaining aborted at the first refueling stop, and, if there were a second refueling, that 10 per cent of this reduced force aborted there. It appears on the basis of the information available that this is a pessimistic estimate. The function of the En Route Maintenance Team is to prepare for combat all aircraft that can be readied within the short time available, and to prepare only for flight back to home base the remaining few aircraft.

The function of poststrike maintenance teams is to get aircraft off base as quickly as possible. Short periods of occupancy are as important as on prestrike bases. Some aircraft will have extensive battle damage beyond the capability of the C and MTF to repair quickly, if at all; and, for seriously damaged aircraft, it appears that mobile depot repair teams airlifted from overseas or ZI depots should be used. The most seriously damaged aircraft will be used as a source of aircraft parts through cannibalization. On poststrike bases the peak traffic load will be lower than that experienced on prestrike bases, since, in general, bombers will be returning in a stream, first from shallow targets and then from deep ones (see Fig. 66*a*). This reduction in peak traffic load significantly reduces the maximum exposure of the strike force to attack on poststrike bases.

Personnel

Crews. Missions mounted from ZI bases are, on the average, about 2.2 times as long as missions from programmed overseas bases. This increase in mission flight time introduces serious problems of crew fatigue, especially in the B-45 with its restricted crew space. These difficulties are characteristic of all intercontinental missions with manned aircraft. They are, of course, more difficult to solve in the case of such missions as have no ground stops, whether we use single-stage or air-refueled bombers. In any event, it appears that crew fatigue is a serious problem. And since it seems that bombing effectiveness is closely correlated with crew fatigue, it is important to have the final step in the long sequence of the build-up and operation of the bombing system performed efficiently. At present, the length of the period of occupancy of en route and prestrike bases is determined partly by the need for crew rest. In the future, requirements for short periods of bomber occupancy will, in general, not permit this function to be carried out after the arrival of bombers on forward bases. Two alternatives have been examined: (1) the elimination of crew rest for the shorter missions from ZI bases; and (2) provisions for exchanging crews at prestrike or poststrike bases.

In the campaigns examined, 25 per cent of the sorties against the industrial-target system involve flight times of 16 hr or less to target in a B-47 or B-52, with an additional 20 hr back to base (see Fig. 66*b*, pages 212–214). An additional 4 hr, on the average, is spent on a prestrike base. On the basis of present SAC mission lengths, it may be possible to operate missions from the northeastern part of the ZI through the United Kingdom without an extended prestrike stop for crew rest. Most crews, however, fly missions averaging 20 hr of flight to target, 26 hr back to poststrike bases, and 40 hr of flying round trip. Not all en route stops are in areas accessible to rapid Soviet attack; periods of occupancy permitting crew rest are possible on ZI en route bases and also on bases in Labrador, Newfoundland, the Azores, Hawaii, Guam, and, to a lesser extent, French Morocco (see Table 45, page 319). On long missions where sufficient crew rest is not possible, the airlifting of combat crews to prestrike bases in transports or tanker aircraft along with the C & EMT in time for rest, feeding, and briefing before the arrival of bombers brought in by ferry crews would permit bombers to be quickly fueled, serviced, and mounted on strike with combat crews rested. In this connection we considered the possible use of fast transports to reduce the deployment time of combat crews to forward bases. The use of this type of aircraft for ferrying crews reduces ferry time from an average of 25 hr to approximately 14 hr. This reduction permits crews to be retained on home base longer for final training, changes in routes, etc. A ratio of 1.5 crews per bomber, availability of approximately 70 per cent, and the withholding of some units in reserve make available sufficient ferry crews for those missions involving crew exchange.

Base Complement. Table 36 presents the permanent base complement for the refueling bases examined. The cost of training and support for this complement is included in total refueling-bases systems cost (see Table 35). This team includes a large damage-repair team for runway repair and base decontamination.

Table 36

REFUELING-BASE COMPLEMENT

	Officers	Airmen	Total
Command and administrative	2	5	7
Base operations	..	3	3
Installations	1	53	54
AACS and GCA	..	11	11
Ground communications	1	18	19
Supply	..	20	20
Food service	..	5	5
Motor vehicle	..	6	6
Air police	..	20	20
Medical	1	3	4
TOTAL	5	144	149

Bomb Storage

From the standpoint of vulnerability, political desirability, and cost, the storage and loading of bombs within the ZI is indicated for the ground-refueling system. The overseas bomb storage and loading function would presumably be reduced to that of providing a few spares for failures detected en route.

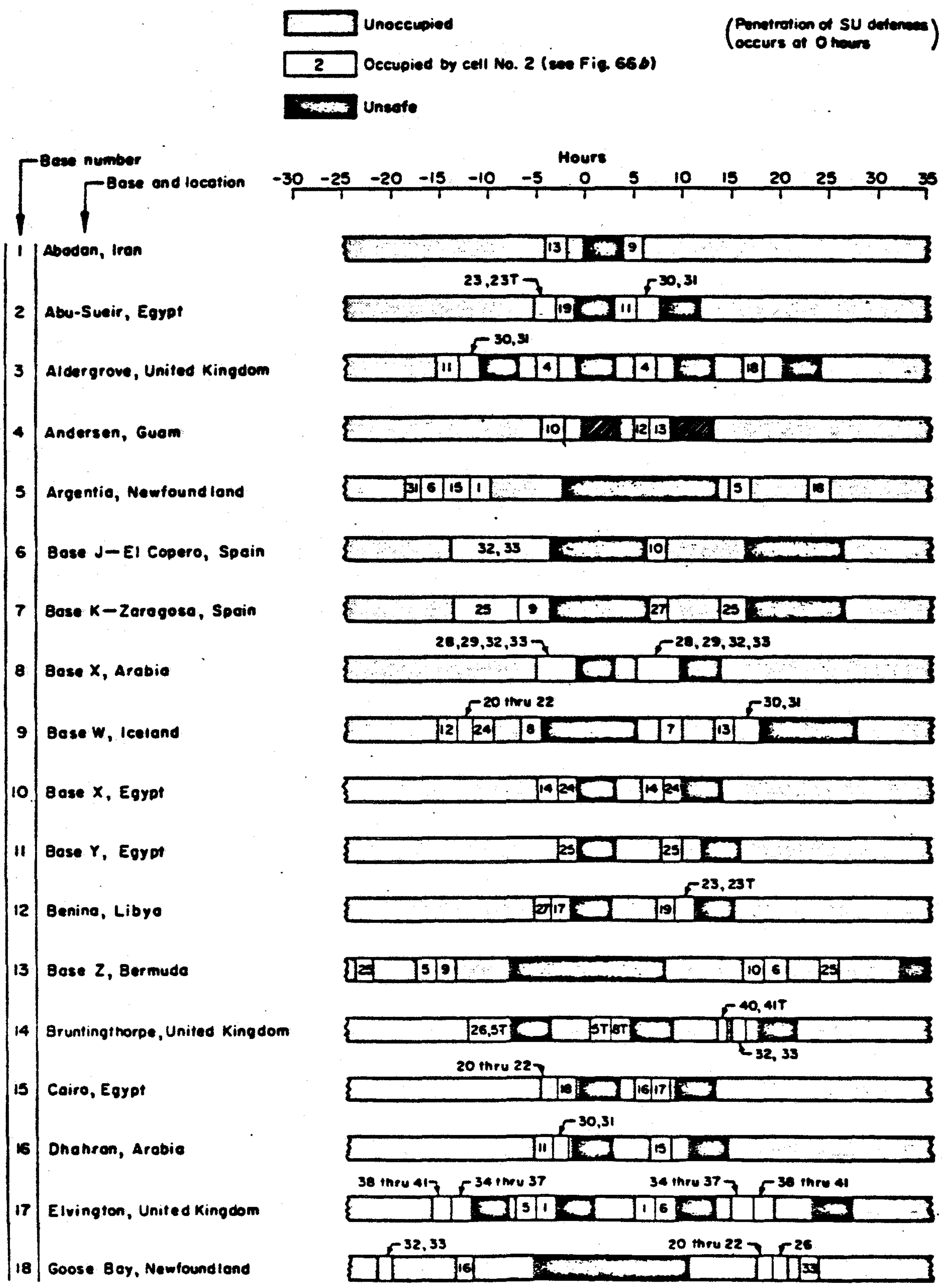
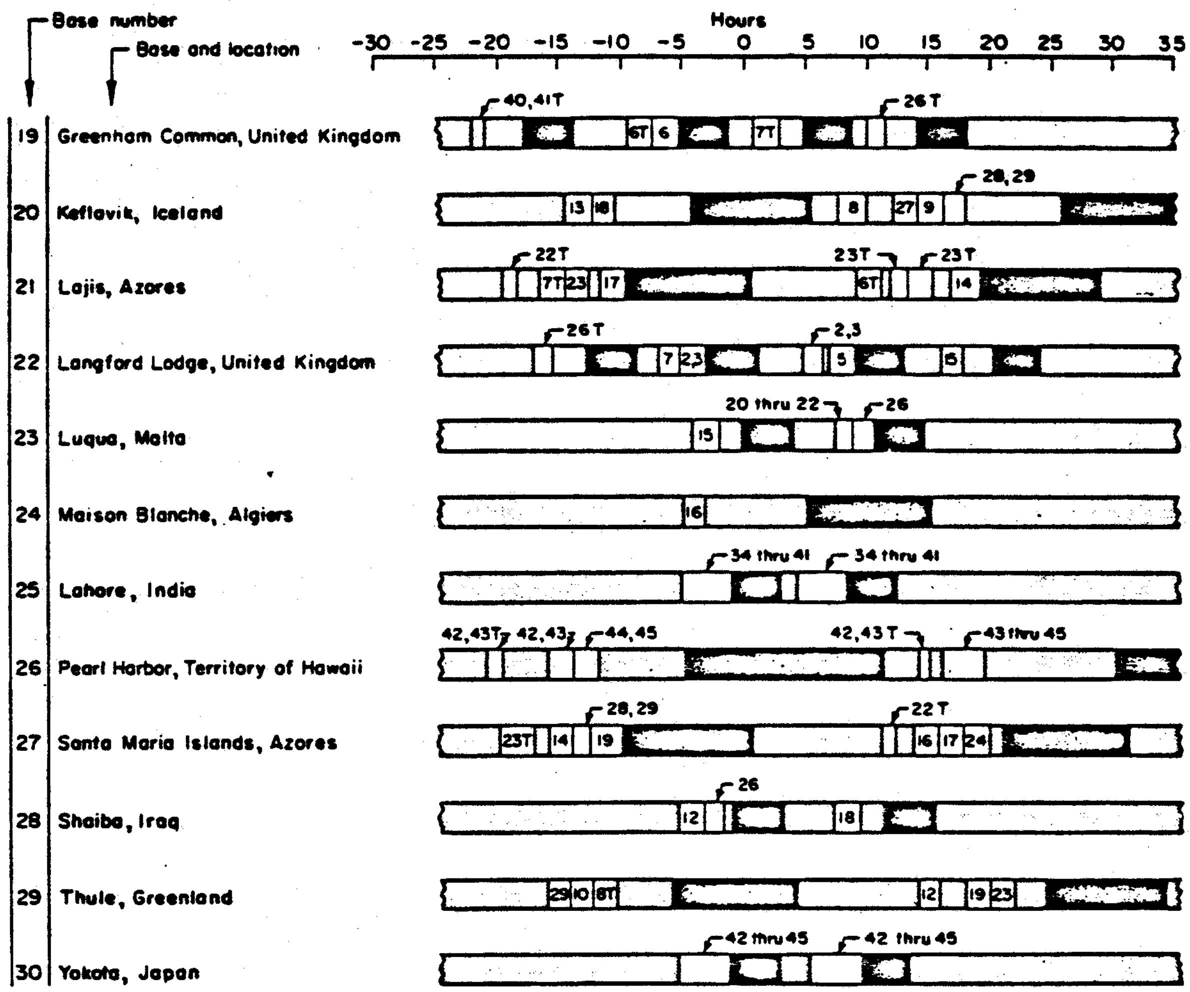


Fig. 66a—Refueling-base occupancy (29 wings, simultaneous penetration, all-region strike)



Airlift

Airlift requirements under the staging method of operations are greatly reduced from the requirements for the deployment and continued support of overseas operating bases. Most of the airlift requirements could be met by the use of unit tankers. Only spare aircraft engines (unless these were prestocked in small quantities on forward bases), spare bombs, mobile depot teams, and, possibly, exchange crews would be carried in transports. Excluding depot teams, there is a requirement of 3 C-54 equivalent transports, a reduction of 75 per cent in MATS support. This reduction in MATS requirement renders SAC much less dependent on support from other commands.

Communications

Whether the ground-refueling system will have a larger or a smaller requirement for communications facilities than an overseas operating base system is

2/1

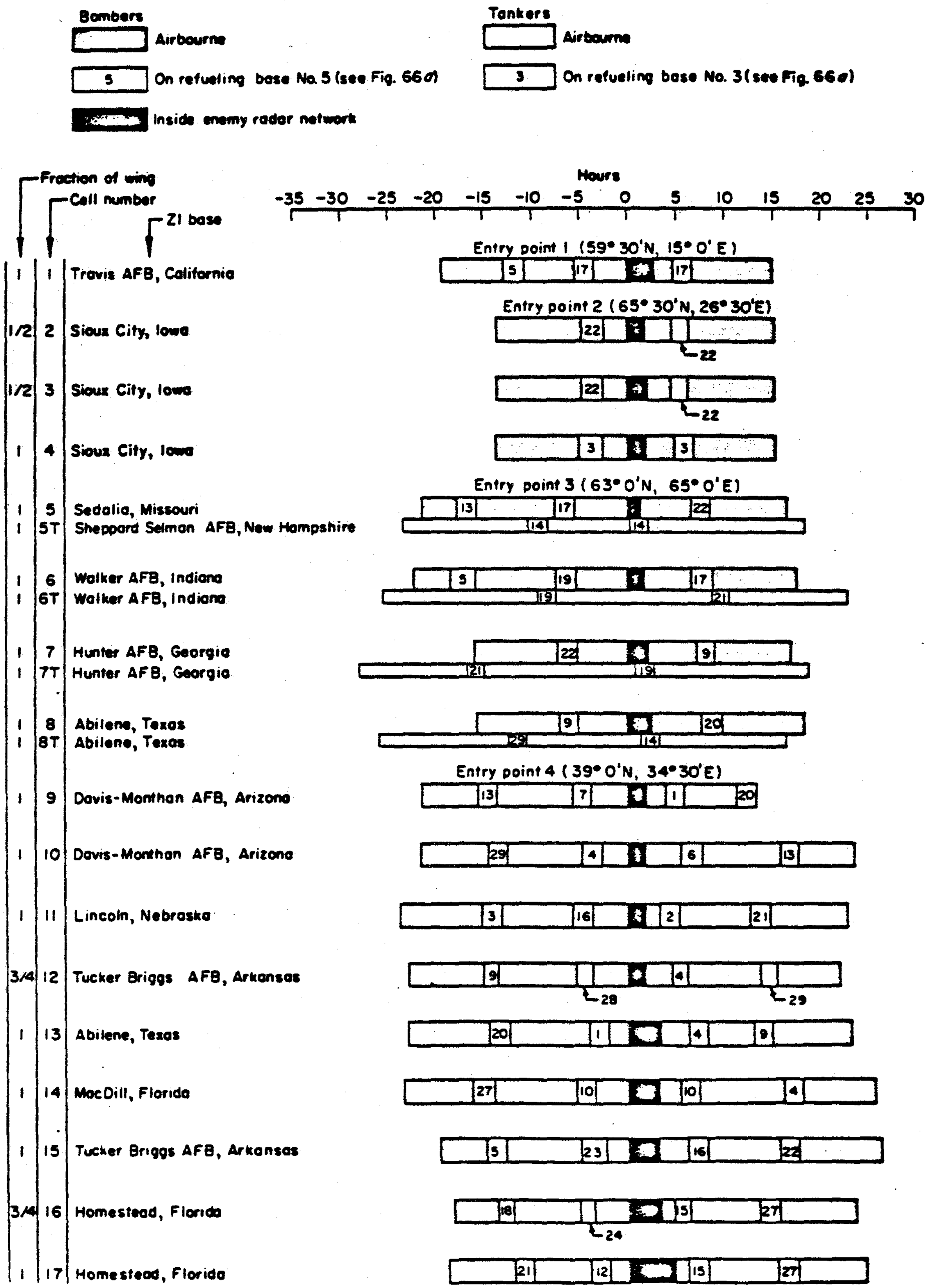
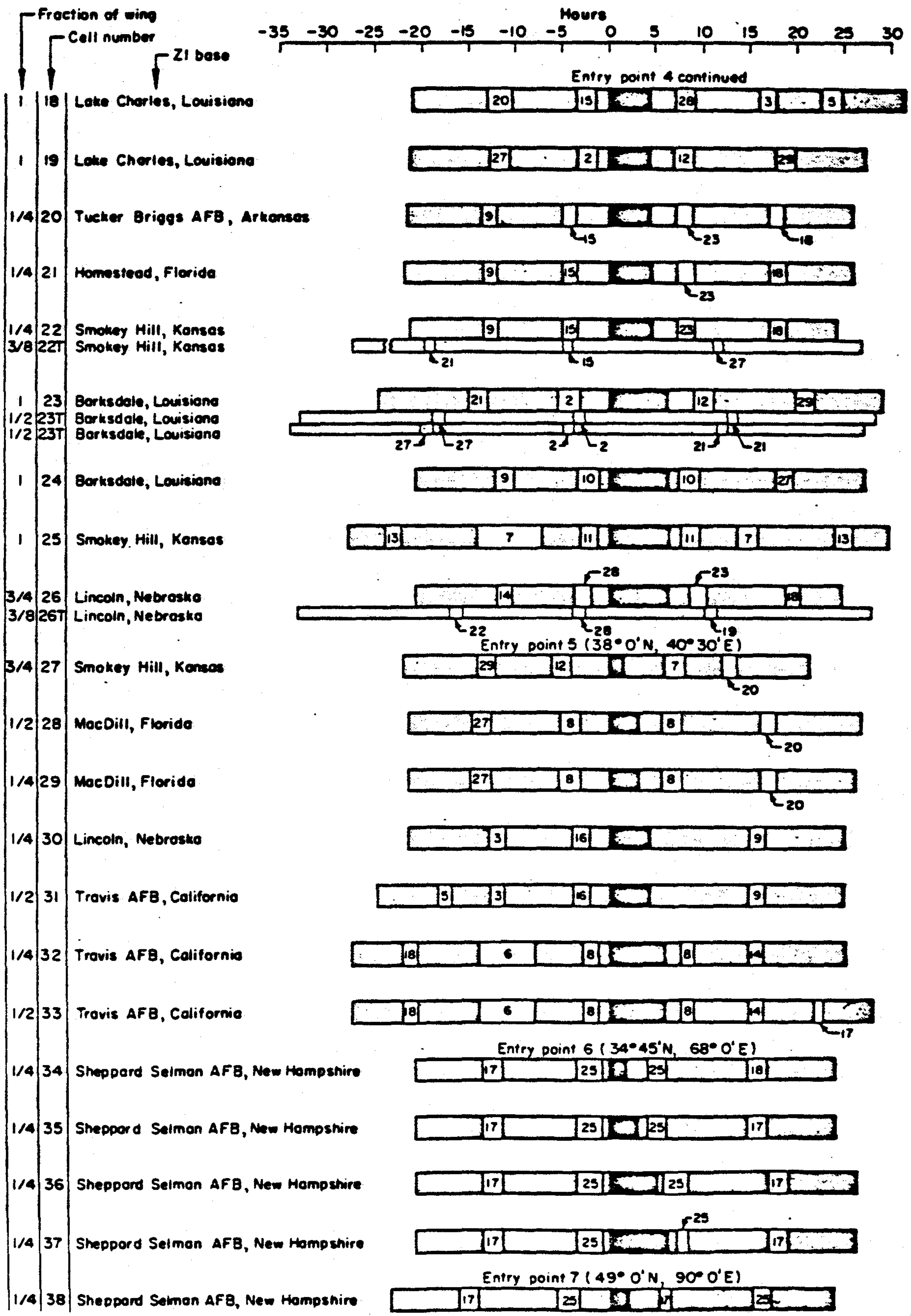
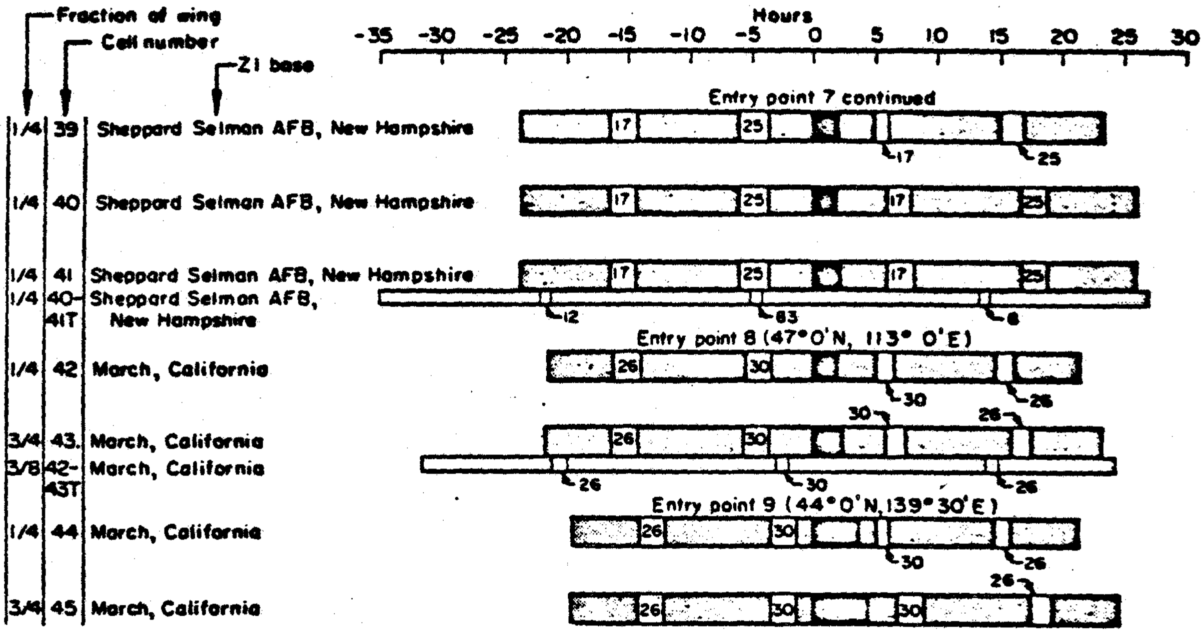


Fig. 66b—Wing combat-mission times (29 wings, simultaneous penetration, all-region strike)


Fraction of wing
Cell number
ZI base
Hours
-35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30
Entry point 4 continued
1 18 Lake Charles, Louisiana
1 19 Lake Charles, Louisiana
1/4 20 Tucker Briggs AFB, Arkansas
1/4 21 Homestead, Florida
1/4 22 Smokey Hill, Kansas
3/8 22T Smokey Hill, Kansas
1 23 Barksdale, Louisiana
1/2 23T Barksdale, Louisiana
1/2 23T Barksdale, Louisiana
1 24 Barksdale, Louisiana
1 25 Smokey Hill, Kansas
3/4 26 Lincoln, Nebraska
3/8 26T Lincoln, Nebraska
Entry point 5 (38° 0'N, 40° 30'E)
3/4 27 Smokey Hill, Kansas
1/2 28 MacDill, Florida
1/4 29 MacDill, Florida
1/4 30 Lincoln, Nebraska
1/2 31 Travis AFB, California
1/4 32 Travis AFB, California
1/2 33 Travis AFB, California
Entry point 6 (34° 45'N, 68° 0'E)
1/4 34 Sheppard Selman AFB, New Hampshire
1/4 35 Sheppard Selman AFB, New Hampshire
1/4 36 Sheppard Selman AFB, New Hampshire
1/4 37 Sheppard Selman AFB, New Hampshire
Entry point 7 (49° 0'N, 90° 0'E)
1/4 38 Sheppard Selman AFB, New Hampshire



not clear at this writing. Several considerations suggest the possibility of an actual reduction. The smaller number of MATS support aircraft involved in the operation, the likelihood that it will be necessary to maintain radio silence in flights from the ZI to the staging bases, and the fact that many of the post-strike and other communication reports will be flown to the ZI in tactical aircraft all tend to reduce the requirements.

In any case, if the presently planned communications facilities will suffice for the ground-refueled system, then marginal differences between that system and the operating base system appear to be of minor importance.

A swift review of this problem confirms the belief that the planned facilities will be adequate.*

Under formerly programmed systems, the essence of the SAC communications problem was the transmission of SAC messages between the ZI and overseas. Strategic Air Command messages are transmitted over the USAF communications system, which has twelve trans-Atlantic circuits, each of which is capable of transmitting at 57,000 groups per day (one group consists of five characters). Of these twelve circuits, three are normally allocated to SAC for its exclusive use. One of these runs between the ZI and the United Kingdom, another between the United Kingdom and North Africa, and the third between the ZI and Fontainebleau, France, to SAC Zebra. During command-post exer-

* We are indebted for this review to R. L. Belzer and J. F. Digby, of The RAND Corporation, and to Maj. B. R. Rile and Maj. G. L. Canastrari, of the Directorate of Communications, HqUSAF.

cises, SAC has allocated an additional four circuits, two of which run to the United Kingdom from the ZI, and the other two of which run to North Africa. This normal allocation and the exercise allocation have been made because of SAC's operational requirement for speedy transmission of messages. It should be noted that none of these circuits are normally utilized by SAC to their full capacity, but under the circumstances this is perhaps not relevant. In FY 1955 the number of trans-Atlantic circuits in the USAF communications network will have been increased to 24. This number will reach 36 in FY 1957. This does not include several other cable circuits which can be obtained through commercial sources in the event of an emergency.

The most important point in regard to feasibility is not the traffic-handling capacity of these circuits or the actual USAF systems requirements, since the communications network will be adequate to supply amply the anticipated requirements; it is rather that SAC, in the future, just as at the present time, has first priority in the use of USAF communications systems. That is to say, it is recognized that the SAC mission is perhaps the most important mission; and SAC's communications requirements would be satisfied first in the event of an emergency, even though this might be at the expense of the communications requirements of other commands. It therefore seems that the only deficiency in the communications system which could obtain would be possibly in the case in which SAC might utilize refueling bases where communications facilities are neither available now nor programmed to be available in the future. Even in this case, messages could be sent using mobile transmitters which are contained in the Seaweed kit. Inasmuch as the bases which would be used with the ground-refueling system would be those which have been programmed for use either as staging bases or operating bases under the 120-wing fiscal 1956 program, the programmed communications system would contain communications facilities at these locations.

SORTIE RATES AND MISSION LENGTH

As the length of combat missions increases, aircraft either spend more time in the air or the number of sorties flown in a given period decreases. Since the amount of time aircraft can spend in the air is clearly limited, although the upper limit practicable may be difficult of determination, large increases in mission length should be expected to result in substantial decreases in sorties flown per unit time. This effect is extremely important to consider in developing an overseas operating base system for use in a war in which both sides are severely limited in atomic capabilities. Under such circumstances, high sortie rates per aircraft from forward bases mean the destruction of a given target system in a shorter time than from more remote bases, and this effect is extremely important in high-explosive bombing, which requires the cumulation of damage delivered by a large number of sorties. However, the significance of sortie rates in the 1956–1961 period in the context of a two-sided atomic campaign will be rather different from what it was in earlier periods. Two questions are

1. What sortie rates are we likely to obtain from different systems?
2. What is the meaning of sortie-rate differences?

In particular we are concerned with differences between overseas operations and missions conducted at intercontinental distances, whether air- or ground-refueled.

Sortie rates attained by a force of bombers using a given base system are determined by (1) maintenance facilities, personnel, and equipment available; (2) the availability of base supplies and of theater resupply; (3) aircraft battle damage; (4) crew recuperability as determined by fatigue and training on new targets; and (5) time for reconnaissance and assembly of target information, and planning and coordination of attacks. These combine to constrain medium-bomber sorties to a planned level of four to seven per month from overseas bases. And many of these constraints are independent of mission distance. Which of them dominate will depend on variable campaign conditions.

The total sorties obtained from forward operating bases per unit of time will be sharply reduced by ground attrition and damage of aircraft, maintenance facilities, personnel and supplies, and forward bases. Depots and other segments of the logistics pipeline may be expected to suffer analogous attrition and damage. A tactic of reserving part of the force in the ZI to keep it from being attrited will reduce the sortie rate.

And apart from overseas ground attrition and the prospect of such critical risks as radiological contamination, SAC has found in the past that the combat effectiveness of units on rotation has fallen off, through inadequate maintenance, and, in particular, that overseas operation of the B-36 would require the establishment throughout the world of facilities comparable to those at Fort Worth. While newer aircraft types are easier to maintain, and overseas stocks are being built up, there will probably remain a substantial difference in maintenance effectiveness between overseas and ZI bases. Recent budget cuts of overseas facilities have been taken in good part out of maintenance and supply facilities. Current B-52 planning factors recognize constraints on aircraft utilization from forward bases, and four sorties per month per aircraft are estimated from either ZI *or* overseas bases.* This means 146 flying hours per month from ZI bases and 54 from overseas bases.

In the case of the B-52, at intercontinental distances, no decrease in sortie rate and a tripling in flying hours per aircraft adds to logistics-support requirements—ground-attrition considerations aside. However, not all support requirements are related to flying hours; many are related to the number of sorties flown. Aircraft battle damage is perhaps most apparent in the category, and, so far as it is concerned, large increases in mission distance up to the point of entry of enemy defenses may have much less effect on sortie rates than small increases after entry. Preflight and postflight inspections, tire wear, and even engine failures are closely related to the number of sorties flown, rather than accumulated flying hours. However, two major items of supply are consumed on a flying-hour basis: overhaul of engines, and fuel. Requirements for these items in the support of overseas versus intercontinental operations are highly dependent on aircraft air- and ground-attrition rates in relation to the loss of engines in depots and of fuel stocks. Logistics requirements should be based on assumptions which insure that we shall be able to operate on a larger scale, if the enemy fails to produce the expected ground attrition, and more engines and fuel should be allowed for intercontinental operations. The foregoing comments qualify the probability of any distinct increase in sortie rates with proximity. Some gross quantitative tests of the ground attrition and the denial factor affecting strike rates for various base systems are indicated in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225. They make clear that for some enemy attack levels the operating base system is at a disadvantage.

But what are the advantages and disadvantages of a somewhat higher sortie rate in an atomic strategic-bombing campaign? From the standpoint of restricting enemy industrial production, there is little difference in destroying an industry-target system within a period of one month or two. Nor are the time differences great enough to affect industrial recuperability. And of course all sortie-rate differences disappear in the unlikely event that the enemy collapses with our first strike. With other targets, counter air and retardation, attack

* *Wartime Planning Factors Manual*, April, 1953, rev., Director of Management Analysis, DCS/Comptroller, HqUSAF.

timing with a high early rate of destruction, is important. Moreover, speed of attack as well as high over-all rates of attack may be critical. However, with our present state of knowledge of the location and vulnerability of the Soviet strategic force, it appears that requirements for destroying this target system will not have a major effect on base decisions.

This point is examined in Part III, which presents the results of some joint Bravo and Delta campaigns. As a possible substitute for the rotation of aircraft to vulnerable overseas bases during peacetime for the rapid delivery of bombs to urgent targets, some consideration has been given to the basing of wings on certain peripheral ZI bases at a high state of alert, ready for immediate attack on D-day. A B-47 wing based at Limestone, and with bombs at hand, would be only 6 hours' flying time from the United Kingdom base on which it would normally be stationed on rotation. And if the attack of the rotation unit were delayed by the delivery of bomb cores by C-124 aircraft flying from the ZI at 200 knots, a wing based at Limestone would have bombs on target before one on rotation in the United Kingdom.

Strategic bombing with high explosive presents a different picture. The objective is the delivery of large bomb tonnages; damage accumulates slowly, and recuperation may be rapid. This type of operation is analogous to the air transportation of high-density, low-value cargo. High force efficiency is obtained by reducing mission length and increasing bomb loads and visits per unit time. Clearly, overseas operating bases are required. The initial contribution of SAC to the Korean War was greatly increased by the availability of bases in the Far East. We must be prepared for similar actions in the future and any type of overseas bases, operating or refueling, are assets of value in this type of action. Refueling bases as well as operating bases provide long lead time items—pavements, fuel storage and distribution systems, and utilities—from which operations could be mounted in a peripheral war and to which further facilities could be added as needed. It does not appear profitable to build extensive operating base facilities worldwide in peacetime in anticipation of peripheral actions which might break out at a wide number of points throughout the world.

The strategic campaign may conclude with the use of high-explosive bombs. This possibility is entertained in Part III. If there were such a later phase of the campaign (after the destruction of the Soviet bombing force or the exhaustion of its stockpile of bombs), we should want to move bombers overseas. However, the likelihood that our stockpile of A-bombs will be exhausted before the completion of any substantial part of the strategic job is diminishing to an insignificant amount. Moreover, the force to be moved overseas will in any case have been reduced by air and ground attrition. Therefore, not all bases need to be built to an operating standard in anticipation of such a later phase of the war. Operating bases already in existence and under construction are sufficient to base any force we may need overseas for high-explosive bombing. This case is treated more adequately in Part III in connection with the joint Bravo and Delta campaigns.

In sum, leaving vulnerability considerations aside, it appears that sortie rates will be reduced by an amount less than proportional to mission length. When we include vulnerability considerations, sortie-rate differences may actually be reversed, since ground damage may reduce sortie rates for surviving aircraft. However, to determine rate of destruction, even more important than the sortie rate of individual surviving aircraft is the total number of sorties which the entire force can mount in a given time period. Given any fixed dollar budget, this latter quantity depends on how many bombers we can buy with this money after expenditures on defenses, operating facilities, airlift, matériel stockpiles, etc. And it depends on how many of these bombers that we buy survive enemy attack on the ground. Ground attrition and the threat of ground attrition reduce the total number of sorties that can be flown in a given time period by the overseas operating base system. The details of how this happens are presented below in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225.

The Delta Mission is not affected sharply by differences in campaign time of the order of magnitude which we have been discussing. However, since retardation and counter-air targets might have strike timing requirements met only by overseas operations, and a later high-explosive phase of the campaign might also require overseas operations, the matter of strike rate and campaign time will be explored further in Part III. We may anticipate: the majority of the strategic-force missions can be accomplished in a shorter time by a refueling-base system than by an overseas operating base system.

CAMPAIGN COMPARISONS

The effect of reduced radius on target and increased logistics cost is combined in the campaign results of Table 37 and Fig. 67. We compare the two intercontinental systems previously described with three (non-ZI) base systems: (1) the intermediate base system confined to the North American Continent;

Table 37

ZI VERSUS OVERSEAS OPERATING BASE SYSTEMS,[a] EXCLUDING GROUND ATTRITION, IN B-47 CAMPAIGNS AGAINST INDUSTRY TARGETS

(Three-year cost in billions of dollars)

	ZI Operating Bases		Overseas Operating Bases		
			Intermediate Systems		
	Air-refueled System	Ground-refueled System	North America	Peripheral	Advanced System
	Minimum-penetration Routes	Minimum-tanker Routes	Minimum-tanker Routes	Minimum-penetration Routes	Minimum-tanker Routes
Tactic	Reserve	Impact	Reserve	Reserve	Reserve
Number of strikes	6	3	5	5	4
Number of B-47's in operating force	708	1230	957	698	754
Number of B-47's in reserve for air attrition	892	0	1024	679	603
Total number of B-47's	1600	1230	1981	1377	1357
Number of B-36-type tankers	1550	43	325	0	26
Number of KC-97's	390	234	1690	1190	143
New cost of bomber force	15.7	12.1	19.4	13.5	13.3
New cost of radius extension[b]	23.9	3.3	26.9	14.6	6.6
New Cost of Complete System	39.6	15.4	46.3	28.1	19.9
Inheritance	4.1	3.5	4.1	4.1	3.5
Incremental Cost of Complete System	35.5	11.9	44.2	24.0	16.4

[a] Defense Distribution III.

[b] Includes en route bases, refueling bases, and tanker costs.

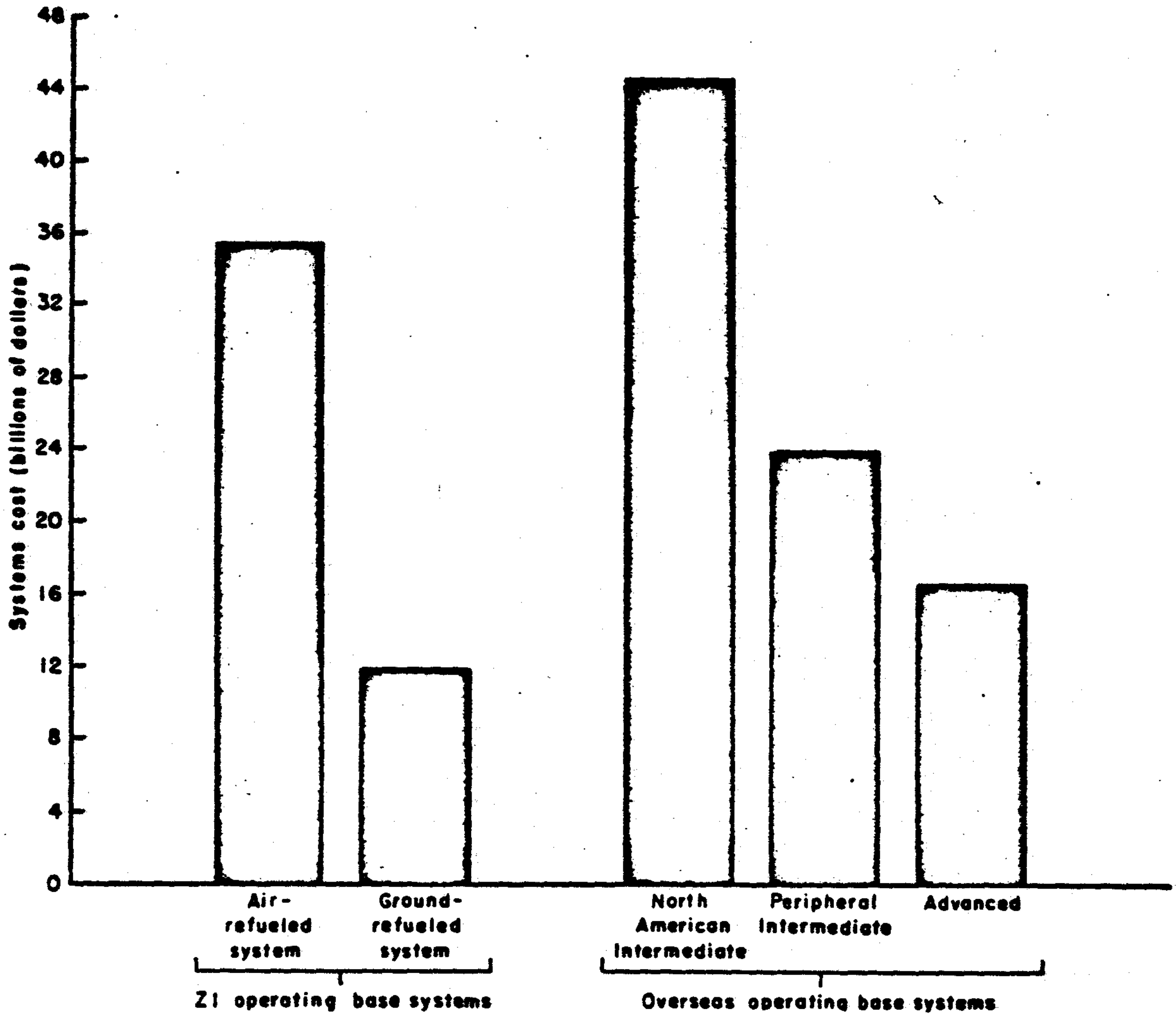


Fig. 67—ZI vs overseas operating base systems—excluding ground attrition: B-47 campaigns against industry targets (incremental 3-year cost)

(2) the peripheral intermediate system; and (3) a system of forward operating bases which corresponds approximately to our formerly programmed system of overseas operating and staging bases.

When we move from the ZI and closer to Soviet targets, but remain in North America, there is an *increase* in total campaign costs. The reduction in tanker requirements (20 per cent along minimum-tanker routes and 10 per cent along minimum-penetration routes) is more than offset by increased base-construction costs, airlift, and the creation of a supporting logistics structure—for tankers as well as bombers. While proximity to the ZI reduces theater logistics support requirements as compared with those of advanced overseas bases, and airlift distances are much reduced, there is a 25 per cent increase in total systems cost as compared with that of the ZI-based air-refueled system. Campaign costs from the peripheral, intermediate base system are about 70 per cent of ZI air-refueled and 200 per cent of ZI ground-refueled systems. The advanced operating base system, which follows a policy of reserve, has a campaign cost about 40 per cent greater than that of the ground-refueled system, which follows the impact tactic. In the campaign shown, the ground-refueled system maintains a higher initial rate of destruction than the overseas operating base system, even assuming that the bombers of the ground-refueled system operate at one-half the sortie rates of those from advanced bases. Moreover, even given this questionable assumption on sortie-rate differences, the ground-refueled system can, by completing the job in two strikes, finish its task of destruction in the same time as the advanced operating base system, with only a slight increase in cost. Even for a two-strike campaign, the costs of the ground-refueled system will be only 75 per cent of the costs of a four-strike campaign for the advanced operating base system.

These campaigns neglect the increased cost of defense on forward bases and the increased expectation of ground loss which, as we shall see in the next section, has a dominant effect on base choice.

SUMMARY: THE EFFECTS OF DISTANCE FROM ZI TO BASE

1. The addition of an overseas component to a bombing system is costly. In particular, overseas location of operating facilities and the associated increase in stocks and airlift are expensive, even if we neglect the problem of vulnerability.

2. A refueling-base system overseas is distinctly cheaper as far as facilities, airlift, and stocks are concerned.

The refueling base does involve functions other than the picking up of fuel. It involves maintenance, for example. However, the purpose of maintenance in a refueling-base system is only to assist as many planes on to target as it can within a safe period of occupancy and to get the rest home. The costs of extra aborts involved in such a policy, as well as the costs of EMT's and C and MTF's, are included in the campaign analysis, as are the costs of prestocking and protecting sufficient fuel for an entire atomic campaign.

3. A choice between an overseas operating base system and an intercontinental ground-refueling system has distinct consequences for the location of prestocked material. Therefore this choice must be made long in advance of the start of any campaign.

4. The conclusion of the section entitled "Bases, Targets, and Penetration Paths," page 135, as to the importance of adding bases, in particular, to the south of Russia is sustained by base loading analyses for both the operating- and refueling-base systems.

5. The comparative cheapness of the refueling-base system is evidenced by campaign analyses. This system has a significant margin of advantage over overseas operating base systems, even neglecting vulnerability considerations.

6. However, the chief motive for the use of the refueling system is the reduction of vulnerability in a period of growing Russian capabilities.

E. Base to Border: The Effect of Base Vulnerability

Up to now we have considered the question of bomber-base operations in the context of a largely one-sided war in which the enemy has been limited to defense. Aside from the constraints imposed by defenses the enemy might employ, we have had the option of choosing base combinations subject chiefly to aerodynamic, political, and logistics constraints. So far we have made no quantitative estimate of the costs of mounting strikes in the face of enemy attack. This is a critical matter, since the destruction of our strike force is clearly a matter of high priority, and it is very likely that the enemy will have the opportunity for the first attack. The damage suffered by our force on the ground, and the types and cost of base defense appropriate, varies widely with differing base systems. With some defenses, only a small percentage of our bombers survive to take part in our attacks. In this section we examine defenses economic for alternative base-aircraft systems and the damage they may be expected to suffer in spite of these defenses. Here the "survival value" of these systems is measured in terms of the systems cost per bomber available for use after enemy attacks. The major alternative base systems examined are the programmed 1956 system, intermediate and advanced overseas operating base systems with increased active and passive defenses, and overseas refueling systems designed to have extremely low vulnerability to enemy attack. In Part III, the effect of enemy attack on our force, variously based, is studied in combination with the target radius, penetration, and logistic effects dealt with earlier, and the joint results are translated into the number of strategic targets killed.

The vulnerability of a strategic base system and measures for its defense can be separated for the purpose of analysis into the following six categories, which correspond approximately to the successive time phases of an attack:

1. The stockpile of aircraft and weapons possessed by the enemy, his commitments to attack on SAC, and methods of employment of the force in relation to the size and location of the target system presented by SAC;
2. Expected survival of attacking bombers to the bomb-release line;

3. The value of the targets presented, as determined by patterns of base occupancy affecting the exposure of aircraft and other systems elements at the time of attack;
4. Physical vulnerability of systems elements; and
5. The recuperability of the force after attack, and the effect of damage to systems elements on the accomplishment of strategic bombing missions.

SOVIET OFFENSIVE CAPABILITIES AND POSSIBLE COMMITMENTS TO SAC NEUTRALIZATION

Expected increases in the size, performance, and quality of the Soviet Long-range Air Force over the next few years are paralleled by expected increases in the number and yield of bombs in the Soviet stockpile of atomic weapons. By 1956, and possibly much earlier, this stockpile and the Soviet delivery capability will permit a major effort to neutralize a large part of our strategic force during the first phase of a war. The destruction of a considerable proportion of our strategic force on the ground will clearly be regarded as an objective of high priority, for, if our strategic bombing force is permitted to operate without interference, within a few weeks most major Soviet cities, plants, transportation centers, and a good many strategic air bases will have been attacked. And the air defense of the Soviet Union will most certainly be unable to prevent widespread destruction. This is our "deterrent" power. Neutralizing it by air defense appears to be out of the question; but neutralizing it, or seriously reducing its effectiveness, by ground attack may be feasible. A large concentration of bombers on an airfield at the time of attack makes a target which is very much easier to destroy than are the same bombers in flight over enemy territory. And SAC will present a number of points of bomber concentration not large in relation to growing Soviet capabilities for atomic attack in the period 1956–1961 (see Fig. 68). Moreover, the Soviet Union has some clear points of advantage in an attempt to attrite our offensive capability by air attack. The location of our bases, the aircraft assigned to them, their facilities, active defenses, and patterns of base use are not easily concealed in peacetime. And while we have some choice of bases in the deployment of our bombers and the time of strikes, limitations in our programmed base structure and the capabilities of our aircraft restrict the alternatives available.

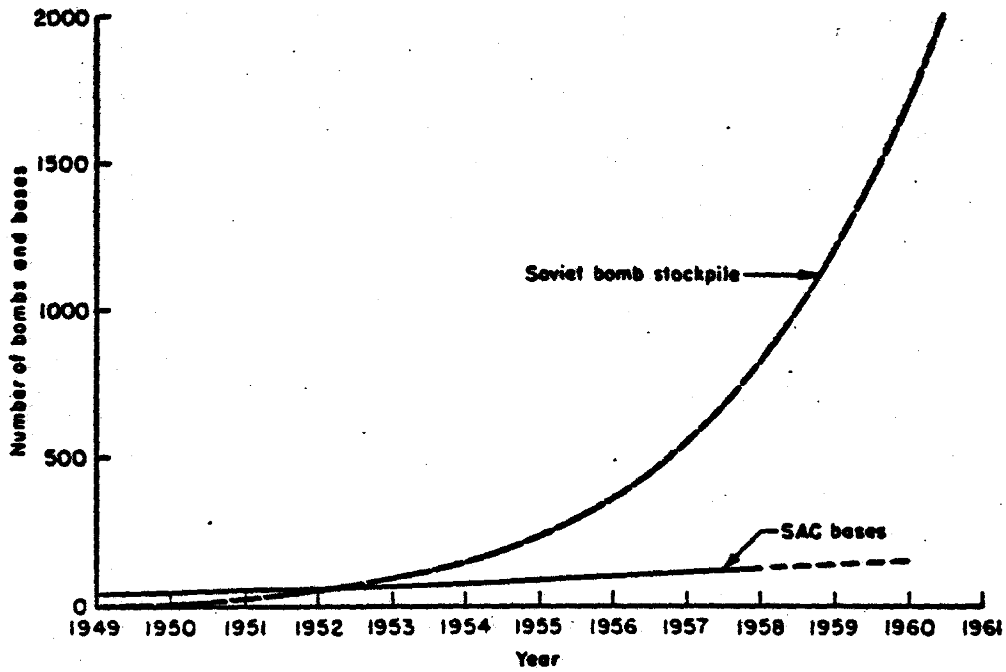


Fig. 68—Expected size of A-bomb stockpile and number of SAC bases world wide, 1949–1960

A war in this period could start in many ways, some of which would find our strategic force in action before the first Soviet attack was launched against it. The Russians might blunder into a war as a result of miscalculating a Korean type of action, or strategic objectives other than SAC neutralization might be selected for their first great offensive move. However, we cannot depend on enemy blunders, and the military advantage of the first atomic strike is so great that it is probable that the first overt move of a war would be an atomic attack against major U.S. targets, including, as a principal objective, the destruction of our offensive striking force. The Japanese chose this alternative in 1941, and the Russians certainly would have as much incentive in 1956. Whether or not the Russians succeed in delivering an initial atomic attack before we do, repeated air attacks can be expected throughout the campaign, especially against our overseas bases.

RAC's ideas on how might bk out.

Aircraft

The characteristics of major aircraft types of the Soviet Air Force estimated for 1956 are given in Table 38. Table 39 shows an estimate of the composition of the Soviet and Satellite Air Forces. At this date, the TU-4 is still expected to

Table 38

EXPECTED PERFORMANCE OF SOVIET AIRCRAFT—1956

	Major Aircraft Types						
	Type 31[a] (Turboprop Modification)	TU-4[b]	EF-150	IL-28[c]	MiG-15[d]	Type 39[e]	Type 37[f]
Maximum speed/altitude (kn/ft)	360/30,000	350/32,000	480/8000	435/SL	582/SL	497/20,000	542/19,500
Cruise speed (kn)	300	175	424	385	450	433	457
Radius (n mi)	3420	1700–2100	1000	690	250	1780	3110
Radius, once-refueled (n mi)	4170	2385–2850	1490	1295	...	2290	4060
Range (n mi)	6650	3100–4000	1860	1365	730	3420	6120
Range, once-refueled (n mi)	7830	4360–5250	2810	2465	...	4440	8020
Radar	(?)	AN/APQ-13 type	(?)	AN/APQ-13 type	...	K bombing syst.	K bombing syst.
Engines	4 turboprop (JUMO-022)	4 reciprocating	2 turbojet	2 turbojet	1 turbojet	6 turbojet	8 turbojet

[a] A prototype of this aircraft is known to exist as of July, 1951. The use of 5000 shp turboprop engines is hypothesized. However, it is known that this engine is at the test stage and is well matched to the airframe.

[b] Some TU-4's are expected to be capable of B-50 performance.

[c] Some IL-28's are assumed to be equipped with bombing radar.

[d] See p. 96. This case assumes a bomb load of approximately 500 lb and a small amount of externally carried fuel.

[e] Performance characteristics are those of the RB-52B.

[f] Performance characteristics are those of the B-47E.

Table 39

EXPECTED COMPOSITION OF THE SOVIET AND SATELLITE AIR FORCES—1956

	Soviet Union	European Satellites
Strategic		
Heavy bomber[a]	100	....
Medium bomber[a]	1000	....
Light bomber[b]	950	....
Fighter[a]	200	....
Transport-tanker	150	....
TOTAL	2400	....
Air Defense		
AW interceptor[b]	300	....
Day interceptor[b]	3000	250
Day interceptor[a]	......	200
TOTAL	3300	450
Tactical		
Fighter[b]	5900	750
Fighter bomber[b]	1400	....
Fighter bomber[a]	700	....
Light bomber	3400	150
Tactical reconnaissance[b]	750	150
Transport-tanker	750	150
TOTAL	12,900	1200

[a] Piston engine.
[b] Jet engine.

be the major long-range carrier in the force,* while the IL-28 will be the predominant short-range bomber. In addition, there may be about 100 long-range, turboprop-powered Type-31 bombers and some jet bombers (EF-150) having a combat radius midway between the IL-28 and a B-47 type. Some of the TU-4 force may be converted into tankers.†

The close proximity to the ocean of many ZI strategic bases and almost all overseas bases offers opportunity for the use of submarine-launched carriers—guided missiles or manned aircraft. Sixty per cent of ZI strategic bases are

* We do not include any B-47-type jets in this estimate for 1956, which is used in the analysis of the vulnerability of the programmed system. However, the vulnerability of each of the *modified* base systems over the period 1956–1961 is tested by assuming Soviet possession of a jet medium bomber and other advanced carriers.

† The Soviets, it appears, have not developed any extensive air-refueling capability. It is, of course, technically feasible for them to do so. However, such a development takes time and, as the curves of the section entitled "Base to Target: The Cost of Increasing Combat Radius," page 61, indicate, represents a significant diversion of resources.

within 100 mi of the sea. The missile very probably would be a V-1 type with a range up to 500 mi. The manned aircraft, similar to a recent proposal to the Navy, could have comparable or greater range. Anticipated bomb yields for small bombs should make it possible for either vehicle to get high airfield coverage. Submarine-launched vehicles have the combined advantages of small echo area and high speed, making detection as well as interception difficult, especially against coastal bases. However, this form of attack appears to have disadvantages as a method of commencing hostilities, and it may present serious operational problems in large-scale use. Nevertheless, the use of these carriers would result in high attrition to SAC. They are of particular importance where means of defense against conventional air attack can be obtained.

Other missile threats may appear during this period. However, on the basis of our missile development program, it appears unlikely that surface-to-surface missiles will present a threat of comparable magnitude to aircraft attacks. (The air-to-surface missile, on the other hand, is a more distinct possibility.) A possible exception may be the Soviet development of a short-range ballistic missile for use against overseas bases. These advanced threats, including submarine-launched carriers, have been tested largely against improved base systems. As it had been programmed, the base system would have suffered unacceptably high attrition from more conventional bombing methods.

The Soviet Air Force, even more than our own, will consist mostly of short-range aircraft in 1956. While there is expected to be a steady build-up in the long-range bomber force, the proportion of short-range aircraft will remain high. The sharp fall-off in the number of aircraft that can be brought to bear against targets at increasing distances from base is shown in Fig. 69. This air force, like our own, will be made up of a mix of aircraft of differing vintage and range performance, and the shaded areas of Fig. 69 indicate uncertainties as to the specific distance beyond which an unrefueled aircraft type cannot attack our strategic bases. Aerial refueling can extend the proportion of the force capable of attack at longer radii, and, over a period of time, a large proportion of Soviet resources could be allocated to long-range aircraft. This can be done only at the cost of a reduced striking capability in total, and, at some time period, both the U.S. and the Soviet Air Forces will have a range-capability pattern of the sort illustrated. The number of Soviet aircraft capable of two-way missions against those of our bases which are 900 n mi from Soviet bases is about 6 per cent of the number that can be brought to bear on bases which are 350 n mi from the Soviet bases. And against bases at 3000 n mi there is a

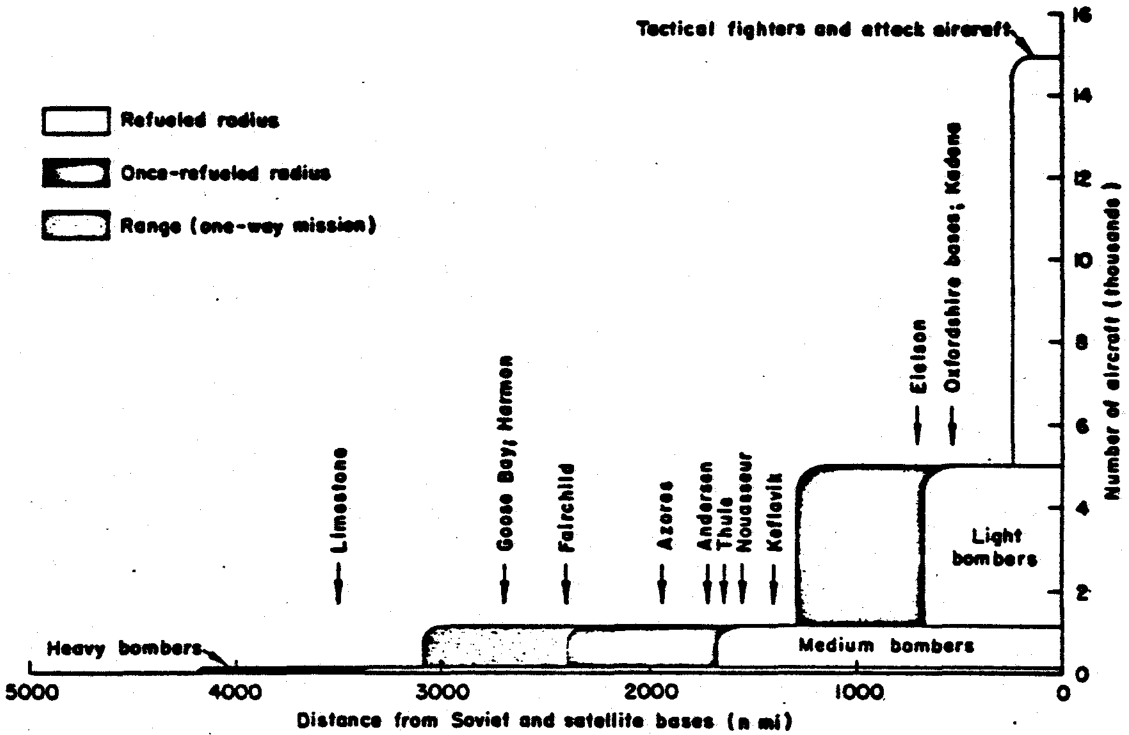


Fig. 69—Soviet Union aircraft capability vs distance from Soviet and satellite bases—1956 (minimum-penetration routes)

further reduction of about 90 per cent, even with extensive use of air-refueling. If one-way mission tactics are used, the peak level of attack that can be mounted against remote targets can be sharply increased, but there is no re-use of aircraft possible.

The significance of variations in aircraft attack levels with distance from base depends both on the type of weapons carried and the level of active defense met. Where high-yield nuclear weapons are to be used and relatively low aircraft losses to defenses are expected, then there may not be a significant decrease in *destructive* potential as distinct from *level of attack* with increasing distance from the Soviet Union. If, on the other hand, a large load must be carried, as in conventional high-explosive bombing, or where large attacking forces are required to saturate defenses, then a reduction in strike-size capability with distance can be of considerable significance.

Bombs

By mid-1955 the Soviet stockpile of fissile material is expected to be equivalent to 300 100-KT bombs;* by 1956 it should total about 400 100-KT bombs;

* *Air Intelligence Estimate*, AIE-1, October 1, 1952 (Top Secret).

and by mid-1960, perhaps 2000 bombs. These estimated stockpile sizes are uncertain within a factor of two, so that in 1956 the stockpile might be as large as 800 or as small as 200 bombs. On the basis of recent Soviet tests, the size of the largest operational weapons expected in quantity by no later than the middle of the 1956–1961 period will be of megaton size, while in 1956 it can be expected that large-yield fission bombs will be available to the Russians. For attacks against the major part of our world-wide strategic base system as programmed, however, neither *many bombs*, in relation to the expected stockpile, nor *large bombs* are required to produce high levels of damage. Bombs ranging in size from 20 to 100 KT are adequate for attacks on the programmed operating bases.

Our conclusions on the high vulnerability of the programmed base structure in 1956 are not sensitive to quite wide uncertainty in the assumed Soviet stockpile, since we expect the Russians to regard SAC as a target of the highest priority, and SAC will not present many targets, as scheduled. As a consequence, even out of the smallest stockpile expected—200 bombs—perhaps 30 would be allocated to SAC destruction. With the more probable 1956 stockpile—in the neighborhood of 400 bombs—SAC should expect to receive at least 100 bombs, if that many could be profitably used against our bases. There should be no surprise if a larger number than this is allocated. By 1960 the number of bombs available for allocation against SAC should be in the hundreds.

We have credited the Russians with a competent operational atomic capability. The capability of employing surface or penetration bursts has been assumed. The use of nuclear weapons exploded at or under the ground is examined primarily in the context of improved operating and refueling bases passively defended against air bursts. The problem of residual contamination following a surface or penetration burst raises the possibility of enemy use of this weapon in order to accomplish both aircraft and structure blast damage and airfield denial.

Other types of attack possible against overseas bases with IL-28 and TU-4 radius include use of fragmentation and general-purpose bombs against aircraft, personnel, and base facilities, and use of time and antipersonnel bombs intended for short periods of base denial.

Finally, we have given brief consideration to the threat of paratroop attack and sabotage on overseas refueling bases. Some implications of the use of bacteriological, chemical, and radiological agents were examined.

Force Commitment and Attack Strategies

Unlike most strategic targets, our bombing force is mobile. We may be able to evade an initial attack, and if our retaliatory power survives, it will quickly be felt by the enemy. However, the use of overseas operating bases in accordance with the mobility plan offers the enemy multiple opportunities for attack:

1. Zone of the interior and overseas rotation bases on D-day in a surprise, coordinated attack;
2. Overseas prestrike and en route bases during the build-up period prior to the first strike; and
3. Overseas operating and staging bases and ZI home bases after the first strike and throughout the campaign.

A surprise air attack against the United States could probably consist of a mass raid directed at both SAC and industry-population targets, or of a sneak raid involving few aircraft directed at SAC bases and other critical targets. There would be advantages to both tactics: The mass raid would attempt the destruction of two important U.S. target systems; the sneak attack, probably at low altitude, might result in substantially higher damage to our strategic force with a smaller commitment of aircraft to one-way missions. As few as 20 bombers and as many as 500 were assumed to be allocated against ZI bases.

The advantages of mounting the first surprise attack of a war (little or no warning of city populations, confusion of defenses) have been generally recognized. The surprise attack is doubly important for attack on strategic bases, since many of the most vital and vulnerable elements on these bases are mobile, and, if the attack comes as no surprise, aircraft, personnel, and essential matériel may have been evacuated from the bases before bomb release. However, it appears that while there is an excellent chance of obtaining indications of an imminent Soviet attack, we cannot be sure of this with an acceptable degree of confidence, given the critical importance of the survival of our strategic bombing force. After the enemy raid is launched, there is little chance of early detection if Soviet aircraft follow routes which avoid inhabited areas and our advanced radars (see Fig. 70). The surprise attack, large or small scale, must be regarded as a major threat to SAC survival.

The advantages of surprise against SAC in the ZI may also be largely dissipated if the attack is not timed such that separate cells penetrate our radar net within a short period of time. Closely timed radar penetration of widely separated cells going to different targets is essential if a large proportion of the

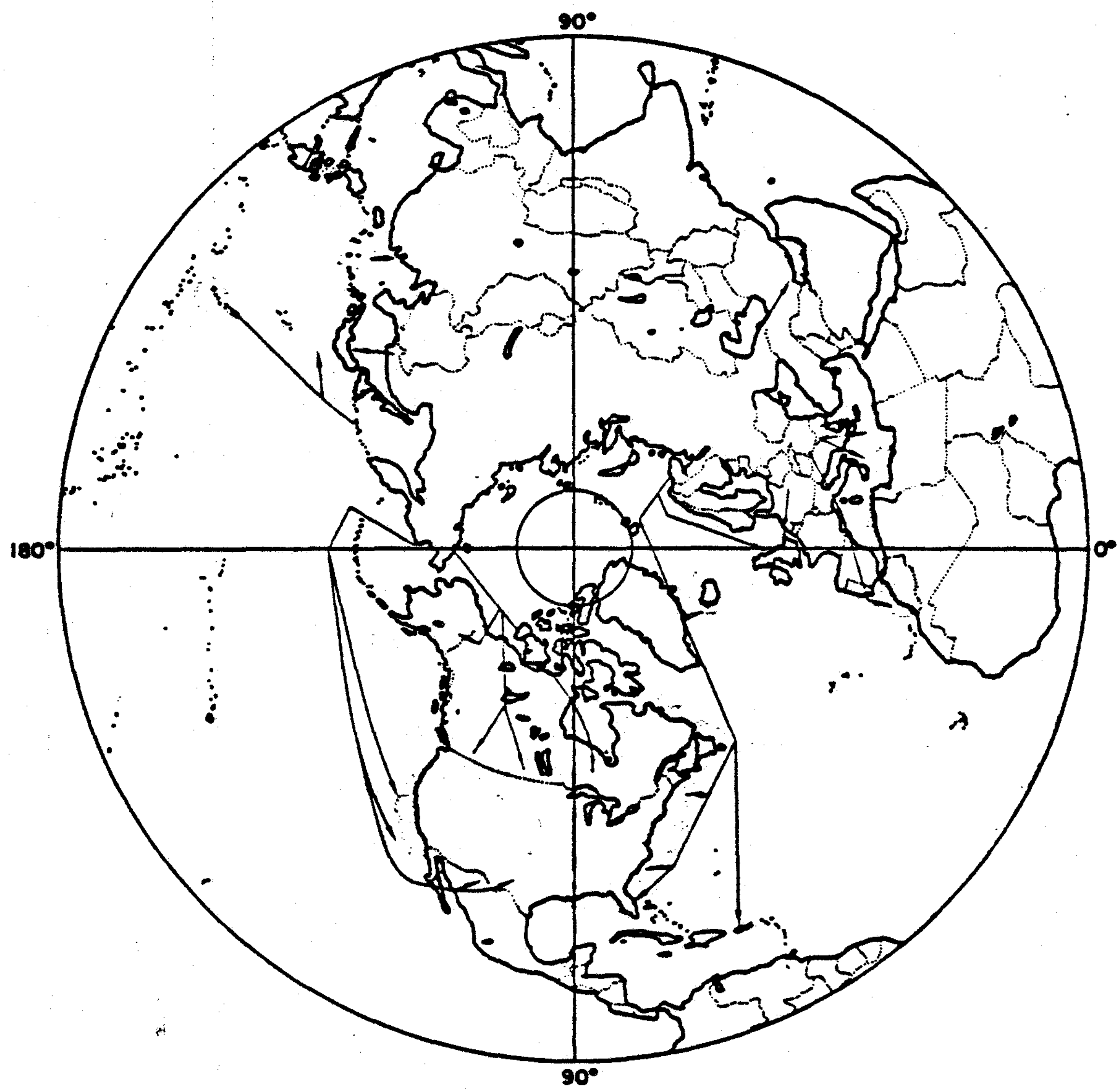


Fig. 70—Soviet attack routes to radar entry points: ZI and overseas bases (USAF radars only shown)

SAC bases attacked is to be found with aircraft on them at the time of bomb release, since the warning time available to our bases is the delay time in the penetration of enemy bombers after initial raid detection plus the flight time from radar net to base. This tactic would give SAC units the least time for evacuation before attack. Since the first Soviet strike could have a long period of peacetime preparation, practice missions having been flown over a good part of the routes, the range of expected arrival times at our early-warning network should be low. It appears that if preplanned loitering is used to offset tail winds, almost all attacking aircraft, at least in the first move, can penetrate the ZI radar net within a period of 30 to 60 min.

While a D-Day attack against units on rotation overseas may be made simultaneously with the ZI attack in order to surprise interceptors, antiaircraft artillery, and bomber units, this will involve a still higher degree of coordination; and since overseas-based units must remain at risk during the period of preparation for strike, there will be no need for immediate attack on these bases. We have assumed a delay of 6 to 8 hr before overseas bases are attacked. This warning period may be used to disperse bombers in areas where additional bases are available. However, the enemy should still have sufficient time to locate and attack dispersed bases before our initial strike can be mounted. Immediate evacuation and dispersal of bombers from overseas bases upon commencement of hostilities is not compatible with preparations for an immediate retaliatory strike.

The second enemy attack period, during initial deployment overseas, will have critical timing requirements, but of a different character. Here, if aircraft are to be destroyed, the enemy must determine which overseas bases are being occupied, and for how long, before the first strike is launched. There is the question of allocating A-bombs to bases possibly empty of bombers at the time of attack. However, the Russians should be able to anticipate our pattern of deployment with considerable success. Peacetime rotation maneuvers can be observed. The Mobility Plan is not highly classified. Base facilities and equipment, including the presence of Aviation Field Depot Squadrons, provide clues as to the intended mission of a base. Intelligence sources and reconnaissance during deployment may provide direct and detailed information on our deployment pattern. During this period we should expect a major effort on the part of the Soviet strategic force to disrupt our strike and to attrite our force on the ground by repeated high-explosive and atomic attacks, perhaps on unoccupied as well as occupied bases. The speed with which the Russians can learn of the arrival of our bombers on overseas bases and mount an attack is a matter of the greatest importance to medium-bomber units first deploying to overseas operating bases and to heavy bombers on both prestrike and poststrike staging bases. We must credit the Soviet force with the capability for rapid attack, especially during the period prior to our first attacks.

A wide range of bomber choice is available for attacks against most of our overseas bases. Attacks on these bases involve mostly unrefueled missions. Single aircraft and mass attacks, high- and low-altitude penetrations, night and daylight attacks, feints, and other tactics can be used to exploit our defense weaknesses or special Soviet proficiencies. In particular, large numbers of short-range jet bombers can be brought to bear against more than half of our overseas bases. Single-strike commitments as large as 300 TU-4's and 1000 IL-28's are likely.

The job of the Strategic Air Command is not likely to be accomplished by the first strike, and repeated strikes against the enemy will be required. Nor is the Soviet counter-SAC mission likely to be completed with an initial D-day attack and attacks during deployment overseas. It may not be until after our first strike that some units will be well exposed to attack. After our first strike, with a large part of the surviving medium-bomber force on overseas operating bases, continuing Soviet attacks on these bases, as well as on overseas staging bases, is to be expected. Further attacks against ZI bases are likely only against base-aircraft systems having low overseas vulnerability—intercontinental ground-refueled systems and, of course, intercontinental air-refueled systems.

The continuing vulnerability of overseas SAC bases depends in part on the success with which the Soviet strategic force can be neutralized on our first attacks. The prospects do not appear encouraging.* First, because we, unlike the Russians, are not likely to have very good information on the location of the enemy's strategic force at the time of attack. Second, because the Soviet strategic air force can make use of many of the active and passive defenses which can serve to reduce the vulnerability of our force—evacuation, staging, etc. It appears that other important passive defenses which serve to reduce base vulnerability to atomic attack have *not* been adopted by the Russians, but we should not count on their failure to protect their bases adequately by the 1956–1961 period. Third, because the number of bombs required to inflict serious damage to SAC in 1956 is a small fraction of the entire Soviet stockpile. Either the destruction of Soviet aircraft capable of carrying A-bombs will have to be essentially complete, or the Soviet A-bomb stockpile will have to be exhausted before the threat of atomic attack will be removed. In Part II we have treated explicitly the question of ground attrition of Soviet aircraft from our attacks, and the wide range of attacking forces considered may be regarded not only as the result of policy on the commitment of forces to SAC neutralization, but as the combined effect of survival of enemy forces and commitment policy. The vulnerability conclusions are little sensitive to wide variation in the level of attack mounted.

The major operational factors assumed for Soviet attacks are

*See pp. 366*ff*.

1. Bomber availability for the first attacks is high (around 90 per cent for long-range bombers), but for succeeding attacks it is assumed to drop to 50 per cent.
2. Two values of CEP have generally been assumed against airfields, i.e., 1500 ft for visual bombing conditions and 4000 ft for radar bombing.

VULNERABILITY OF THE FORMERLY PROGRAMMED BASE SYSTEM

Force Concentration with Respect to Soviet Attack Capabilities

The 120-wing strategic base system called for the following types and numbers of bases world wide: 33 ZI home bases; 26 overseas operating bases for medium bombers; 42 overseas fighter, tanker, and staging bases (13 capable of heavy-bomber staging); and 6 en route bases for overseas deployment. The location of this base system with respect to Soviet attack capabilities is presented in Fig. 71. This figure shows that—

1. Sixty-eight per cent of all overseas strategic bases are within Soviet jet light-bomber radius. Within this zone are 60 per cent of the overseas operating bases and 76 per cent of the overseas staging bases.
2. *No* overseas operating bases and only three overseas staging bases lie beyond TU-4 unrefueled radius.

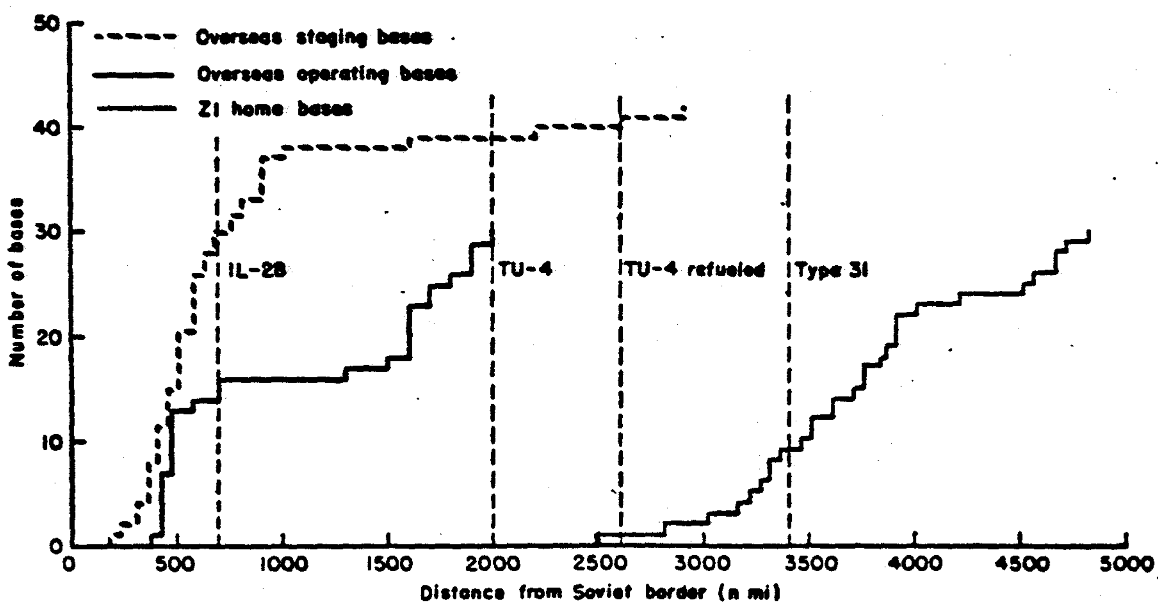


Fig. 71—Base location with respect to Soviet attack zones

3. No ZI strategic bases lie within unrefueled, and only one within once-refueled, TU-4 radius. However, 17 per cent are within Type 31 unrefueled radius, and 35 per cent are within Type 31 once-refueled radius.
4. All ZI bases can be reached by TU-4's (some refueled) or Type 31 aircraft on one-way missions.

While most of our bases can be reached by large numbers of Soviet aircraft on unrefueled, two-way missions, the Mobility Plan permits us to station most of our bombers in peacetime on bases most remote from the Soviet Union. However, perhaps 20 per cent of the medium-bomber force will be on rotation on overseas bases, whereas all our heavy-bomber units are likely to be stationed in the ZI at the time of attack.

Distance alone will not suffice to protect the strategic force from attack. Of greater significance is the number of high-value airfields in relation to the Soviet bomb stockpile and aircraft and bomb requirements for successful attack. Consider the system as formerly programmed: All of the strategic force is stationed on about 40 bases world wide (7 overseas, 33 in the ZI). These 40 bases present a far from equal-valued target system, and a large proportion of our effective striking potential is located at considerably fewer points. Seven ZI bases contain all heavy bombers (excluding those in depots and on bailment), and about 21 bases in the ZI and overseas contain all combat-ready medium bombers. Initially, then, less than 30 targets contain the atomic striking force. And within this small set there are significant differences among units, due to state of readiness, etc.

With the commencement of hostilities and the execution of SAC strike orders, the exposure of the strategic force to attack is changed rapidly: (1) all units go on a high state of alert; (2) if E-day is named immediately, a large part of the force starts to deploy overseas, and, for at least a while, these units no longer present static targets; (3) on the other hand, movement to overseas bases exposes the striking force to repeated attack by larger numbers of Soviet aircraft. With the U.S. strike pattern assumed here for illustration,* there is a considerable variation in the exposure to attack of different types of bombers: (1) 67 per cent of the total strategic force might be committed to the first strike. This would be almost all of the combat-ready part of SAC; (2) 50 per cent of the B-47 striking force would be exposed to IL-28 attack during pre-

* We do not refer to any actual SAC war plans, current or past, in this report.

strike build-up overseas; (3) only 36 per cent of the B-36 strike force would be within unrefueled TU-4 radius prestrike, but 80 per cent would be within IL-28 radius while on poststrike bases before returning to the ZI.

In addition to being located at more advanced bases during this critical period, B-47's have slow build-up overseas. As many as 3 days may elapse between the arrival of the first B-47's on overseas bases and the launching of the strike. The corresponding prestrike build-up times for heavy bombers may range from 12 to 24 hr. And *after* the first attacks, most B-36's return to the ZI after a poststrike stop of 12 to 24 hr, while B-47's remain on overseas operating bases in preparation for later attacks.

The vulnerability of SAC while preparing for the first strike on overseas bases is critically dependent on the ability of the enemy to learn of the presence of our aircraft and to mount attacks rapidly. The speed with which this can be accomplished depends on the method of observation required and the readiness of this force for attack. If the enemy can learn quickly of the arrival of our bombers on base from intelligence sources, and if his bombers are being held in readiness for attack, then our bases are likely to be attacked within the shorter periods indicated in the discussion of refueling bases (see Table 46, page 327). The longer periods apply if intelligence or reconnaissance information is delayed and there is a longer preparation period before attack. This spread in probable delays before Soviet attack on prestrike bases is small in relation to the time aircraft typically spend in preparation on advanced bases. Even with considerably less than a 3-day build-up period, the likelihood of Soviet attack before the launching of the strike is extremely high. Heavy bombers on prestrike bases are less exposed to attack, even assuming high Soviet capabilities for attack in general, due to their remote location and shorter periods of occupancy. However, if the Russians can launch attacks within 6 to 8 hr after our strike, the major part of our heavy-bomber strike force would probably be caught on poststrike staging bases.

Some variation in deployment pattern and attack tactics is possible. A smaller proportion of the total force may be sortied on the first strike, and there will be some choice of both operating and staging bases to be occupied. And B-36's can attack some Soviet targets directly from their ZI home bases without the need for a prestrike stop.* These are important capabilities, for, in addition to the obvious advantages to the B-36's of their being mostly not on overseas bases,

* For example, B-36's can hit Leningrad from Carswell AFB, and Moscow from Limestone AFB, with poststrike stops in the United Kingdom.

by introducing uncertainty as to our strike timing or the location of our units, we reduce the probability of bombers being caught on base; and we may force the expenditure of A-bombs on empty bases. However, there are constraints which limit variations in the pattern of deployment possible with the 1956 base system:

1. While there is a considerable expansion in the overseas base program, this is offset by increases in the growth of SAC. In order for peak strikes to be mounted, most overseas bases are occupied by two or three squadrons of bombers. And some of the staging bases in the system are considered safe only for emergency use.

2. The prestrike exposure period overseas is lengthened by the difficulties of moving overseas, within a few days, from several hundred to more than a thousand bombers, tankers, and transports. En route stops are necessary for fueling and for crew rest, and limited en route base facilities prevent the simultaneous movement of all aircraft deployed for the first strike. Limited bomb-loading facilities have increased delays in the past, since medium bombers must phase through bomb-loading sites over a few days. This constraint will be largely eliminated by 1956, bomb components being stored at many more points in the ZI and overseas.

3. The functions performed on prestrike bases—crew rest and briefing, bomb testing and loading, final aircraft inspection, fueling, and servicing—take considerable time. Crews may be given an 8- to 12-hr rest period. And on many forward bases the speed with which these functions can be performed is limited by the facilities available—parking aprons, fuel-transfer facilities, ground-handling equipment, etc.

4. Poststrike staging periods are determined by the need for aircraft servicing, minor repairs of battle damage (aircraft with serious damage must wait for the arrival of mobile depot teams), and crew rest and debriefing. In addition to the facilities constraints noted in connection with prestrike occupancy, rapid poststrike aircraft removal is limited by the equipment and personnel limitations of C and MTF's.

5. Finally, with the size of the Soviet stockpile of bombs increasing much more rapidly than the number of bases available for our use, the Russians may be in a position to deny us the use of these alternate bases.

The strategic air campaign is unlikely to consist of well-defined "strikes" by the United States alternating with Soviet "strikes." One strike might consist of attacks over a period of a few days; and, after the start of the campaign, attacks might not involve widespread coordination of penetration. Some bombers might be "turned around" on poststrike bases and sent back to attack other targets. In sum, the post-first-strike disposition and operation of our strategic force is unlikely to be regular or completely predictable in character. However, with all these uncertainties surrounding the initial phase of the campaign—uncertainties facing the enemy as well as ourselves—one important vulnerability consideration remains clear: with our present method of operating medium bombers, whenever the enemy attacks an overseas operating base there is a high probability that it will be occupied by bombers.* Aircraft spend most of their time on the ground, and our overseas operating bases are to perform the wide range of functions needed for continuous operation: aircraft maintenance and repair through field maintenance; aircraft servicing; supply support; personnel administration, housing, and feeding; crew training; etc. At the time of enemy penetration of our overseas radars, but not necessarily at the time of bomb release, there will be an 85 per cent expectation of finding aircraft on base. Most other elements remain continually exposed to attack.

One possible distribution of strategic units following the first strike is shown in Table 40. Most of the B-47 force is stationed on about 20 overseas bases, and these units are much more easily accessible to Soviet attack than on D-day. B-36's are assumed to return to ZI home bases. During the interval between strikes, the location of our units is no longer as ambiguous as during deployment, and attacks could be made on overseas operating bases with a high expectation of finding the bases occupied. B-36's, unlike B-47's, restrict overseas base use to staging only and prepare for later strikes on relatively remote bases, exposing themselves to attack only on prestrike and poststrike bases.

Active Defense Effectiveness

Our programmed active defenses for 1956 cannot be expected to stop atomic attacks either in the ZI or overseas. These defenses have, in general, a kill potential low in relation to the size of the attacks that can be mounted against them. However, there are substantial differences in the defenses available to different base areas and in the forces that must be committed for successful attack. The result of Soviet attacks against different strategic bases, for various tactics and defense-weapons effectiveness, is presented in Fig. 72. These results show that, in 1956:

*The possibility of overseas base evacuation is considered later.

Table 40

POSSIBLE POST-D-DAY DISTRIBUTION OF STRATEGIC UNITS

Base Area	Aircraft Type	Number of Wings[a]	Within Combat Radius of—
ZI	B-36	7	Type 31, TU-4 (once refueled)
	RB-36	3	
	B-47	9	
	RB-47	1	
	F-84F	2	
Overseas			
United Kingdom	RB-36	1	IL-28, TU-4
	B-47	5	
	RB-47	1	
	F-84F	2	
French Morocco	B-47	5	TU-4
	RB-47	2	
	F-84F	2	
Spain	B-47	4	TU-4
	RB-47	1	
	F-84F	1	
Iceland	B-47	1	TU-4
Greenland	B-47	1	TU-4
Alaska	B-47	1	IL-28, TU-4
Japan	RB-47	1	IL-28, TU-4
	F-84F	1	
Guam	B-47	1	TU-4
Okinawa	B-47	1	IL-28, TU-4
TOTAL		52	

[a] Plus tanker squadrons.

(1) A mass surprise raid at high altitude against all ZI strategic bases and other targets designed to provide an individual bomber survival probability of 0.70 will require the commitment of approximately 400 TU-4 or Type 31 aircraft (excluding tankers). If the Russians employ countermeasures effectively, or if our defenses do not perform as well as expected, an attack of this size will have an average bomber probability of survival (excluding aborts and operational losses) of 0.96. On the other hand, if the attack does not come as a surprise and our defense units are alerted, the average survival may be as low as 0.53.

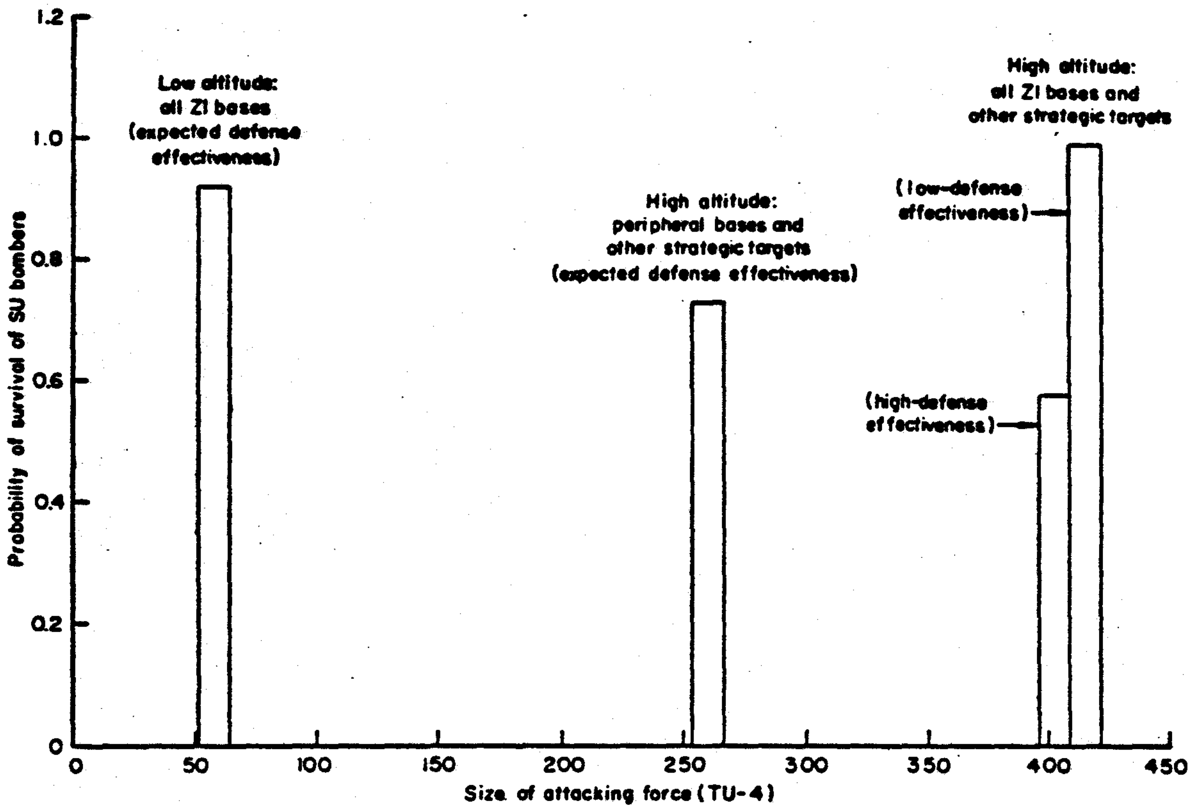


Fig. 72—Soviet bomber survival through active defenses: ZI

(2) A low-altitude attack involving about 50 TU-4 or Type 31 aircraft directed at all ZI SAC bases will have about a 0.9 probability of surviving our programmed active defenses.

The initial allocation of 1000 IL-28- and 200 TU-4-type bombers to attack overseas areas containing strategic bases provides single-strike survival probabilities upward of 0.9 if straightforward, high-altitude attacks without deceptive tactics are employed. With the use of countermeasures, feints, and low-altitude attacks, much smaller forces can be committed to this mission.

One of the chief limitations in the effectiveness of our overseas fighter defenses is inadequate radar coverage for the alerting of these units and for effective control. Typically, only a few of a fighter squadron's interceptors are on the alert line (4 per Air Defense Command (ADC) Squadron), and the remainder become available after delays of minutes to hours, which depend on the state of alert and maintenance condition of the aircraft. Since many overseas bases will have no more than 45 minutes' warning of high-altitude attacks, and 15 minutes' or less warning of low-altitude attack, only a relatively small proportion of our deployed defenses will have the opportunity of engaging in combat. Some ZI peripheral bases will also suffer from this "seacoast degradation." Moreover, this inadequate warning permits the enemy to use feinting and wave tactics in order to reduce further the weapons brought to bear on bomb carriers.

The use of doglegs to avoid area defenses or to reduce warning time can be used against us in the same manner as indicated in the section entitled "Bases, Targets, and Penetration Paths," page 135. Our strategic bases are usually protected in asymmetric fashion by radars and interceptors, and dogleg routes can be used to reduce losses. Attacks against southern ZI bases, using dogleg routes through Mexico, greatly reduce expected losses to interceptors. Similarly, minimum-penetration paths can be used to good advantage against French Morocco, Iceland, Alaska, and other areas (see Fig. 70).

There is a considerable difference in the cost of attacking different base regions. The ZI and the United Kingdom are to be defended heavily in comparison with other base areas. Within the ZI, in particular, there is a considerable variation among base groups (some of these differences are shown in Fig. 73).

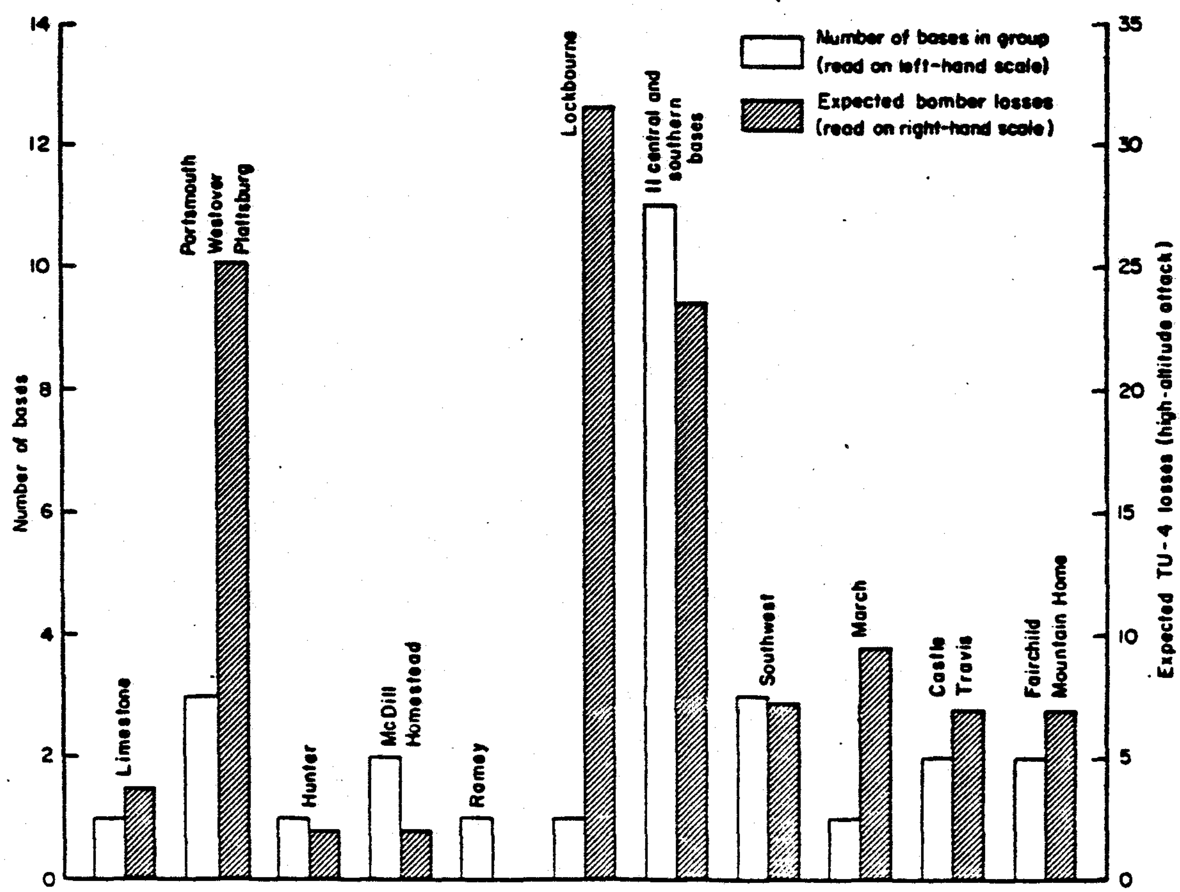


Fig. 73—Cost of attacking separate ZI base regions

For example, expected losses in attacking two bases in the Great Lakes region (Lockbourne and Bunker Hill) are greater than the losses expected against eleven bases in the Plains states and the south. The ADC is *not* distributed primarily for the defense of SAC, and there is substantial mismatching between our SAC base distribution and ADC interceptor distribution. However, the position of bases such as Bunker Hill and Lockbourne is worsened in the context of joint attacks including industry and population as well, since the Chicago, Cleveland, and Detroit areas could be attacked jointly at little extra cost in bombers. Similarly, attacks on Portsmouth, Westover, March, Castle, and Travis and other ZI bases fit well into a joint industry-population-SAC attack strategy. There is considerable incentive to combine the attacks, for not only are bombers committed to attack on the ZI unlikely to be available for re-use, but also attrition by our defenses in an attack after D-day may be as much as 50 per cent higher than in a D-day surprise attack.

Defense effectiveness will vary over the course of the campaign. Starting with low effectiveness against a surprise attack, after some hours our interceptors will be in a high state of alert. With intensive flying and, in particular, attrition of overseas base facilities and supplies and air and ground attrition of interceptors, there will be a degradation in effectiveness. And, since many of our overseas-based interceptors are to be stationed on bomber bases, they will suffer from enemy attacks on SAC. The defenses of Keflavik, Thule, Lages, and Goose Bay will be so affected. Even where fighters are separately based, the Russians may choose the tactic of attacking our fighter bases in order to reduce attrition in later attacks on bombers as they deploy overseas.

The Elements at Risk and Their Vulnerability

These major functions are normally performed on an operating base: (1) aircraft landing, parking, and take-off (2) aircraft and ground-equipment maintenance and repair; (3) storage and distribution of spare parts and other supplies, including petroleum; (4) bomb loading and (sometimes) storage of non-nuclear bomb components; (5) housing and support of personnel; and (6) command, communication, and administration. Each of these activities contributes to the support of an effective combat force, and physical destruction or damage to any of the elements on a base must be assessed by the effect on major base activities and consequently on wing combat effectiveness. Since the operational meaning of physical damage is very much a function of strike timing, climate, and availability of resupply, base vulnerability must be evaluated for each of the conditions under which the strategic force is likely to be operating. For example, the effect of damage to structures at March AFB at any season would be quite different from the same damage to Thule in winter. In order that an estimate can be made of the effects of successful enemy attack on our bases, we examine briefly the contribution of each of the major base elements (aircraft, personnel, supplies and equipment, pavements, and structures), their physical vulnerability, and the effect of the loss of each element on wing combat effectiveness.

Aircraft. Combat aircraft constitute an element which is (1) essential to the mission of SAC, (2) costly, and (3) essentially irreplaceable during the campaign. A surprise attack on strategic operating bases world wide would find only a small percentage of the assigned bombers off on training missions—about 8 per cent, on the average. At night or on Sunday a smaller proportion would be away. However, while aircraft spend most of their time on the ground, this does not mean that our bombers will necessarily be found on base by enemy bombers, and the SAC evacuation plan is intended to reduce the number of aircraft found on base at the time of attack.

Evacuation of Aircraft. With this plan, when approaching enemy aircraft are identified, those aircraft in flyable condition are rapidly readied for flight and evacuated, with minimum crews if necessary, to orbit areas and to alternate emergency bases. Where possible, nonevacuable aircraft are dispersed to the periphery of the field. The time required for the evacuation of flyable aircraft will vary with the time of day, day of the week, and degree of alert of the strategic force. It is difficult to estimate what the evacuation pattern will be like 3 years hence, and data on current experience show a considerable variance attributable in part to differences among aircraft types, local situations at different bases, and the realism with which exercises are carried out. Figure 74 presents a range of estimates of the proportion of bombers evacuated as a function of time after warning, based on the assumption that the decision to call a Red alert is made without delay. (In fact, at present this decision for SAC is associated with extensive responses, both by ADC and by the civil population—responses of such moment that long delays are made likely. This matter is treated below on page 289.) The upper curve shows expected times for Condition Alpha evacuation—emergency evacuation if necessary with minimum crews—when SAC is on alert. It appears that, on a one-wing base, about 65 per cent of the aircraft will be able to take off within an hour of the decision to evacuate. On a two-wing base, this might be reduced to the neighborhood of 50 per cent by traffic constraints on the rate of take-off. The middle curve for

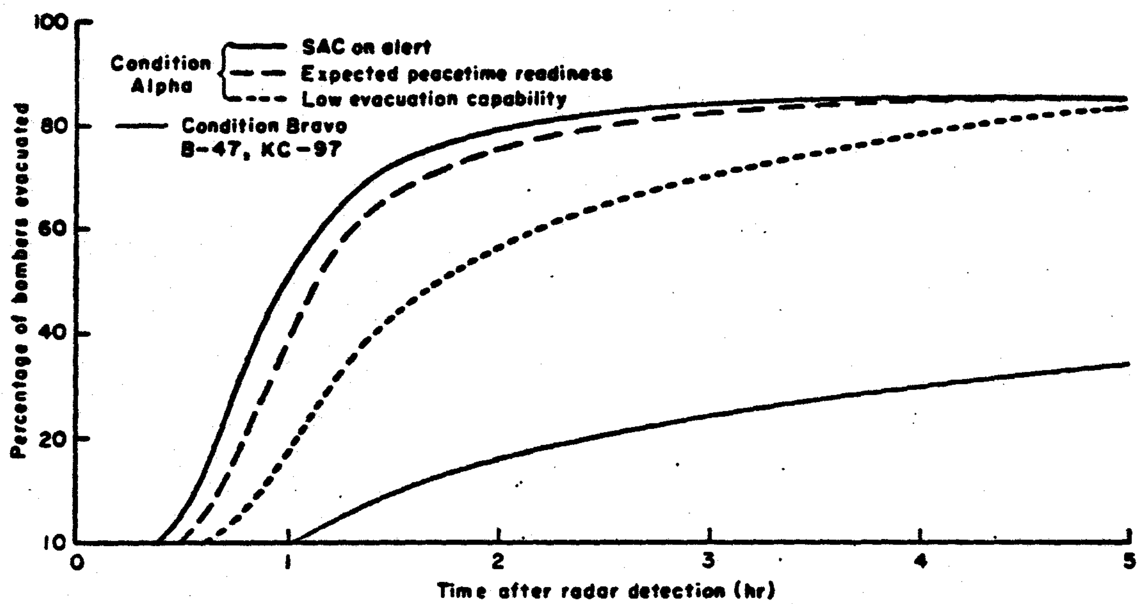


Fig. 74—Aircraft evacuation times

Condition Alpha evacuation we assume to apply to the case of a surprise attack without any prior alert, in which evacuation goes off smoothly—minimum crews are assembled quickly, traffic moves smoothly on the base, and there are no serious accidents tying up the operation. The lower Condition Alpha curve represents the lower bound of evacuation expected. Finally, the rate at which aircraft can be brought into Condition Bravo, ready for deployment overseas with full combat crew and flyaway kits loaded, is shown for medium-bomber units. B-36 aircraft take from 6 to 8 hr to prepare for deployment.

Successful use of evacuation for defense depends on (1) sufficient warning for evacuation and (2) infrequent execution, if evacuation is to be used as a continuing defense. The warning times expected within the ZI are shown in Fig. 75 for the two attack routes described above—relatively direct routes and minimum-penetration routes. The precision with which the Russians can time penetrations has an important effect on damage, since evacuation begins shortly after the *first* Soviet bombers are identified, and late arrivals may find empty bases. On the basis of SAC experience, it appears that almost all Soviet bombers could penetrate the ZI radar net within a period from 30 to 60 min. The patterns of evacuation and of attack described combine to give the proportion of SAC aircraft on base at the time of bomb release, as shown in Fig. 76, neglecting for the moment losses of Soviet aircraft en route to target. We find that

1. If the evacuation plan works as expected, a surprise high-altitude Soviet attack along relatively direct routes with a 30-min spread in bomber

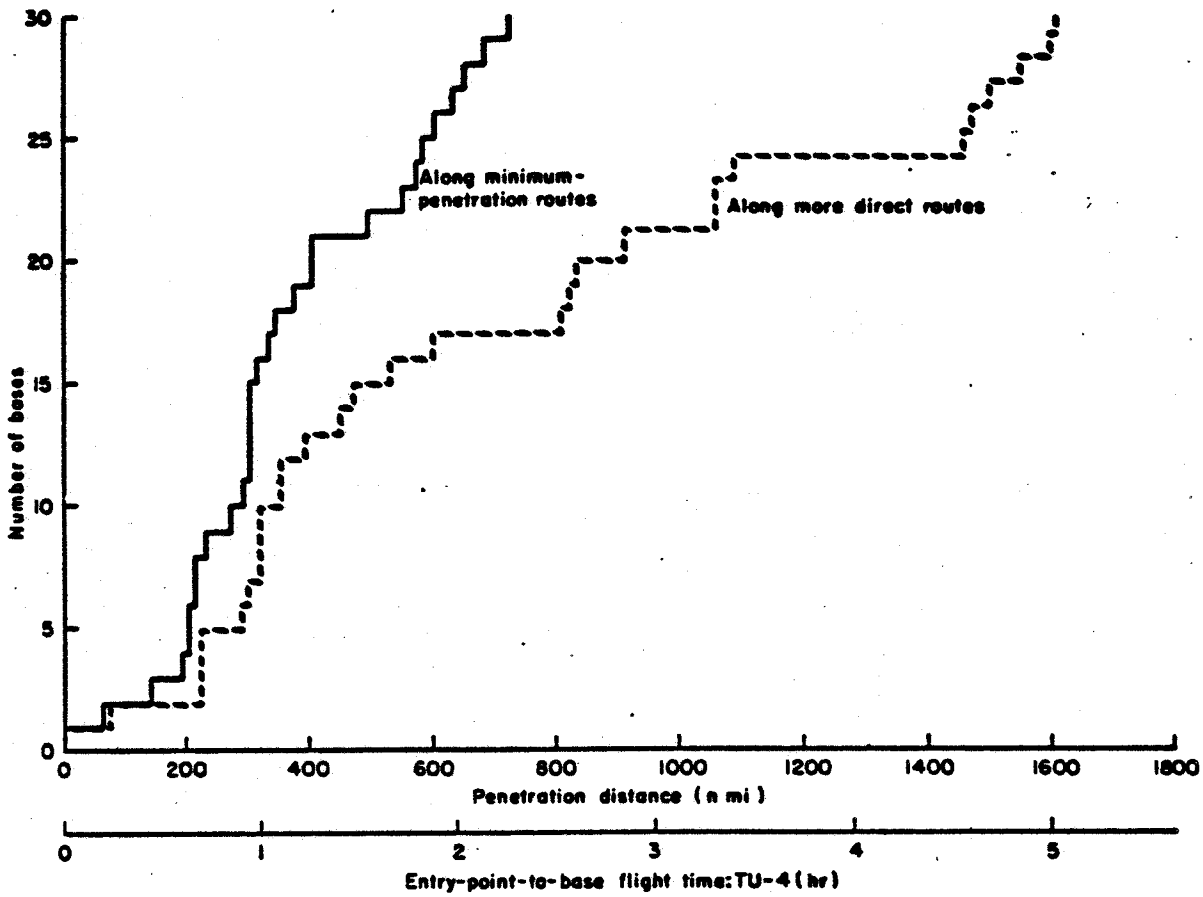


Fig. 75—ZI base penetration distances: high-altitude attack

radar penetrations will find *40 per cent* of SAC aircraft on base at the time of bomb release.

2. If Soviet aircraft can follow minimum-penetration routes, closely timed, up to 60 per cent of SAC may be on base at the time of bomber arrival. Low-altitude sneak attacks increase still further the proportion of aircraft found on base.
3. If SAC is on alert, and if the Soviet attack is poorly timed and not along minimum-penetration routes, as low as *20 per cent* of SAC may be found on base at the time of attack.
4. Practically no bombers will have time to take off in Condition Bravo, and overseas deployment of the surviving force will be delayed at least by the time required to reassemble aircraft, flyaway kits, and personnel.

The advantages of rapid overseas deployment in order to strike at Soviet air bases as quickly as possible must be balanced against the increased attrition to SAC if evacuation is delayed until aircraft are loaded and ready for overseas

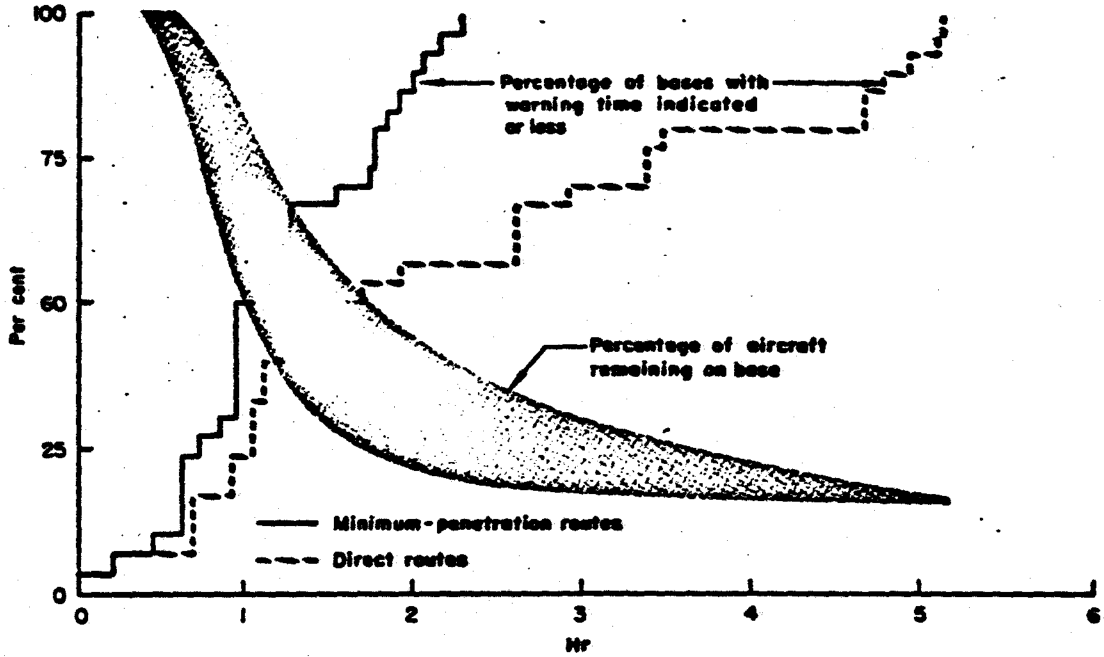


Fig. 76—Warning and evacuation: ZI (1956)

deployment. Failure to evacuate SAC rapidly may result in the loss of most of the force. It appears that plans for immediate deployment are not compatible with immediate evacuation, and, with the high ground attrition of SAC indicated, evacuation should not be delayed in order to speed deployment.

If the Russians choose to attack the ZI first on D-day, as appears likely, aircraft on rotation overseas may be able to evacuate before the subsequent attack on their bases. Such an initial evacuation should be regarded as a more or less automatic reaction to the commencement of hostilities, rather than as a measure which will serve to protect these aircraft until they can be sent off on the first series of attack. For they must land after a few hours, and, since most overseas bases will have entirely too little warning for evacuation after detection of an approaching force, they will be exposed to attack (see Fig. 77). The decision to evacuate may be based on indirect and perhaps ambiguous information in such base areas as the Azores, North Ireland, and French Morocco.* However,

* Attacks from eastern Germany directed against our bases in England and the two in northern Ireland will be tracked by European radars for a period lasting from 45 min to 1½ hr (IL-28). This time should be sufficient for evacuation, if execution is started immediately upon penetration of radars in western Germany. However, if evacuation is commenced whenever Soviet aircraft penetrate, then U.K.-based bombers will spend most of the time in the air. If they wait for take-off until the raid is clearly directed against the United Kingdom or against the area in which specific bases are located, then insufficient time for evacuation will remain. Only the two bases in northern Ireland and possibly those on the west coast of England, with no more than a squadron to a base, may have sufficient screening distance to withhold evacuation safely until a raid can be clearly identified as a threat to them.

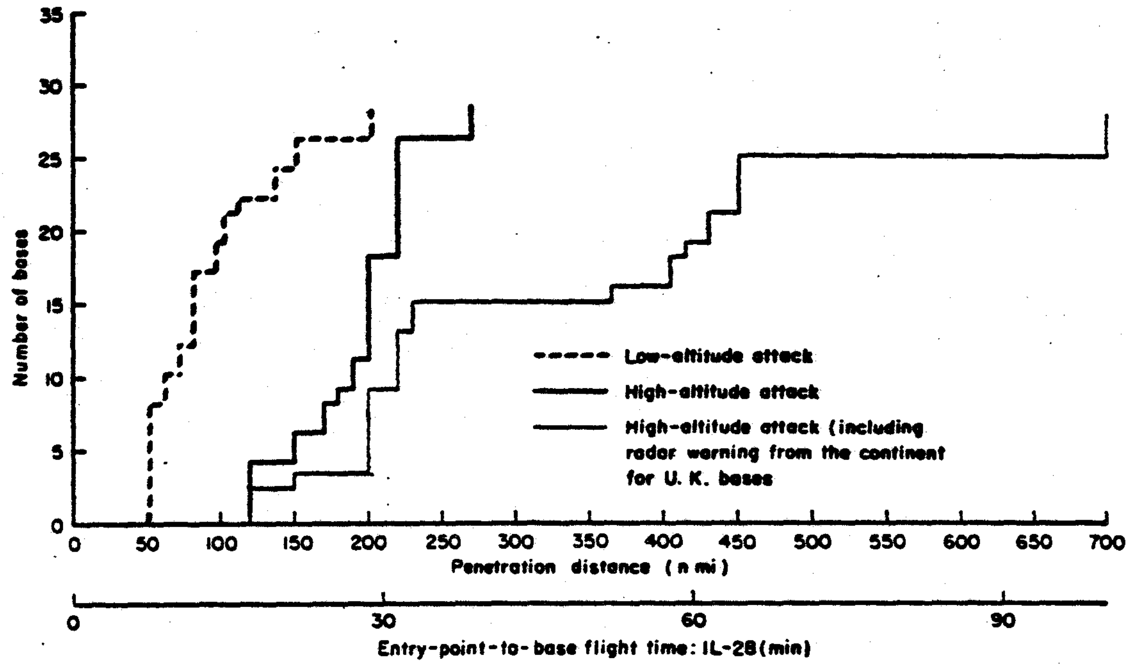


Fig. 77—Overseas operating base penetration distances

the reliability of warning leading to evacuation from overseas bases is at best highly uncertain, evacuation will have to be carried out frequently, and the possibility of frequent evacuation may limit the usefulness of this measure for defense.

Aircraft evacuation and the preparation of aircraft for combat missions cannot be carried out simultaneously, and, even assuming that warning is available from radar or other sources, it can hardly be used as a continuing defense where frequent enemy penetrations are possible. And the threat of atomic attack makes even single aircraft penetrations dangerous. Probably evacuations as often as once a week could not be tolerated during wartime. The level of Soviet air activity during the early weeks of the campaign at most overseas bases would appear to exceed this standard, and it certainly would if we were clearly depending primarily on evacuation for defense overseas. It is important to note that it is not necessary for Soviet aircraft to make repeated *attacks* on our bases, but rather that we detect at frequent intervals the presence of aircraft that can *potentially* attack us. Thus, reconnaissance missions, penetrations against targets other than SAC, feints, and misidentification of our own aircraft may lead to evacuation. And we shall have neither adequate radar coverage overseas for the screening and evaluation of these penetrations nor strong enough active defenses to permit us to ignore all but the largest attacks.

If evacuation from overseas bases can be ruled out on grounds of frequent execution as well as inadequate warning, what of evacuation from those ZI bases that do have adequate warning? We may have to be concerned with frequent evacuations on either side of D-day, if the Russians fly ferret missions off our coasts during peacetime as well as flying reconnaissance missions and making repeated attacks after D-day.* The appearance of one or two Soviet aircraft, if not quickly followed by the appearance of many others, is not enough to threaten more than a small fraction of SAC ZI bases. Repeated, large-scale penetrations of ZI coastal radars will be difficult against most parts of the ZI on two-way missions. Only the Pacific Northwest is as accessible as are some overseas base areas. There is an important difference between ZI interior bases and those open to relatively frequent Soviet penetrations. Units on Bunker Hill and Lockbourne can afford to be less concerned about the penetration of numbers of Soviet aircraft that should cause anxiety at Fairchild and Limestone, not only because of the greater evacuation time available, but also because of the presence of considerably stronger active defenses between these interior bases and the edge of the radar net.

In concept, the evacuation plan appears to be ideally suited for the protection of bombers, since the protection of this vital systems element by other means is much more uncertain and costly. Evacuation is not without its problems, and its cost and feasibility must be examined in the light of different enemy attack capabilities, different base locations, and its effect on our strike timing.

Physical Vulnerability of Aircraft on the Ground. The vulnerability of aircraft on the ground has been the subject of recent tests. While, at this writing, the engineering studies of the damaged aircraft and extrapolation of the results to the B-47, B-36, and B-52 are not available, it is clear from obtainable data that aircraft are "soft" targets. We have used the criteria presented in Table 41 in estimating the vulnerability of aircraft to atomic and high-explosive attack. *Destroyed* aircraft have suffered major structural damage, very extensive surface damage, fires, etc. The *serious damage* category includes those aircraft having fractured structural members, extensive skin dimpling, warping and tearing of control surfaces, and injury to instruments and electronic and hydraulic systems. This damage would require depot repair, and aircraft so damaged

*The *direct* cost of evacuating a B-47 wing is about $250,000. In addition, degradation combat effectiveness results from its execution, and this degradation should be included in comparisons of evacuation with other types of defense measures. This degradation has proved to be difficult to measure, and no estimate of it is included. Peacetime evacuation, however, has some payoff as an exercise to increase SAC's facility in its accomplishment.

Table 41

PHYSICAL VULNERABILITY OF SOME SAC ELEMENTS

	Atomic Bomb		HE Bomb	
	Blast (overpressure in psi)	Thermal Radiation (cal/cm²)	Type	Mean Area of Effectiveness (ft²)
Aircraft (B-47, B-52)[a]				
Destruction	5 to 10[b]	..	20-lb fragmenting 100-lb GP	3,600[c] 9,500[c]
Major structure damage	4 to 8[b]	33	20-lb fragmenting 100-lb GP	67,800[d] 331,000[d]
Surface damage[e]	3 to 4[b]	22	....	....
Minor damage[f]	2	..	....	....
Installations				
Runways and airfield pavements	Cratering and deformation	..	....	Cratering
Hangars, operations, and communications facilities				
100 per cent collapse	8	..	....	15,000 to 25,000/ton
50 per cent collapse	5	..	....	15,000 to 25,000/ton
Shops and warehouses				
100 per cent collapse	10	..	....	15,000 to 25,000/ton
50 per cent collapse	7	..	....	15,000 to 25,000/ton
POL storage				
Above ground, full	15	..	....	([g])
Above ground, less than full	5	..	....	([g])
Below ground	55 to 200[h]	..	....	Cratering
GCA and communications antennas	5	..	....	....
Supplies and Equipment				
Exposed equipment				
Vehicles	15	..	....	....
Cranes	25	..	....	....
Docks	7	..	....	....

Table 41 (continued)

	Atomic Bomb		HE Bomb	
	Blast (overpressure in psi)	Thermal Radiation (cal/cm²)	Type	Mean Area of Effectiveness (ft²)
Supplies and Equipment—continued				
Sheltered equipment Vehicles Aircraft spares Other supplies	Dependent on degree of collapse of structure housing item			

	Blast (overpressure in psi)	Radiation		Type	Mean Area of Effectiveness (ft²)
		Gamma (roentgens)	Thermal (cal/cm²)		
Personnel					
Exposed	......	100 to 200 (50 per cent casualties)	6	....	....
In structures	Building collapse (100 per cent casualties, 50 per cent mortalities)	......	..	....	....

[a] The B-36's are more vulnerable than the jet bombers.
[b] Lower value is for side-on or tail-on orientation; upper value is for nose-on orientation.
[c] Destruction by fuel fire.
[d] At most, major structural damage; may be less.
[e] Damage to skin of control surfaces or bomb bay doors.
[f] That is, damage to plastic windows.
[g] Vulnerable to perforation and fuel fire caused by GP bombs.
[h] Depending on amount of earth cover.

would be out of action for weeks and possibly for months (this depends on the total number of aircraft to be repaired and the extent of Soviet attacks on our depot repair facilities). *Minor damage* is defined as damage that would normally be repaired at base level: replacement of plastic windows, control surfaces, bomb bay doors, etc. This type of damage contrasts markedly with that produced by high-explosive bombs, which latter type is likely to affect different parts of different aircraft hit. In the case of A-blast, the possibility of repair by cannibalization is greatly limited, and replacement for damaged components must come out of stock. However, those stocks of spare parts that are at base level are likely to be damaged at the same time as the bombers. If replacement parts are available, minimal base facilities substantially intact, and personnel casualties low, then this repair can be accomplished within a day or two. On programmed bases, few aircraft receive minor damage, since the enemy should have available bomb sizes producing high levels of serious damage and destruction. With widespread local (microscopic) dispersal, minor damage might become significant.

Installations. The major function of most operating base facilities (65 per cent by value) is to shelter those activities which are directly or indirectly related to the combat effectiveness of the wing. Physical damage to structures whose chief function is to provide shelter has meaning primarily in terms of (1) indirect damage to the contents of the buildings, and (2) deterioration and loss in efficiency resulting from the absence of this shelter. For most locations, at least in the initial phase of the strategic campaign, the first effect is dominant. Even for a period of short duration, the second effect is of importance at Arctic bases, where the severe climate would cause greatly decreased operating efficiency in the absence of shelter. The need of adequate shelter for efficient operation, especially in peacetime, is obvious, but the absence of shelter for a relatively short period in wartime would appear to be less important (except in the Arctic) than the other damage effects examined.*

Other base facilities (35 per cent by value) have a more *direct* functional relationship with major base activities. Runways and other airfield pavements, fuel storage and distribution, and power generators are in this category. Physical damage to these facilities will have an immediate effect on the combat capability of the wing.

Base structures (hangars, warehouses, shops, operation and communications buildings, housing, etc.) on most bases will collapse at 5 to 10 psi overpressures. And collapse may be followed by fire. Fuel storage and distribution facilities are vital, and, if located above ground, bulk storage tanks are vulnerable to both atomic and high-explosive bombs. At overpressures ranging from 5 psi (empty tanks) to 15 psi (full tanks), collapse is estimated to occur.

*While activities such as instrument and electronic repair normally carried out in a controlled atmosphere would suffer more from a loss of shelter than most maintenance activities, this degradation would be less important than the physical damage to fragile test equipment which would result from building collapse.

Below-ground fuel storage is vulnerable only to ground or penetration atomic bursts nearby or to high-explosive bombs—difficult to deliver on this facility in quantity. Some components of the fuel-distribution system (pumps, power generators) will suffer from moderate blast overpressures or from direct high-explosive hits. Damage to the fuel-distribution system will mean greatly extended fueling times for aircraft and longer periods of aircraft exposure on overseas staging bases.

Airfield pavements are not vulnerable to atomic air burst (except to large thermonuclear weapons), but they are vulnerable to a ground burst, and the crater produced by the surface burst of a 40-KT bomb (300 ft in diameter) will effectively destroy a runway if the bomb can be dropped on or very close to it. However, this calls for *extremely high accuracy*, and most bases have more than one runway (see page 324*f*, below). The residual contamination which follows a surface or penetration atomic burst raises the possibility of Soviet use of these weapons for base denial purposes as well as for runway cratering. An overseas operating base so hit may be put out of operation for weeks. Staging bases which have intermittent aircraft occupancy and possibly intermittent personnel occupancy should be less severely affected, and they may be operable within a matter of days, or possibly hours, depending on bomb size and other factors (see pages 327*ff*, below). It should be noted that an atomic attack in effect reduces an operating base to a staging base by the destruction of structures, stores, etc. Means to overcome this threat, including the development of decontamination techniques, respirators, clothing, and the training of wing personnel are being developed by the Air Force, and base denial from residual contamination appears to present a less serious problem than direct damage to aircraft, personnel, and structures.

The cratering of airfield pavements by high-explosive attack is a threat to refueling bases in particular, which normally do not offer attractive elements, such as aircraft, as targets. Time and antipersonnel bombs can also be used in order to immobilize airfields for considerable periods of time, the presently scheduled equipment and manpower being used for defense against this form of attack.

Equipment and Supplies. The major functions performed on an operating base—maintenance, servicing, and repair of aircraft; bomb testing and loading and occasionally storage of nonnuclear components; housing and support of personnel; fuel storage and transfer; storage of other supplies; communications, etc.—depend on the continuing availability of unit essential equipment, flyaway kits, station kits, and a wide variety of base stocks. And as initial supplies are exhausted, continuing resupply from the logistics system must be available.

The destruction of fuel on a base will have an obvious, immediate effect on operations. This destruction is unlikely, since at least part of the stocks on most bases will be under ground, and on many bases above-ground fuel storage will be far enough from the desired ground-zero for aircraft damage for the fuel to have a fair probability of survival. However, bulk fuel *may* be a primary target on staging and overseas operating bases prior to the arrival of bombers from the ZI, and bulk-fuel storage is a suitable target for high-explosive attack, especially on those bases that can be reached by IL-28 bombers. While most theaters have substantial off-base stocks of fuel, there may be delays in transportation and distribution to aircraft. The effect on continuing operations may be important if resupply from the ZI is delayed through enemy attacks on our ports or shipping. At the least, we can say that fuel is essential, and that it is often exposed above ground on our overseas bases. While the fuel stored underground appears to be invulnerable to air-burst bombs of moderate size, the fuel-distribution system is not as tough. On most bases, pumps, the most vulnerable link in the distribution system, are located very close to the parked aircraft—presumably the primary target. With damage to the fuel-distribution system, fuel can be transferred at only a low rate, and aircraft exposure on prestrike and poststrike staging bases will be considerably extended.

The loss or damage of vehicles, docks, communications, instruments, electronic systems, aircraft repair and bomb-loading equipment, tools, and flyaway kits will seriously degrade operations immediately, and unless replacements are made available, continued operations will not be possible. The assumed vulnerability of base matériel has been presented in Table 41 (page 252*f*).

Like aircraft, flyaway kits and unit essential equipment can be preserved from attack on ZI bases by evacuation. They can also be stored off base. However, in the Soviet attack cases postulated above, there would probably be less evacuation of unit equipment and supplies than of aircraft, the most valuable element. The evacuation of over half a million pounds of equipment and supplies from bases within the short time available generates a heavy requirement for vehicles and personnel for loading, and most bases would be hit before evacuation was completed.

When wartime operations begin, a demand for matériel will be generated by normal wear and tear of flight, repair of battle damage to aircraft, and repair of ground damage to aircraft. At the same time, the supply of this matériel may be decreased back along the line of supply through attrition from enemy attack. The operational effectiveness of the force, even at the outset of the campaign, may depend critically on the availability of a minimum essential quantity of replacement aircraft spares and other supplies. The degree of concentration of aircraft spares in the system is greater than the concentration of aircraft. While detailed examination of the vulnerability of the depot support structure is beyond the scope of this study, it is worth noting that attacks on depots do not add substantially to the number of ZI and overseas targets hit. Most SAC spares will be located in six ZI depots, and the spares of any aircraft type will be largely concentrated in two ZI zonal depots. Attrition to depot supplies will have an effect on operations rather sooner than is apparent from the putative "thirty days of supply" carried in squadron flyaway kits, with the high attrition to flyaway-kit supplies on our overseas operating bases that is expected. The vulnerability of depots takes on a new meaning as the "cushion" between aircraft operations and depot support disappears through a combination of increased consumption and decreased supply.

Personnel. The protection of personnel against attack is a necessary requirement of any defense, not only because we value life highly, but also because SAC operations depend on the highly organized team efforts of specialists in many fields. Crews, especially "select" crews, are particularly valuable, and replacement for these men as well as for many maintenance and other positions would take many months.

Measures for protecting wing personnel on ZI bases are similar to those for the protection of aircraft and mobile matériel. They can be evacuated from bases in vehicles, on foot, or possibly in tankers and bombers. However, the evacuation of personnel conflicts with the evacuation of aircraft and matériel, and the net time available for evacuation of the latter is reduced if personnel are to be removed from base before bomb release.

Overseas, the opportunity for personnel evacuation is much more limited. Attacks with essentially no warning are possible; an attack without warning, or with only a few minutes of warning, will find most personnel critically exposed. And where sufficient warning is available for evacuation of personnel, it may not be possible simultaneously to evacuate bombers and flyaway kits.

Whether or not personnel will be exposed to attack, especially on overseas bases, in 1956 depends on the extent to which simple and inexpensive defense measures are generally adopted by that time. The use of slit trenches will reduce by a considerable factor the lethal radius of an A-bomb dropped. A protective measure of this sort can be rapidly provided, and the long lead times associated with the protection of many other systems elements are not involved here. Other measures described below are even better.

Expected Damage to Some Strategic Bases

The physical damage which will result from atomic attack on twelve of our scheduled 1956 bases for a range of bomb sizes and aiming errors is presented in Table 42. We find that very high damage levels result for a wide range of bomb sizes and bombing accuracy, most of which should be well within 1956 Soviet capabilities. Most, but not all, of the elements on base at the time of attack are destroyed or rendered unusable for the campaign.

Our strategic bases in many respects present ideal targets for atomic attack. Most base elements are highly concentrated, even on our relatively dispersed French Moroccan bases, and a single aiming point is close to optimal for the great majority of the elements the enemy is likely to want to destroy. Even where dispersal is practiced overseas, the softer targets (aircraft) are farther from the base center, while the targets requiring higher overpressure are concentrated close to it. Consequently, base layouts correspond roughly to the overpressure pattern of the atomic bomb.

A 20-KT bomb dropped with a 4000-ft CEP will destroy or severely damage close to 85 per cent of the aircraft on the ZI bases examined. Most of the remaining aircraft will receive minor damage, requiring replacement of some damaged airplane components before combat missions can be flown.*

Base structures are damaged only slightly less. On the average, 55 per cent of the hangars, 45 per cent of shops and warehouses, and 70 per cent of operations and communications buildings are collapsed. Most of the remainder suffer serious damage. Flyaway kits and communications and electronics equipment in warehouses are assumed damaged in proportion to warehouse collapse.

Bulk fuel has a better chance of survival than other fragile base elements, due to its location well away from the selected aiming points. Underground fuel and pavements are undamaged. There is, however, at least a 30 per cent expectation of damage to the fuel-distribution system.

Approximately 60 per cent of the personnel on base at the time of attack become immediate casualties, and about 30 per cent of the total probably die.

*In calculating base damage against our scheduled bases, we assumed throughout aiming points and heights of burst optimal for aircraft destruction, except for surface-burst cases discussed below.

Table 42

EXPECTED DAMAGE TO SAC BASE ELEMENTS

Base	CEP (ft)	Aircraft: Destroyed	Aircraft: Major Repair	Aircraft: Light Repair	Installations: Hangars 100% Collapse	Hangars 50% Collapse	Shops and Warehouses 100% Collapse	Shops and Warehouses 50% Collapse	POL (Above ground)	Operations and Communications 100% Collapse	Operations and Communications 50% Collapse
100-KT BOMB											
Bergstrom (ZI)	1500	1.0	....	....	1.0	....	1.0	....	0.65	1.0	....
	4000	0.85	0.15	....	0.85	0.15	0.75	0.2	0.45	0.75	0.2
Ben Guerir (FM)	1500	0.65	0.3	0.05	0.95	0.05	0.95	0.05	....	0.95	0.05
	4000	0.6	0.3	0.10	0.75	0.2	0.7	0.15	0.05	0.7	0.15
Dhahran	4000	0.81	0.17	0.02	0.94	0.05	0.72	0.19	0.45	0.75	0.15
Eielson	4000	0.80	0.18	0.02	0.94	0.06	0.72	0.16	0.40	0.71	0.12
Goose Bay	4000	0.69	0.22	0.08	0.76	0.13	0.53	0.26	0.15	....	....
Lages	4000	0.85	0.15	....	0.78	0.12	0.16	0.17	0	0.44	0.22
Little Rock	4000	0.86	0.14	....	0.99	0.01	0.73	0.23	0.29	0.66	0.20
Santa Maria	4000	0.80	0.19	0.01	0.95	0.05	0.76	0.24	0.50	0.64	0.14
Thule	4000	0.71	0.20	0.08	0.84	0.11	0.36	0.23	0.43	0.72	0.24
Wheelus	4000	0.79	0.14	0.06	0.75	0.12	0.62	0.22	0.44	0.63	0.22
Typical overseas base[a]	4000	0.44	0.23	0.14	0.66	0.15	0.36	0.21	0.18	0.55	0.19
40-KT BOMB											
Bergstrom (ZI)	1500	0.95	0.05	....	0.95	0.05	0.95	0.05	0.6	0.95	0.05
	4000	0.6	0.25	0.1	0.6	0.3	0.55	0.2	0.25	0.55	0.2
Ben Guerir (FM)	1500	0.45	0.3	0.15	0.8	0.2	0.85	0.1	....	0.85	0.1
	4000	0.3	0.35	0.15	0.55	0.25	0.5	0.2	....	0.5	0.2
Davis	4000	0.68	0.30	0.02	0.67	0.11	0.53	0.20	0.06	0.50	0.22
Goose Bay	4000	0.47	0.35	0.08	0.58	0.18	0.37	0.18	0.05	....	....
Little Rock	4000	0.69	0.26	0.05	0.80	0.20	0.56	0.16	0.06	0.54	0.12
March AFB	4000	0.63	0.33	0.04	0.68	0.18	0.56	0.14	0.24	0.47	0.18
Thule AFB	4000	0.48	0.37	0.14	0.62	0.18	0.27	0.07	0.22	0.56	0.15
20-KT BOMB											
Goose Bay	4000	0.33	0.35	0.14	0.42	0.16	0.24	0.11	0.04	....	....
Little Rock	4000	0.55	0.33	0.07	0.53	0.26	0.42	0.18	0.06	0.33	0.24
Thule	4000	0.32	0.32	0.21	0.44	0.17	0.11	0.17	0.15	0.40	0.16

[a] Multipurpose air base: 2 medium-bomber wings overseas, dispersed (area dispersal against high explosive).

In addition to the 60 per cent of immediate casualties, an additional 20 per cent have to be relieved of duty within about one week.

Larger bombs (from 40 to 100 KT) increase the proportion of aircraft destroyed as compared with those receiving lesser damage, but the already low proportion *immediately* available for combat is hardly reduced further.

In sum, there is a high probability that those elements not evacuated from ZI bases before bomb release would be destroyed (except pavements and operating-fuel storage, located underground), and a unit on base at the time of attack would be effectively destroyed. If the attack occurred *after* the deployment overseas of medium-bomber units, or after the evacuation of aircraft, flyaway kits, and personnel, this damage would have little effect on the campaign, since bases abandoned in accordance with the Mobility Plan have no immediate function to perform in the campaign. Zone of the Interior heavy-bomber bases, on the other hand, would have to support continuing operations, and damage to facilities, apart from losses of aircraft, flyaway kits, and personnel, would degrade continuing operations. On most bases a mixed situation would exist: some aircraft, flyaway kits, and personnel would be off base at the time of attack, and only those remaining would be exposed to the damage indicated. No estimate has been made of subsequent combat effectiveness of wings which survive with unequal fractions of aircraft, supplies, and personnel, since the direct loss of aircraft alone appears unacceptably high.

Expected damage on overseas bases would differ little from that in the ZI. Aircraft on bases with large dispersal areas would force the use of the larger bombs—40 to 100 KT in size—to achieve high coverage. On Ben Guerir, for example, an average of 65 per cent of the aircraft would be destroyed or seriously damaged by a 40-KT bomb dropped with a 4000-ft CEP. A 100-KT bomb dropped with the same accuracy would destroy or severely damage 90 per cent of the aircraft. With a 1500-ft CEP, likely in daylight attacks, bombs of 20- to 40-KT size would give high coverage on all but our largest bases.

We have not attempted to fix optimal bomb-yield–CEP combinations for attacks on our bases. Differences in total fissile-material requirements for different bombs that may be used against SAC are small in relation to the uncertainties regarding the Soviet fissile-material stockpile. It appears that bombs of about 40 KT in size are adequate for high levels of damage, except for a few of the largest bases. With low CEP's, possible in daylight attacks, bombs as small as 20 KT in size would be suitable against most bases. We shall have only four or five bases so spread out that bombs of a size as large as 100 KT might be profitably used for very high coverages.

Overseas base damage would affect strategic operations differently, depending on intended base functions and the system elements on base at the time of attack:

1. Any unit attacked *while bombers were on base*, either before or after the first strike, would lose or have damaged most of its aircraft equipment, flyaway kits, and nonevacuated personnel. A unit so hit would be effectively destroyed. And since B-47's on overseas operating bases would spend most of their time on bases accessible to Soviet attack, the expectation of such damage is high.

2. Overseas operating bases hit *before* the deployment of tactical aircraft overseas would suffer damage which would not prevent base use, except for a brief period for recuperation that should not last longer than a few days, since airfield pavements would remain available for use. However, these bases would be useful largely for staging purposes only.

3. Damage to overseas staging bases *while unoccupied by bombers* would introduce a delay for recuperation of perhaps a few days before these bases could be used. Longer prestrike and poststrike occupancy periods would result. However, the functions performed on these bases are relatively simple, and they are performed in large part with matériel and by personnel brought in with the tactical aircraft. Damage to communications, ground-handling and power-generation equipment, and casualties to base personnel would reduce the traffic-handling capacity of bases intended for staging use, but the essential elements required for the mounting of strikes would appear to remain substantially intact.

Expected damage to parked aircraft from high-explosive attacks is fairly high for heavy Soviet attacks; structures, and especially pavements, are less easily damaged. Dispersed parking of aircraft on overseas bases generally does not reduce expected damage from atomic attacks but very substantially reduces expected loss to high-explosive bombs. Force requirements for effective high-explosive bombing attacks are high compared with requirements for atomic attack, and most of the TU-4 force and a large part of the IL-28 force will be required for simultaneous attack against our overseas base system.

Expected Damage to the Formerly Programmed Force

So far we have discussed separately the component parts of the base vulnerability problem: the strategic force as a target; resources devoted to attack against it; bomb delivery on base; elements at risk at the time of attack; and physical damage and some of the implications of this damage. These components considered jointly permit an assessment of total strategic-system vulnerability.

D-day Attack: Zone of the Interior. A surprise Soviet attack against ZI strategic bases would probably result in unacceptably high damage to SAC. These results can be summed up as follows:

1. For a total bomber commitment of 300 to 500 bombers to all ZI targets, and the commitment of 30 to 60 bombs specifically against SAC, from 50 to 70 per cent of the ZI strategic bases would be hit, and 20 to 30 per cent of the ZI-based aircraft and associated flyaway kits and other mobile matériel would be destroyed or seriously damaged. Most of the facilities on the bases hit would be damaged and rendered unusable until replaced or repaired. Less than 10 per cent of the aircraft would be able to take off in Condition Bravo ready for deployment overseas; most of the surviving aircraft would have to assemble with surviving flyaway kits and personnel at alternate emergency bases before deploying overseas. Attack would be at high altitude, coordinated for penetration of our ZI radar net (60-min spread in bomber penetration times) and along relatively direct routes. No Soviet use of deceptive tactics or countermeasures is assumed, and the SAC evacuation plan performs as expected (see Fig. 78).

2. The Russians should be able to accomplish significantly greater damage by sending more bombs to each base, attacking at low altitude with a smaller

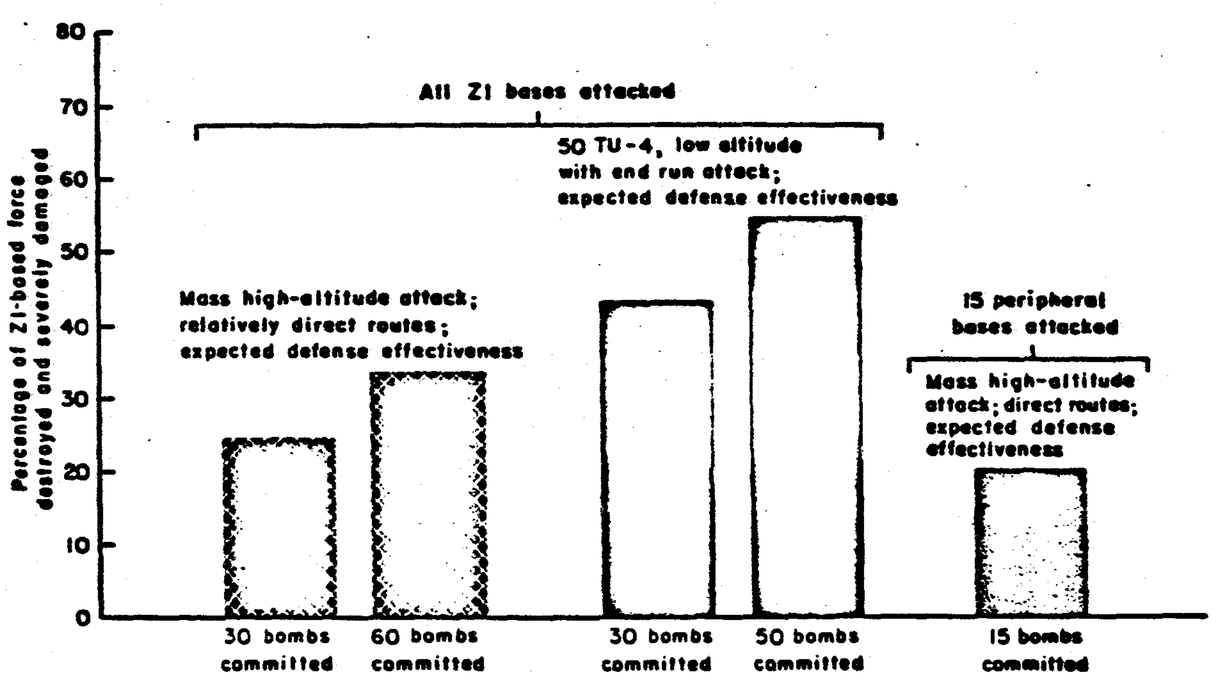


Fig. 78—D-day attrition: ZI

force, achieving better coordination of penetration, and following minimum-penetration routes. Forces committed to attack might be reduced by these measures and by the attacking of only peripheral bases, using countermeasures, etc. By these measures, as few as 50 to 100 bombers might be profitably committed to ZI attack—and SAC ground attrition upward of 70 per cent might result. In the high-altitude-attack cases, most of the aircraft destroyed would be those which required shallow penetrations, and the strategy of attacking only these bases would yield almost as much ground attrition at a substantially lower cost in bombers. The 15 bases nearest the edge of our Atlantic, northern, and Pacific radar boundaries would suffer 70 per cent of the aircraft loss. If attacks were confined only to these areas, the Soviet attacking force could be reduced in size by nearly 50 per cent.

In sum, it appears that SAC could suffer extensive damage to aircraft, personnel, and matériel in a surprise attack on the ZI. This damage, even with far from optimal enemy tactics—high altitude, selection of direct routes, etc.—would be unacceptably high, and it might be within enemy capabilities to destroy a majority of SAC ZI-based aircraft.

D-day Attack: Overseas. Units on rotation overseas would suffer high attrition from initial Soviet attacks. With a force of about 50 TU-4's, 200 IL-28's, and 20 A-bombs (mostly 40-KT bombs, with perhaps a few as large as 100 KT) about 55 per cent of the aircraft, supplies and equipment, and facilities on the occupied bases would be destroyed or severely damaged on a single strike and follow-up strikes mounted within a matter of hours or days. On a single strike, damage to about 50 per cent of the bombers stationed overseas would result from large-scale high-explosive bombing attacks on units on rotation. Attacks involving about 100 TU-4's and 500 IL-28's would be required for this level of damage.

Post-D-day Attack: First SAC Strike. We find a distinct difference between the expected attrition of medium bombers and that of heavy bombers on prestrike bases. Heavy bombers would stay on overseas prestrike bases for relatively short periods and would stay mostly on bases far removed from the Soviet Union. Some heavy bombers might not prestrike-stage overseas at all. In short, if heavy bombers remain on base for only 12 to 16 hr, as we have assumed, and on remote overseas bases at that, then attrition to aircraft and other mobile systems elements should be slight (see Fig. 79).

Medium bombers would fare less well. With anticipated rates of deployment overseas, the Russians would have an opportunity to attack most of these units

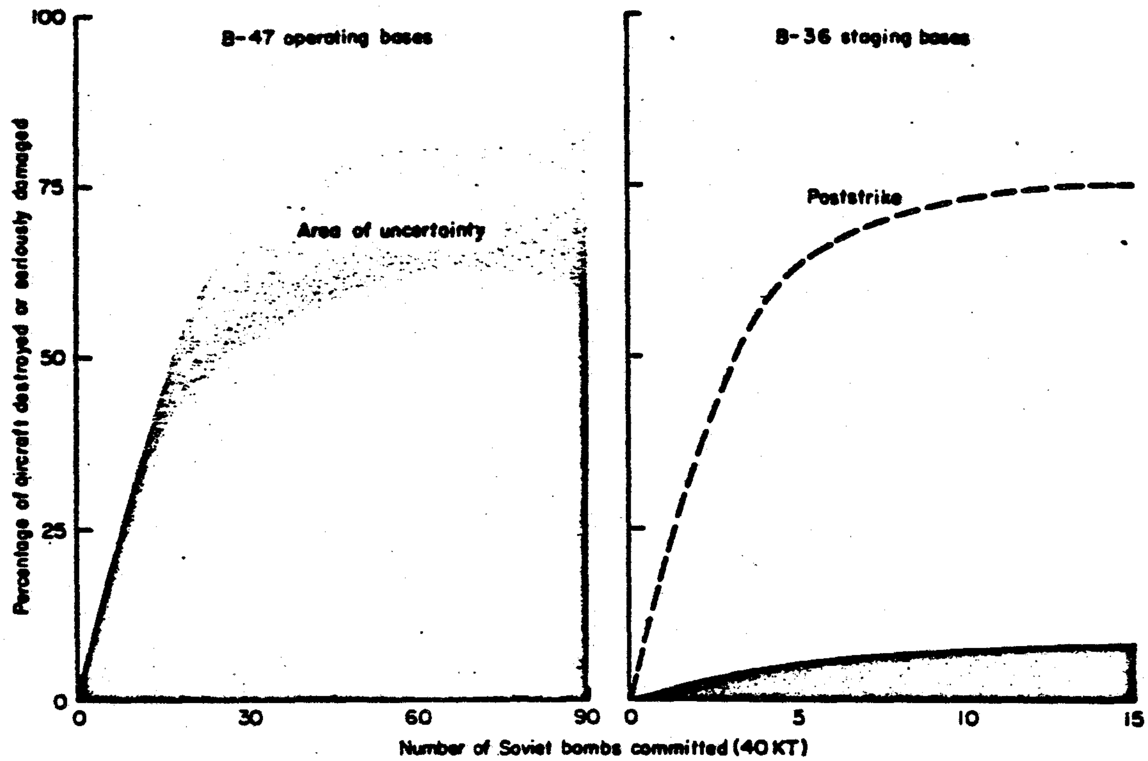


Fig. 79—Overseas ground attrition: aircraft

prior to launching of the first strike. If the build-up time were as long as 3 days, there would be opportunity for repeated Soviet attacks. Aircraft attrition ranges from 20 per cent in the case of high-explosive bombing attack to 75 per cent in the case of large-scale atomic attack.*

Russian attacks on heavy-bomber poststrike bases might result in higher attrition than on prestrike bases. These bases are closer to the Soviet Union in order that bombers can be light over enemy territory. If our flyable bombers remained for as long as 24 hr on these bases before returning to the ZI, the enemy would be afforded a considerable period for attack. And while likely periods of occupancy could be inferred from the departure of our bombers from over Soviet territory, speedy attacks on our poststrike bases might be impossible as the result of base damage caused by our attack, Soviet evacuation of aircraft, interrup-

*This lower limit assumes a substantial Soviet effort to stop us before the first strike—but not at the expense of investing A-bombs on possible "empty" bases. In 1956 we may be able to afford to put A-bombs on Soviet bases with or without aircraft. The Russians presumably cannot afford to be as profligate in 1956, and they risk missing aircraft when they attack operating bases during the period of overseas deployment, or when they attack staging bases at any time. *Note that evacuation introduces uncertainty of bomber occupancy on ZI bases as staging does on overseas bases.* However, well before 1961 the Soviet bomb stockpile should permit attacks on unoccupied as well as occupied bases.

tion in communications, etc. Figure 79 shows a large estimated range of attrition on poststrike B-36 bases. This uncertainty comes from indeterminacies as to the speed with which our bombers can be moved through poststrike bases and from different time lags before the mounting of Soviet attacks against these bases. With an occupancy period as long as 24 hr, it appears that poststrike heavy-bomber attrition might be as high as prestrike medium-bomber attrition.

Post-D-day Attack: The Continuing Campaign. The position of B-47 units stationed on overseas bases after D-day would be similar in most respects to the position of units on rotation on D-day. Most attacking bombers would survive to bomb, and our aircraft would generally be on base at the time of attack. The attacking formations required for successful penetrations would be so small that practically complete destruction of all Soviet aircraft capable of carrying A-bombs or the exhaustion of the Soviet stockpile of A-bombs would be necessary before we could occupy programmed overseas operating bases with confidence that we should not suffer high ground attrition.

B-47 units held in reserve in the ZI and B-36's operating from ZI bases should suffer relatively little attrition after the initial surprise attack. Repeated large-scale, one-way attacks against the ZI would be unlikely. Our active defenses would be on a high state of alert, and rapid evacuation of bombers should be possible. However, damage to base facilities from an attack, on D-day or later, would seriously impede operations, and alternate bases might have to be used for the campaign.

Conclusions

Concerning the effect of such high levels of ground attrition on the accomplishment of the major missions of the strategic force, we draw no explicit conclusions. It appears that, for some of these damage situations, the ability of the surviving force to accomplish its tasks is by no means certain. And at the very best it is not economic to procure and maintain a force of aircraft and a base system most of which will contribute little to the campaign.

The levels of loss indicated are by no means certain. Some of the requirements for attack may not be possible or acceptable to the Soviet Union: highly coordinated attacks, one-way missions against the ZI, extensive aerial-refueling, etc. And the enemy may have a more limited atomic capability than we expect. At this writing, however, these capabilities cannot be ruled out, and we cannot trust the survival of our strategic force to the expectation that these capabilities will be impossible for the Soviet Union to meet.

Vulnerability conclusions affecting different base areas are differently sensitive to Soviet capabilities, commitments to SAC neutralization, and SAC strike deployment. There is some flexibility in base choice, in strike time, and in the proportion of the force to be deployed. However, there will exist physical constraints which will limit these alternatives. Least sensitive is the conclusion that our overseas operating bases will be primary targets, that the Soviet strategic force will, with a high probability, succeed in putting A-bombs on most of these bases, and that units using these bases will be effectively destroyed. Less certain is the damage likely to be suffered on our staging bases and the damage likely to be suffered on ZI bases. In the following section we examine measures intended to reduce the vulnerability of the strategic force, including, in particular, the intensification of those measures discussed above which appear most promising.

REDUCING THE VULNERABILITY OF THE STRATEGIC FORCE

The problem of reducing the vulnerability of the strategic-base structure does not exist for a point in time, but rather it extends from the present to an indefinite future. With time, the type and magnitude of the threats presented changes; measures adequate against 1956 Russian capabilities may be inadequate against 1960 Russian capabilities. It is important to select a base system which has value not only for present, but also for later systems. This does *not* mean that we should not adopt measures which will have only a short-life usefulness. It merely means that we recognize that such measures must be "amortized" over a short period. Many of the inexpensive, microscopic passive defenses examined are in this class. The Air Force has a large inheritance of bases from the past; it is building many more; and changes in this base structure are not made rapidly. Some measures for reducing vulnerability which radically change the character of the base structure may take years to accomplish; but other measures, ones which involve a change in patterns of base use or comparatively minor changes in installations or equipment, can be accomplished in a relatively short time. In this section we examine a variety of possible types of defense in the light of these criteria: (1) the cost versus the effectiveness of alternate measures; (2) the sensitivity of different measures to changes and uncertainty in Soviet capabilities, in force commitment to SAC neutralization, and in weapons performance; and (3) constraints on our abilities to achieve certain defense postures. In comparing alternative defenses on economic grounds, we have chosen to measure the effectiveness of defense measures in terms of the cost of preserving aircraft and other systems elements from ground loss and having them available for combat throughout the campaign. In Part III, the more complete criterion of measuring effectiveness in terms of total campaign cost is used. We have not examined the defense of the logistics-support structure beyond base level.

Two costs must be considered when a bombing system operates in the face of enemy attack. These are (1) for the defenses—active and passive—which prevent damage, and (2) for those elements destroyed which must be replaced if we are not to be denied their use for the campaign. Active and passive defenses incur dollar costs during peacetime before the start of the campaign; ground losses incur dollar costs in reserves for expected ground attrition or result in a reduction of operational payoff—fewer targets destroyed, sorties mounted, combat aircraft available. In most of the defense comparisons, we use as a measure the availability of aircraft capable of performing combat missions. However, some defense choices must be made in the larger campaign context (e.g., the reserving of bombers in the ZI as a means for reducing force exposure on overseas bases), and in Part III some critical defense choices are examined on the basis of target destruction in such a campaign context.

Many defenses examined are sensitive to the number and characteristics of the bombs and carriers employed against our force, tactics employed, and timing of Soviet attack. How can a rational choice be made with such uncertainty? First, there are passive-defense measures which cost so little and return so much for high-enemy capabilities that there is little question that we are justified in adopting them (e.g., personnel shelters on overseas bases). Second, defenses vary in their sensitivity to bomb size and bomb stockpiles; and while the size of the Soviet stockpile and the size of bombs available are imperfectly known, it is a growing stockpile and it will contain larger bombs over a period of time. If we overestimate enemy capabilities in our choice of a defense scheme for 1956, the enemy will have corrected our error by 1961. Third, the passive defenses we adopt act as insurance against damage by an enemy attack which uses a small number of small bombs and carriers. If the strategic force adopts passive defenses which, say, triple the amount of fissile material that must be delivered to accomplish a given degree of damage, then, if we are fortunate, the Soviet atomic capabilities will have been exceeded. If not, then the other potential U.S. targets—tactical air, Army, industry, and population—gain protection. For example, the dispersal of aircraft on many existing overseas bases has reduced vulnerability to high-explosive bombs, and this forces the expenditure of atomic bombs if the Russians are to achieve high damage rates early in the campaign.* It appears that it will be possible to defend the strategic force against a high Soviet attack capability with high probability and at reasonable cost.

The application of some of these defenses is subject to physical, political, and production limitations. Expansion in our overseas base system is limited in some areas by lack of sites for 10,000-ft runways, and by the reluctance of countries which are prospective hosts to permit the granting of further base rights. Political considerations are preventing local dispersal in the United Kingdom. Underground construction presents problems in the Arctic. Some more efficient active-defense weapons will not be available in quantity in 1956. However, most of the alternatives we illustrate are generally feasible.

Zone of the Interior Bases

The defense of SAC ZI units consists in (1) protecting bombers and other mobile systems elements from an initial surprise attack and, in the case where bombers do not deploy overseas, from continuing attack; (2) providing fixed facilities for operation throughout the campaign in the face of enemy attacks for those systems with continued ZI basing. The protection of the ZI-based force makes use of each of the types of measures outlined above, and particular emphasis is placed on measures which exploit the mobility of many essential systems elements. The defense of ZI-based units is common to all systems: programmed; modified, advanced, and intermediate overseas operating based; and intercontinental air refueled and ground refueled. They must all be defended against a D-day surprise attack, and the intercontinental systems must be capable of sustaining continued operations from ZI bases.

Overseas Bases

If we are not to abandon overseas bases altogether, we must choose between increasing active and passive defenses in order to make operations with acceptable ground attrition feasible, or changing the function of these bases to that of staging. It appears that both avenues of defense should be followed. Overseas strategic fighter and fighter interceptor units requiring basing overseas can

* Increasing the cost to the Russians of destroying our strategic force is small consolation to those who are concerned with the accomplishment of the SAC mission. And without looking at the war in a larger context we cannot be certain how much to spend on SAC protection. It appears, however, that many of the defenses will survive this larger survey.

benefit from improved active and passive defenses. However, the method of defense appropriate to the largest part of the strategic force is an intensification of the SAC staging method of intercontinental operation combined with increased active and passive defenses of forward bases.

DEFENSE MEASURES

A reduction in base vulnerability can be obtained by changes in each of the five areas described below, which correspond approximately to the successive time phases of an attack:

1. Reduce expected level of attack and target value by *macroscopic* passive defense.
2. Reduce level of attack by *active* defense.
3. Reduce the elements at risk at the *time* of attack.
4. Reduce physical vulnerability and coverage of base elements by *macroscopic* passive defenses.
5. Reduce recuperation time by damage-control and *recuperation* measures.

Macroscopic-defense Measures: Large-scale Base-system Changes

Under the heading of macroscopic passive-defense measures we include the dispersal, multiplication, and relocation of base functions to separate airfields over distances which range all the way from a distance just exceeding the lethal diameter of the largest bomb expected (H-bomb) up to thousands of miles. We consider two distinct types of large-scale base-system change: One is multiplication and dispersal of some or all base functions within a given theater; the other involves the removal of functions to locations remote from Soviet striking power.

Dispersed Operation. Widespread dispersal of vital elements of our strategic force to separate bases has been frequently suggested as a defense against atomic attack. Our programmed base system incorporates a wide range of types of dispersal: One B-36 wing is assigned to each ZI base where two would be possible and, vulnerability considerations aside, also economic; one medium-bomber squadron has been assigned to some UK bases; dispersed aircraft parking is provided on many overseas bases; a widespread overseas staging-base system is being developed. These measures are intended to reduce the point concentration of systems elements. The differences are only of scale. We distinguish between large-scale (macroscopic changes) dispersal, which involves additional airfields, and changes within and around a base (microscopic changes).

Dispersed *operation* of no more than one wing per base, one squadron per base, or even part of one squadron per base has been suggested as a defense against atomic attack. By dispersed operation we mean the establishment of separate and distinct bases for the continuing peacetime or wartime operation of bomber units capable of providing complete base-level support, including the three echelons of maintenance, supply, housing, etc. The only function not performed at each base may be that of command and administration. Since no base is dependent for support (except for command) on any other base likely to be attacked, such dispersal has the effect of multiplying the number of points that the enemy must hit in order to destroy a given proportion of our strategic force and its base support. Where the enemy has a limited stockpile of atomic weapons or a limited delivery capability, this measure acts to preserve the force by presenting more targets (each of lower value) than the enemy can hit. Where the enemy has an atomic delivery capability which exceeds our degree of dispersal, then the net gain in survival of the strategic force through dispersal may be trivial, and the force surviving from a fixed budget for the procurement of bases and bombers may even be *less* than if we had not dispersed. The payoff from macroscopic dispersal is critically dependent on the relative size of the base system we present and the number of bombs the Russians commit and successively deliver on our bases. Figure 80 shows indirectly the effect of a range of base dispersal on ground attrition (leaving aside for the moment the reduction in aircraft attrition through the execution of the evacuation plan) for three levels of Soviet bomb commitment against the ZI. Expected 1956 ADC effectiveness has been assumed. For a Soviet bomb commitment of 30 bombs on one strike, there is a substantial reduction in attrition as we disperse from two wings per base to one wing per base. If one squadron were assigned to a base with this low bomb commitment, less than 10 per cent of the bases would be hit. Unfortunately, we have no assurance that the Russians will not be capable, within quite wide limits, of matching our additional operating bases with additional bombs, and the result of some higher bomb commitments is shown. The defense of basing our bomber force in the ZI with only one squadron to a base (which would involve the addition of 102 bases to the 30 scheduled, if all units were to be so dispersed) will be offset if the Russians are able to commit, say, 150 bombs to attack SAC. We have no assurance that the greater number of bombs required will not be committed, since the expected

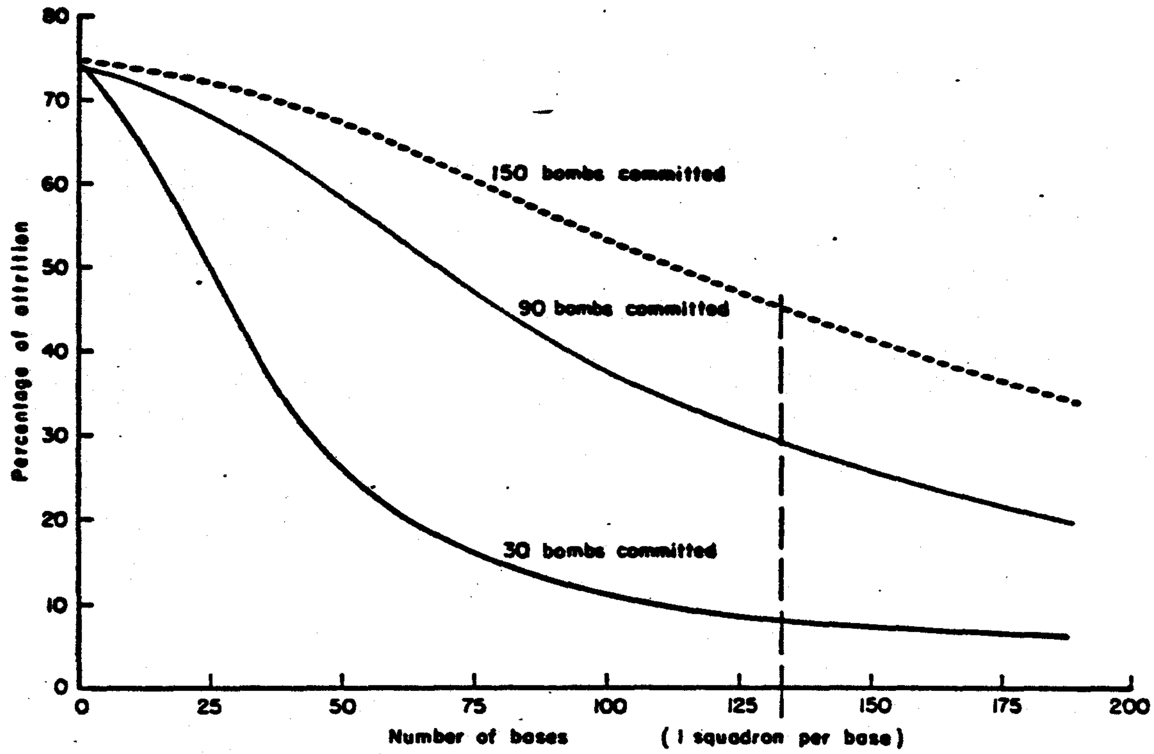


Fig. 80—The effect of base multiplication on attrition for various Soviet bomb commitments: ZI

size of the Soviet stockpile in 1956 is approximately 400 100-KT bombs. It might be as large as 800. And it will be growing rapidly.

Dispersed operation involves costs for us as well. Additional bases, equipment, and personnel must be procured. An estimate of these costs for separate squadron operation of the B-36 has been presented in a previous RAND study.* The costs of three degrees of concentration of B-36's and B-47's (two wings per base, one wing per base, one squadron per base) are summarized in Table 43. Going from two wings to each base to one wing adds about 5 per cent to the total 3-year system cost of buying and operating a wing of bombers. Further dispersal to squadron strength adds about 15 per cent more to the system cost. Squadron dispersal of the strategic force would cost over $2 billion.

Figure 13, page xxvii, shows the net effect on the bomber force we can procure and have in a state of survival if we take a fixed budget for the procurement and operation of our strategic force in the ZI (including costs for aircraft, bases, personnel, equipment, stocks, etc.) and subject it to various levels of

*_The Cost of Decreasing Vulnerability of Air Bases by Dispersal—Dispersing a B-36 Wing_, Cost Analysis Section, The RAND Corporation, Report R-235, June 1, 1952 (Secret).

Table 43

B-47 SYSTEMS COSTS

(In millions of dollars)

	2 Wings per Base		1 Wing per Base		1 Wing on 3 Bases	
	Initial	Annual	Initial	Annual	Initial	Annual
Installations						
Technical facilities	39.5	.....	29.5	....	55.6	....
Personnel facilities	25.0	.....	15.6	....	29.6	....
Maintenance	.....	3.1	.....	2.2	.....	4.2
Major equipment						
Mission	200.0	22.2	100.0	11.1	100.0	11.1
Support	20.0	.....	10.0	....	10.0	....
Minor equipment						
Organizational	13.0	0.8	6.5	0.4	10.8	0.7
Ground radar	0.6	0.1	0.6	0.1	1.8	0.3
Stocks						
Initial	3.7	.....	2.5	....	3.5	....
Readiness reserve	4.4	.....	2.2	....	2.5	....
Spares	94.4	.....	47.2	....	47.2	....
Transportation	1.8	2.2	0.9	1.1	1.3	1.6
Personnel						
Training	42.0	10.5	22.8	5.7	28.0	6.9
Pay and allowances	.....	19.0	.....	10.2	.....	14.3
Travel	1.2	1.0	0.6	0.5	0.8	0.7
Maintenance						
Mission aircraft	.....	17.2	.....	8.6	.....	8.6
Support-aircraft	.....	1.2	.....	0.6	.....	0.6
POL						
Mission	.....	9.6	.....	4.8	.....	4.8
Support	.....	0.6	.....	0.3	.....	0.3
Miscellaneous	.....	2.6	.....	1.3	.....	1.3
Service and miscellaneous	.....	0.8	.....	0.4	.....	0.4
Intermediate commands	.....	6.0	.....	3.0	.....	3.0
Overhead	.....	34.4	.....	17.2	.....	17.2
Total	443.8	129.1	238.4	67.5	291.1	76.0
Cost of Bombers	90		45		45	
Cost per bomber	4.9	1.4	5.3	1.5	6.4	1.7
Three-year Cost	9.3		9.8		11.5	

enemy attack. For small bomb commitments by the Russians, the reduction in ground loss with dispersal is greater than the reduction in the force of aircraft that can be procured. However, if the Soviet Union is willing to commit up to 120 bombs, there will be no net gain in bombers surviving for combat. These results, which exclude the effects of evacuation, apply to overseas areas. Where evacuation is possible, dispersed operation is still less economic, as shown by Fig. 14, page xxviii.

Eighteen strategic bases are scheduled for bomber, tanker, and fighter use in the United Kingdom. Unless a major part of our strategic force is based there (and our present policies tend to reduce dependence on this area), not more than one or two squadrons would have to be located on each base. But the attacking of eighteen bases in 1956 will take a much smaller proportion of the estimated Soviet stockpile of bombs (4.5 per cent) than the attacking of ten bases would have taken in 1950 (20 per cent). And in the United Kingdom there is the additional threat of high-explosive attack. The levels of damage presented indicate that where high-explosive as well as atomic attack threatens, dispersal, to be justified, must have the effect of straining the enemy's air-delivery capability for conventional bombs as well as his A-bomb stockpile.

So far we have referred only to the dispersal of aircraft having dispersal of supporting base elements. Other systems elements may require protection by macroscopic dispersal independently of the method of protecting aircraft: in particular, the protection of nonmobile base elements that are vulnerable to attack and that are difficult to protect by such measures as evacuation. Alternate airfields are provided for aircraft evacuated from ZI home bases and for the reassembly of aircraft, personnel, and flyaway kits, as a component of SAC evacuation and deployment plans. While the expected survival of runways, taxiways, and aprons on home bases is high, the loss or damage of other base facilities will make strike preparations difficult, and the threat of a surface burst or thermonuclear-weapon attack will make use of these bases for strike preparation impossible for a considerable period (if extended periods of base occupancy are required). Consequently, the availability of airfields, not for dispersed peacetime operation, but for alternative wartime use in preparation for overseas deployment or for continued use during the campaign, is of importance. At present, Training Command, Air Materiel Command, and municipal airfields are being used as alternate bases, and a large number of fields are available for emergency use at little added cost in facilities. Little augmentation to these fields is required if they are to be used only in connection with the evacuation plan. If, however, operations are to be conducted intercontinentally and the threat of base denial increases as expected over time, then alternate bases may require added minimal facilities, such as airfield pavements, fuel, fuel-distribution systems, etc. The cost of providing these supporting facilities would come to between $1 million and $5 million for each alternate base so augmented. Overseas, there is a multiplicity of nonmobile systems elements—runways, fuel storage—offered by the extensive system of staging bases that can be used in the event that our operating bases are denied us when needed. We may also be able to use NATO tactical bases, British bomber bases, and municipal airfields. The cost of increasing a fighter base to minimal medium-bomber standards overseas comes to about $8 million as compared with $40 million to $60 million for a new medium-bomber base.

Relocation (ZI and Intermediate Operating Base Systems). A second type of macroscopic base defense is relocation of base systems elements on sites more remote from the Soviet Union. Operation from intermediate or intercontinental distances in order to reduce the choice of types and number of aircraft with which the enemy can attack is a defense of this character. The utility of this measure must be evaluated in weighing the vulnerability of the *intermediate operating base systems*, since distance from the Soviet Union is the characteristic which distinguishes them from the advanced operating base system. The measure is of undeniable use in reducing vulnerability to high-explosive attacks. These require repeated sorties to cumulate damage and generate a large sortie requirement for this reason. Unfortunately for the defense of such a system, this effect is not very important when we expect atomic attacks. As the discussion of sortie rates in the section entitled "Base to ZI: The Cost of Operations outside the ZI," page 187, made clear, the administering of damage to a soft target using nuclear weapons does not require repeated visits. And, as the discussion of the physical vulnerability of aircraft, presented earlier in Part II, showed, these are soft targets. In consequence, backing off short of the ZI, where evacuation is feasible, does not help very much. Large-scale relocation of systems elements to the rear is of value only as it permits us to adopt *other* defense measures—active and passive—not feasible or effective close to enemy territory. The use of evacuation in the ZI is possible only because of the distance of these bases from the Soviet Union and the existence of ADC radars and interceptors to screen small enemy attacks and feints.

In sum, protecting SAC by matching increases in the Soviet stockpile of bombs with additional operating bases is an uneconomic business—especially since we have little confidence in our estimates of Soviet capabilities. However, those forms of macroscopic dispersal which make use of large numbers of existing facilities and which require little in the way of additional funds appear attractive. In particular, this is true of the use of alternatives for emergency operation in the ZI and the use of alternate bases for staging overseas.

Increased Active-defense Effectiveness

Active defenses have several advantages over passive defenses: They force the commitment of a larger bomber force for a given survival probability, reduce the resources available for reattack, and cause more gross errors and higher CEP's. Defense primarily by passive means leaves the initiative to the offense; and a relatively minor effort may result in major disruption, if not damage, to the defense. In most respects, however, the use of active defenses for strategic-base defense must be regarded as complementing rather than replacing the use of passive defenses. Defense largely by active means is not likely to be economic, and it calls for a confidence in the effectiveness of our weapons against enemy carriers, routes, attack tactics, and countermeasures which does not appear to be warranted at present. A combination of active and passive defenses is called for, and the relative proportions of each depend on base location, enemy attack capabilities, costs, and weapons availability.

Overseas Bases. The kill potential of our programmed overseas interceptor units could be substantially improved by added radar, but *it would remain low in relation to the expected number of attacking aircraft, even under optimum conditions of warning, control, and feint protection.*

The time required for detection and identification of a raid, warning transmission, fighter-scramble, climb-to-altitude, flight-out, detection, conversion, etc., amounts to about 20 min as a minimum for F-86D interceptors against a high-altitude TU-4. With imperfectly maintained radars, lags in transmission, initial vectoring errors, etc., it can take as long as 40 min. This amount of warning *is* scheduled for many overseas bases against high-altitude attacks, but is generally more than twice the coverage scheduled to be available against low-altitude attacks. In the case of low-altitude attacks against Keflavik, Nouasseur, and Lajes, only fighters on air patrol would have a chance to engage if minimum-penetration routes were flown by the Russians.

The effectiveness of ZI-based fighters is limited in a surprise-attack situation by the rate at which pilots can be assembled and aircraft readied for combat.

At such overseas bases as Thule and Goose Bay, the pilot-assembly problems should be less difficult; and in order that two-thirds of the fighters may engage in combat, at least 30 min of additional warning (150 mi with TU-4 attacks) must be provided in addition to that required for efficient interception.

Figure 81 shows the effect of greater radar cover on the combat effectiveness of our F-86 defenses. With an increase in coverage from 50 out to 250 mi, the interceptor kill-potential shows a very large increase against straightforward Soviet attacks. However, the enemy may feint, attack in waves, or use other deceptive tactics. With radar cover insufficient to reveal the pattern of the attack, the defense commander has to face the choice of withholding a part of his fighters as insurance against feints or successive attacks, or he must risk having few or no fighters available if a second wave materializes. If deceptive

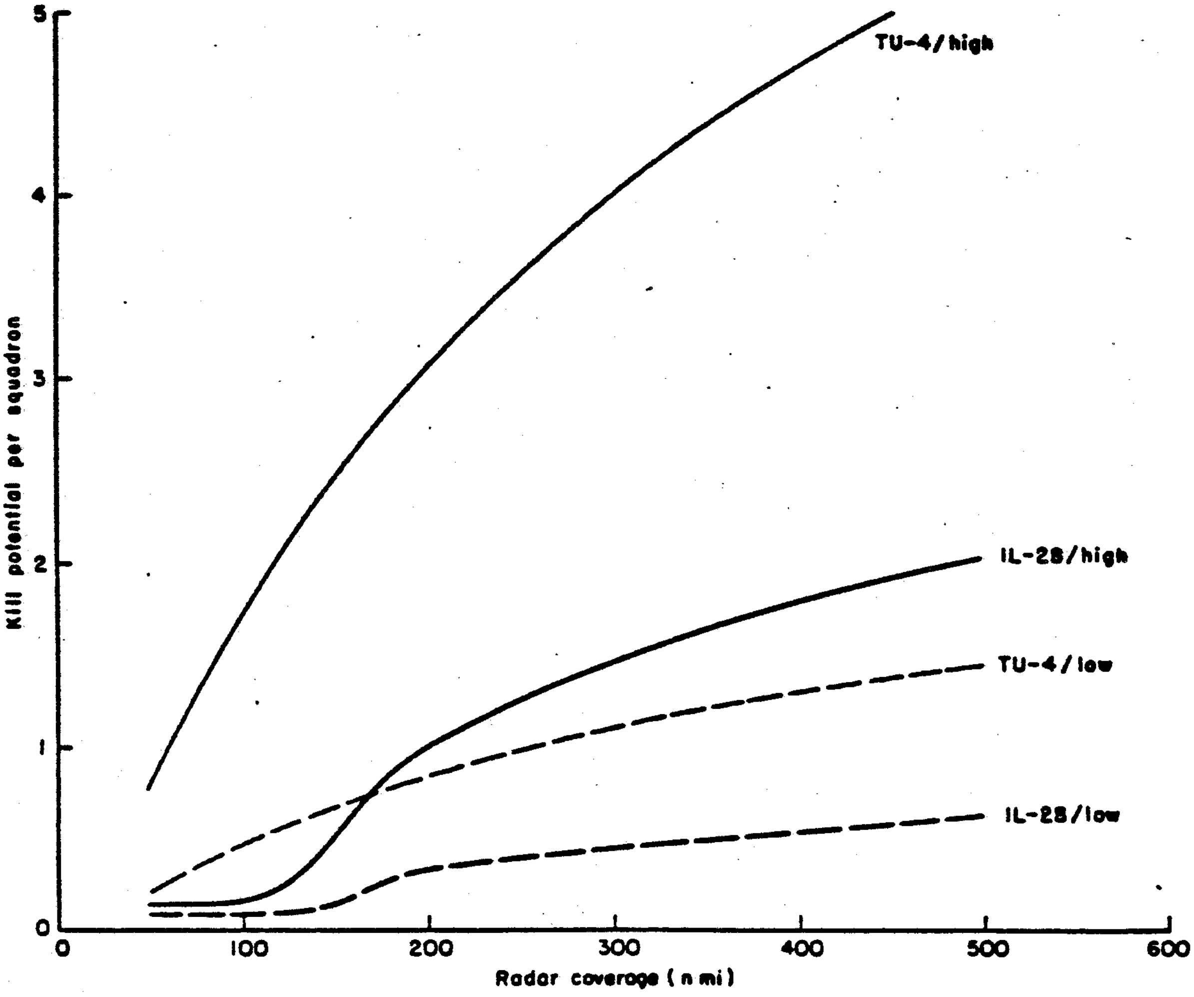


Fig. 81—Effect of radar augmentation on effectiveness of F-86 defenses: overseas bases (full commitment; no feint protection)

tactics are used against us, a further increase of about 200 n mi is necessary to maintain interceptor effectiveness.

Augmentation of overseas strategic-base radar coverage of the magnitude indicated raises serious cost, feasibility, and performance questions. If all 20 of the non-United Kingdom overseas operating bases were to be furnished with sufficient radar to provide a moderate level of protection against a TU-4 threat (300 mi), a minimum of 50 high-altitude ground radars, 300 low-altitude radars, and at least 20 airborne early warning (AEW) stations would be required.* The total procurement and 3-year operating cost of these additional radars would come to $2.7 billion. The requirements for overseas AEW aircraft would be two and one-half times the number scheduled for the defense of the United States. And this radar coverage provided is adequate only if the Russians do not use higher-performance aircraft than we expect. Providing 300 n mi of radar coverage around Keflavik may be sufficient if only TU-4 bombers are expected, but if refueled or wing-tip-coupled IL-28 or EF-150 bombers can be used, the effectiveness of the defenses is greatly diminished.

Even with augmented radars, the defense kill potential of our programmed interceptors and guns would remain low in relation to the size of Soviet attacks expected. Augmentation of the same type of interceptors and antiaircraft artillery (AAA) as that programmed would have the result shown in Figs. 82 (below) and 15 (page xxxi).

For bases that can be brought under IL-28 attack, even very large increases in defense effort reduce enemy bomber survival only moderately. Bases within TU-4 unrefueled radius show a greater improvement, and those requiring refueling show a distinct reduction. High-explosive attacks can be made unprofitable against bases beyond IL-28 radius. However, these active-defense weapons are expensive to procure and operate relative to their effectiveness, and if the cost of defending SAC is charged to the same budget as are the bombers, there is no significant increase in the force available for combat. The cost of added radar, interceptors, and AAA of the type presently scheduled more than offsets the saving in bombers, and there is a slight net *decrease* in the number of bombers available for combat for a wide range of Soviet attack levels. These defenses cost about as much as they save.

*We have excluded consideration of augmenting UK radar coverage, since this is clearly a matter that involves defense of NATO tactical airfields as well as British population and industry, and it does not seem feasible to isolate SAC defense.

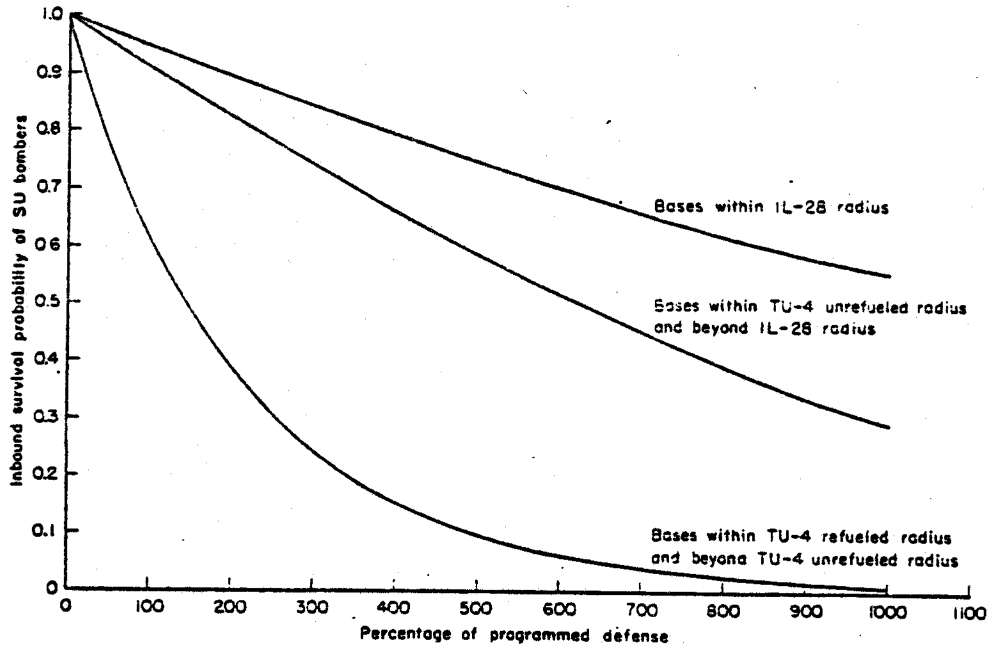


Fig. 82—Effect of increased active defenses on Soviet attacks against overseas bases: current weapons (assuming augmented radar)

In 1956 a number of new defense weapons will be coming into operation, and others will be in late stages of development; these new weapons will affect these comparisons. The new weapons are

1. Nike local-defense guided missiles;
2. Loki rockets;
3. Interceptors armed with large warhead rockets (Bird Dog);
4. Talos local-defense guided missiles.

With these weapons a higher level of defense can be achieved at a given cost. However, most of them will not be available for overseas base defense in 1956. When they are available in quantity—in 1957 and 1958—they may have to meet more advanced threats than the TU-4 and IL-28.

The high cost of providing adequate radar cover and the isolation of many overseas strategic bases indicates defense of these points by local-defense guided missiles rather than interceptors. However, the effectiveness of these new weapons, as of those programmed, is sensitive to enemy use of countermeasures. Burst chaff will unlock the Nike and Loki tracking radars, and, under some circumstances, airborne intercept (AI) tracking radar. Use of mass chaff may saturate ground radars. Enemy use of area- and local-defense decoys seriously degrades all types of defense weapons. And other countermeasures are under development by the Air Force or have been proposed. The effect of these measures would be a degradation by factors from two to ten or more times the kill potential of our defenses.*

Even with augmented low-altitude radar coverage, the threat of low-altitude attack remains serious as long as our AI radars are inoperative at low altitude. The use of optical sights is required, and, until modified, interceptors with Falcon and Bird Dog rockets will not be effective at low altitude. Nike appears to have a capability of lower altitude than formerly expected, but below 500 ft it is likely to be ineffective. And at altitudes below 100 to 200 ft, Skysweeper, Loki, and T-131 local-defense weapons are little effective. Daylight penetrations at these altitudes are feasible, and the use of one of various toss-bombing techniques by IL-28 bombers will effectively negate attempts to provide a high defense level. With the TU-4, low-altitude bombing methods of the sort described in the *Air Defense Study*† may be possible. If the zoom tactic should be feasible, then a low altitude penetration of area defenses followed by a climb to medium altitudes for bomb release would still degrade our defenses appreciably. This is indicated in Fig. 83, where we have deliberately taken the optimistic view that the enemy will have to climb to medium altitude.

Zone of the Interior Bases. The active defense of ZI bases, like that of bases in the United Kingdom, cannot be separated from the defense of other targets. This applies especially to radar augmentation and to area weapons, where the costs of defense must be weighed against reduced vulnerability of SAC, industry, and population. However, most of SAC is located well away from the center of gravity of industry and population. The defense of ZI bases primarily by interceptors would require a large augmentation above current ADC plans for the defense of cities. These interceptors, therefore, would have to be charged mostly to SAC defense. For this reason, the use of local defenses for many ZI bases appears preferred in comparison with the use of fighters. However, like that of area defenses, the effectiveness of local defenses depends critically on the level of attack and enemy capabilities in the field of countermeasures.

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*E. J. Barlow, *Electronic Countermeasures against U.S. Air Defense: 1953–1960, The* RAND Corporation, Research Memorandum RM-1080, May 1, 1953 (Secret).

†E. J. Barlow and J. F. Digby (eds.), *Air Defense Study*, the RAND Corporation, Report R-227, October 15, 1951 (Secret) p. 97.

Besides the uncertainty regarding the ability and intentions of the enemy and the effectiveness with which our defense weapons will perform, we must acknowledge a major element of uncertainty as to the warning time required to enable us to decide to use, and then to use, our defense weapons. Some time will be needed to make the physical preparations for firing, in the case of local-defense weapons. For a surprise attack on D-day this may easily be overshadowed by the time required to evaluate indications that an attack is in progress and to make the decision to fire. Since excessive haste in this matter may mean loss of lives on a civilian aircraft, even in a false alarm, the decision will have to be made by someone high in the chain of authority. Because we have very little knowledge of the time it will take to amass the information, evaluate it, reach a decision, and pass it on, we have tested local defenses under three alternative assumptions regarding the amount of warning time required to fire local defenses; namely, 1 hr, half an hour, and no warning time required. It should be observed, however, that the longer time requirements are likely to be the more realistic ones. Figures 83 and 84 show the results in terms of bombers surviving two different initial SU attacks on the ZI, if a fixed budget for the ZI portion of SAC is allocated among bombers and local defenses in various ways.

In one allocation, we spend the budget entirely on the purchase of the programmed number of SAC wings. There are no explicit expenditures on defense, but area defenses and the radar network are assumed to be those of the system proposed for 1956 in the RAND Air Defense Study.* The warning time required to evacuate SAC has been estimated on the assumptions that evacuation is divorced from take-off in Condition Bravo, and that a statistical raid evaluation plan is adopted as an automatic trigger for SAC evacuation.† In the analysis of local defense and evacuation which follows, this allocation will be used as a bench mark and will be called the "basic" case.

With the other allocations, we sacrifice some bombers and their associated systems components for various numbers of Nike batteries. Nike has been chosen since it is the most advanced local-defense weapon expected to be available in operational quantities in the early part of the period considered in this study. The 3-year systems cost per Nike battery is $9 million.

* E. J. Barlow, *Active Air Defense of the United States, 1954–1960*, the RAND Corporation, Report R-250, December 1, 1953 (Secret—Restricted Data).

† Both are discussed on p. 289 of this section.

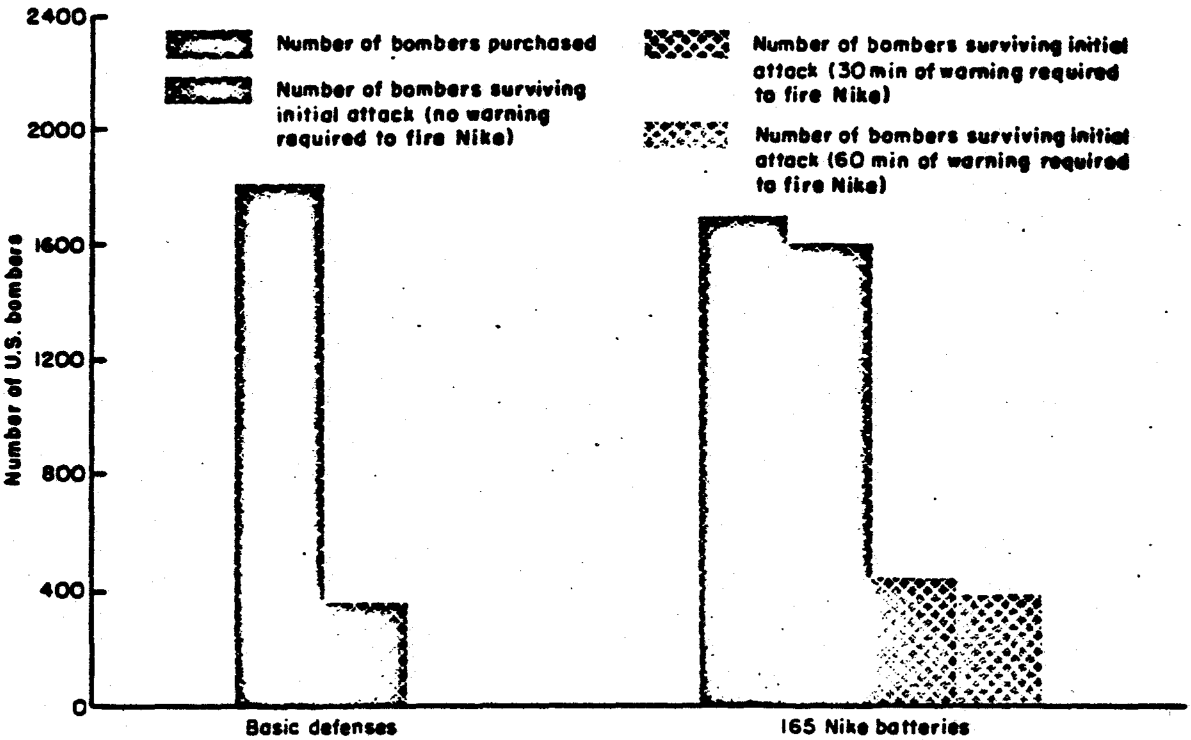

Fig. 83—Nike local defenses for SAC in the ZI (small SU force attacking at low altitude)

An essential requirement for any defense of SAC is the ability to afford reliable protection to SAC against a wide range of enemy attack levels and tactics. A defect of a defense consisting primarily in a Nike missile system on the current design is immediately evident. This system has sharply degraded effectiveness against targets below 500 ft, and it is completely ineffective against those below 200 ft. If the enemy achieved the ability to release his bombs at extremely low altitudes (e.g., by using rocket-assisted bombs, or by toss bombing), his attack on SAC would be virtually completely unhampered by Nike defenses. Because the benefits which follow from a successful strike against an opponent's strategic air arm are extremely great, and because we cannot depend on the technological infeasibility of a low-level-bomb-release capability for this period, this operational blind spot is a serious defect in Nike if it is to serve as the sole or principal ingredient of SAC's defense. *This has not been reflected in Figs. 83 and 84.*

However, because SAC's destruction offers great benefits to the enemy, and because the number of aiming points it presents is necessarily rather limited in relation to quite reasonable attack forces, even a local defense without blind spots is unable to provide the kind of protection we require. To illustrate this

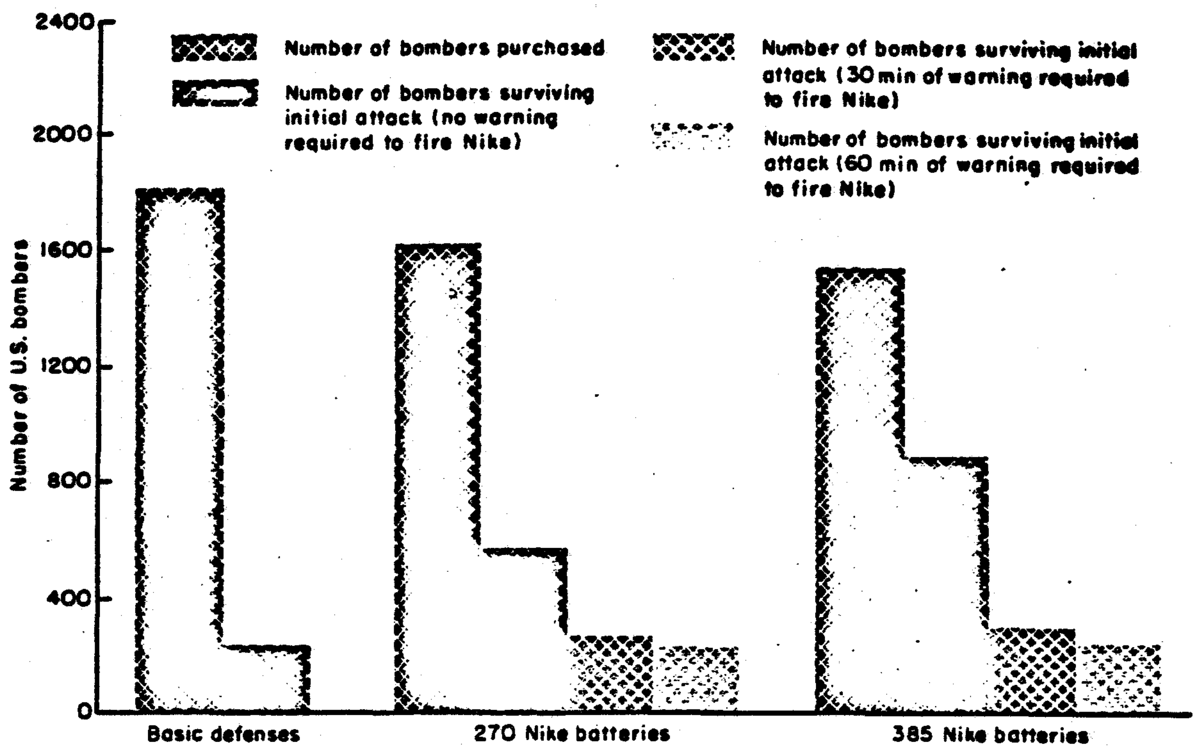

Fig. 84—Nike local defenses for SAC in the ZI (large SU force attacking at low altitude)

point, we have chosen two types of attack situations which employ forces well within the estimated capabilities of the Soviet Union for 1956. Both involve low-altitude attacks (although it is assumed that the attacking bombers must climb to an altitude at which Nike has maximum effectiveness before beginning their bombing runs). In both, the enemy employs mixed forces of TU-4's and Type 31's. He schedules his strike so that all cells penetrate our radar network simultaneously. This tactic appears to minimize the warning received by us when we have an effective statistical raid evaluation scheme. It might be possible for the enemy to reduce still further the warning received by some small number of bases by scheduling the early arrival of, say, five aircraft. However, by adopting this tactic he incurs the risk of having the early arrivals trip the alarm and thereby increase the warning to the bulk of the bases. No random variation in the time of penetration has been assumed. This sort of variation would operate in a fashion analogous to the early-arrival scheme. It should be noticed that, with a radar network like the proposed 1956 network of the Air Defense Study,* which provides no radar coverage against low-altitude attackers for many of the

* Barlow, *Active Air Defense of the United States, 1954–1960.*

SAC bases, an attack with simultaneous penetration is largely equivalent to one which has as its aim simultaneous bomb drop.

The first attack is directed against SAC alone and consists of 200 aircraft, predominantly TU-4's, and 60 bombs. The effect is shown in Fig. 83 for the basic defenses, and for additional defenses consisting of 165 Nike batteries purchased at the sacrifice of 1 wing of heavy bombers and 2 wings of medium bombers. In this case, the effectiveness of Nike depends critically on the amount of warning time required to make the decision to fire. If no warning is required, Nike defenses serve to protect a very large proportion of the bombers purchased, and the number of bombers surviving the attack is far greater than with the basic defenses. For increasing warning requirements the difference diminishes rapidly, falling to insignificance at the 1-hr level.

In the second situation, the attack on SAC is part of a larger raid against urban and industrial targets. The enemy force directed against SAC is composed of 500 TU-4's, 150 Type 31's, and 120 bombs. Moreover, the enemy is supposed to use countermeasures (suitable formations, various kinds of chaff, but no decoys) which degrade the kill potential of Nike by 50 per cent. As in the first situation, the bomb run is assumed to occur at medium altitude where Nike is effective.

Two levels of Nike defenses are considered for this situation. The lower level employs 285 Nike batteries, obtained at the cost of 2 heavy-bomber wings and 3 medium-bomber wings, while the higher employs 385 Nike batteries obtained at the cost of 2 heavy- and 5 medium-bomber wings. The results are shown in Fig. 84. If Nike should require no warning at all, Nike defenses would show a marked superiority to the basic defenses in the case of the heavy attack. However, both the absolute and relative margin of superiority are narrower than in the first, lighter attack. Where warning is required to employ Nike, the difference declines as before; and of the cases tried here, only in that where no warning is required are the differences made by Nike significant.

In sum, if we wish to improve the basic defenses, doing so primarily by means of Nike has three defects:

1. Nike possesses a particular blind spot which can be exploited by bombers at very low altitude.
2. Nike, like other active defenses, requires warning to be employed effectively.
3. Nike's effectiveness, like that of active-defense weapons generally, depends on the level of attack.

Under assumptions favorable to Nike, we have seen that its effectiveness is no less sensitive to the kind of enemy attack than that of the basic defenses. Even with the extreme assumption that no warning is required—or, which is the same thing, that all Nike installations have sufficient warning to fire—the number of bombers surviving is less than 50 per cent of the number programmed for procurement. If we were to increase radar coverage to give each base at least, say, half an hour's warning, we should automatically increase the effectiveness of evacuation. A defense based on evacuation of aircraft will be considered next, and the value of local defenses as a supplement of evacuation will be examined.

Although local defenses cannot provide the kind of highly reliable protection we want for SAC, this is not the whole of the story. They could still have considerable value. For one thing, they would create some uncertainty for the enemy, because he could not be sure how much time we should require to evaluate warning before firing. This would deter him from a sneak attack, even given the expectation of execution according to plan. But it would also mean that, if the plan went awry, errors would be penalized by further crew attrition and the likelihood that not only might there be no bombers on base at the scheduled time of bomb release, but, since the bomb release might not take place, the base itself might be unencumbered by the attack at all. But while local defenses are a useful supplement, they are no substitute for a high-reliability defense of our strategic force.

Conclusions on Active Defenses. The net gain to be obtained from augmented active defenses depends on the levels of enemy air attack expected, and this in turn is determined partly by the SAC base–Soviet base distance. In particular, for bases which can be attacked by jet light bombers, active defense, even with improved defense weapons, appears unprofitable as a primary measure for defense of operating bases overseas.

The situation is somewhat better for bases within unrefueled TU-4 radius, but it is only when we consider ZI bases that relatively high levels of active defense have any major effect. In order for the Russians to saturate high defense levels at remote bases, large forces of scarce and relatively vulnerable bombers must be committed to this attack—and no bomber re-use is possible if one-way missions are necessary. Unfortunately, there are too many uncertainties surrounding the size of Soviet attacks and possible use of countermeasures for us to rely primarily on active means of defense with the weapons likely to be available in the time period examined.

In conclusion, we find: (1) A moderate increase in overseas base radar coverage will somewhat increase defense effectiveness. However, buying sufficient radar in order to get *adequate* protection does not appear economic or feasible. (2) Adding more active defense weapons of the types presently scheduled for 1956 overseas base defense in order to achieve a high level of defense costs about as much as it saves in reduced ground attrition. (3) The use of newer weapons presently under development (Bird Dog, Nike) would, in favorable circumstances, substantially reduce the vulnerability of overseas bases beyond IL-28 radius and that of the ZI bases, but sole reliance on these weapons is impossible because of their sensitivity to enemy capabilities and our uncertainty about these capabilities. This is made clear by the ZI case where enemy apparent cell sizes were much smaller than those they could muster against our overseas system. How much active defense in total it is economic to buy depends on the joint effect of active and passive defenses discussed below.

Reducing Elements at Risk at the Time of Attack

While both creation of more targets than enemy bombs and the stopping of enemy bombers are costly and uncertain of achievement, a defense by not being on base at the time of attack appears relatively feasible, economic, and reliable. And this is the primary method of defense exploited in the overseas refueling base concept. In order for evacuation to be an effective defense, there must be adequate, reliable warning and infrequent execution. As programmed, SAC in the ZI will have totally inadequate warning at many of its bases and marginally adequate warning at others. The SAC overseas bases will have totally inadequate warning and will also be subject to frequent attack.

Making the evacuation plan effective in the ZI would appear to involve (1) increased warning combined with (2) improved evacuation procedures. The former might be obtained by extension of our radar coverage through the use of an advanced line of radars, by adding contiguous radars to our present radar network, or by relocating units to bases more remote from the edge of our warning boundary. Improvements in the evacuation plans might be brought about by detaching the triggering of SAC evacuation from dependence on Air Defense and Civil Defense Red alerts; separating the plan for evacuation from the plan for deployment (by not delaying evacuation in order to assemble personnel and matériel); removing possible bottlenecks, such as engine starters; reducing personnel assembly time by having crews live on or near base, and by training non-crew members for evacuation duty as observers, etc.; and, where necessary, retaining minimum evacuation crews on base.

Increased Warning. The usefulness of distant early warning has been discussed in a previous RAND study.* Such a line under ideal conditions would provide from 5 to 12 hr of warning to ZI bases. And this warning could be used not only for evacuation of substantially all aircraft and all flyaway kits and personnel, but it would also permit evacuation in Condition Bravo and the overseas deployment of bombers without delay. As was pointed out in the above-mentioned study, however, a line close to Soviet territory, in good part over the ocean, and not backed up by fighters could be freely penetrated by Soviet aircraft during peace or war. And with a large gap between our forward line and the presently scheduled ZI radar, penetration of the advanced line would leave uncertain the possibility of the appearance of Soviet aircraft only a few minutes away from many SAC bases. If SAC were to evacuate with each Soviet feint, its effectiveness would be seriously degraded. And the contribution of the line after the start of hostilities would be largely eliminated if the Russians could destroy segments of it. However, Soviet penetration of this line could be used to indicate assembly of personnel and preparation of aircraft for evacuation, rather than complete evacuation. And we might be able to ignore penetrations of a few aircraft on grounds that, as far as SAC was concerned, the damage threatened was not excessive. Since it appears likely that improvements in the SAC evacuation plan will permit evacuation within 2 hr, the creation of an advanced warning line largely for the defense of SAC can hardly be justified. In any case, the creation of a distant early-warning line cannot be quickly accomplished. It represents a major construction and equipping effort, and some development, largely in communications, needs to be done. Unless present plans are substantially altered, this line will not be contributing warning to SAC in 1956.

The warning available to SAC under the program is close to being adequate for emergency evacuation in the event of high-altitude TU-4 attack. Extending ZI coverage outward an additional 200 mi on the average and filling gaps in the south and southwest would provide enough warning for the evacuation of 60 per cent of aircraft on peripheral bases (with improvements in evacuation procedures) and of 75 per cent of all ZI-based aircraft, in the event of low-altitude TU-4 attack. This sort of radar augmentation may be found in the

* E. J. Barlow, *Distant Early Warning in the Defense of the United States*, The RAND Corporation, Research Memorandum RM-1031, November 24, 1952 (Secret).

"1960 Network" of the Air Defense Study.* The augmentation over the 1956 programmed radar network consists mainly of low-altitude coverage radars and AEW aircraft. The 3-year cost of this augmentation, excluding those elements of it which are primarily motivated by the defense of targets other than SAC, comes to about $1 billion.

Relocation of SAC bases to areas with greater warning is another possibility which has been mentioned. So long as we are committed to the maintenance of a strongly defended heartland in the northeast, this measure will be an attractive one. It has the advantage of enabling SAC to derive bonus benefits from measures which are taken to protect cities and industries against new types of threats. For example, without base relocation the radar augmentation required solely for SAC will increase as the speed of Soviet bombers increases. The advent of a jet or fast turboprop bomber could increase the coverage needed for peripheral bases to about 600 mi. Furthermore, increments of AEW radar well offshore are provided at increasing costs per aircraft on station, since much time is lost flying to and from stations. On the other hand, providing radar warning for SAC bases outside the heartland will benefit, as a by-product, such critical elements of our war potential as the A-bomb storage sites which are largely located outside the northeast heartland. Relocation of SAC bomber bases does not have this by-product advantage. Furthermore, relocation to the interior of the country might prove to be at least a slight disadvantage against such later threats as the intercontinental ballistic missile or a high-speed but short-range jet bomber. A complete evaluation of this measure would have to include consideration of questions such as these. We believe this investigation should be made.

Added radar coverage offshore contributes little protection against submarine-launched attacks. If further investigation shows the threat of submarine attack to be an operationally feasible weapon for the Russians, other measures to permit evacuation would have to be adopted.

One possible form of this threat is Russian use of short-range guided missiles similar to those developed by the U.S. Navy. These might have an acceptable accuracy at a range of about 200 mi in the 1956 period. Seventy of the 72 scheduled overseas bases and 12 of the 32 ZI SAC bases are within this distance of the sea. (Another 3 of the ZI SAC bases are within this distance of the Gulf

* Barlow, *Active Air Defense of the United States, 1954–1960*, pp. 53, 59. If SAC is to depend on warning from this radar augmentation, it is obvious that it will have to be acquired sooner than 1960.

of Mexico.) Another possibility is Russian use of a longer-range submarine-launched MiG-type manned aircraft with an 800-n-mi range, or greater, carrying a small atomic bomb—either on a one-way or a two-way mission with return to a submarine rendezvous offshore. Either of these threats, if attacks could be coordinated, would sharply reduce the warning SAC would receive, and the radar augmentations would contribute little or nothing. Our present radars have only a marginally adequate capability to detect small high-flying jet aircraft of the type that might be launched from submarines, and the first warning of attack might come from bomb burst over peripheral bases. Even if detection at our coast were made certain by the use of improved radars, evacuation from coastal bases would not appear feasible against this threat.

Defense against these carriers by active means, especially near the coasts, is extremely difficult. They have a low vulnerability, small radar echo area, and may be launched close in to their targets. In 1956, they would be essentially unopposed in going against peripheral SAC bases, since the ability of our radars to track a small manned aircraft and vector interceptors against it is questionable. However, a method for the long-range detection of submarines (perhaps out to 600 mi), LOFAR, is under development. If successful it may make impossible the launching of widespread, coordinated attacks against the ZI. Still, underwater detection may be subject to the same limitations as over-water coverage, in that frequent penetration can be made without violation of our national territory.

If submarines can approach our coasts undetected and launch atomic carriers, the only measure insuring evacuation appears to be location of units sufficiently far inland that minimally adequate warning of attack will be available, and the phasing in of some such radar as the AN/FPS-7. Defending SAC in the ZI in this way would involve the giving up of 12 peripheral bases by SAC if defense were to be obtained against the short-range guided missile, and the abandoning of 18 or more bases if 1½ hr of warning were to be obtained against the submarine-launched jet fighter. This would involve, in the latter case, an expenditure of about $700 million for the relocation of bases. If launchings from the Gulf of Mexico were available to the enemy, then 15 bases might have to be given up to avoid the short-range missile, and the preponderant majority of our bases might have to be abandoned to avoid the hypothetical submarine-launched fighter.

The justification of expensive defense measures on this basis requires further evaluation of the threat. The evidence for Russian development of this technique and the difficulties involved in this type of attack should be examined. The Russians would presumably require not merely a feasible and adequate but a highly reliable technique for their initial strike. The reliability of submarine-launched missiles or manned aircraft is questionable on grounds of the reliability of the weapons when so launched, on grounds of their availability for launching after a long underwater journey, and also on grounds of coordination difficulties. Furthermore, there is a question as to the adequacy of this technique. The range achievable by either the manned aircraft or the missile is uncertain. Finally, we need to consider the costs to the Russians in terms of both the development of this technique and the requirement for submarines at a crucial time. We must recognize, however, that, if this threat is real, the defense measures enumerated are justifiable even though expensive, because SAC itself is both expensive and critically important.

Improved Use of Warning. The first requirement for improved evacuation of SAC is the divorce of emergency evacuation from deployment in combat-ready condition (Condition Bravo). The effects of this on speeding the process of evacuation have already been indicated in Fig. 73, page 244; it also will speed the decision to evacuate by making it independent of a determination to deploy an offensive atomic strike against a supposed aggressor.

A second requirement has to do with the calling of a Red alert for SAC. ADC currently associates this decision with those involving extensive defensive action (including firing) against a supposed enemy, as indicated on page 280, above, and with drastic interruption of civilian affairs. Obviously a decision having these effects requires considerable evaluation.

On the other hand, with an effective statistical raid-evaluation scheme, the evacuation of SAC can and should be made automatic, contingent only on the tripping of the evaluation mechanism.*

The corridor-control system off our coasts should reduce the number of unknowns in the system to the point where the appearance of five to ten unknown aircraft would trigger the alert system. This is not to say that a few enemy aircraft could not penetrate deeply without being called hostile, but a force large enough to achieve a significant amount of damage to SAC would have little chance of penetrating without alerting the defense system. It is possible that statistical controls which are based on an hourly number of unknowns might not detect a raid carefully planned for cumulative infiltration, in which the early infiltrating bombers loitered in some of the blind regions of our radar

* A more detailed discussion of the problem of warning SAC is contained in the Appendix.

network. This suggests the utility of considering a double test which, in addition to the hourly rate, would take account of the cumulative number of unknowns over the maximum loitering period (perhaps 12 hr); or, better, which would observe any tendency toward steady increase in the number. It might be possible to discriminate unknowns on the basis of the geographic pattern of unknowns which would result from this sort of tactic.

If this type of statistical evaluation scheme results in no more than two or three false alarms a year, the resulting SAC evacuations can be considered beneficial exercises for SAC which will increase its facility in evacuation. This decision problem is close to the essence of any attempt to improve evacuation procedures, since the time requirement involved in evaluation and transmittal can be quite large relative to many of the other time requirements involved in SAC evacuation.

Third, present evacuation times are lengthened by the need to assemble personnel. The presence of minimum evacuation crews on or near base at all times would permit the evacuation of as much as 80 per cent of the aircraft from a 1-wing base in less than 1 hr and from a 2-wing base in about 1½ hr. A B-47 can be evacuated by a pilot and one other person, not necessarily a crew member, capable of performing engineering duties. During periods of emergency SAC goes on alert and minimum evacuation crews are on hand. However, maintaining this state of alert for long peacetime periods would probably require added crew personnel. And the cost of adding fully trained B-47 and B-52 pilots appears to be very high—over $1 million per pilot on a 3-year basis, when we take into account the number of flying hours, POL consumed, maintenance costs, etc. There is some question, however, as to the requirement for a fully trained pilot to accomplish evacuation, if it is found that additional pilots are required to maintain minimum evacuation crews on hand. One means of accomplishing this would be to maintain on hand a group of pilots having sufficient skill and training to take off and land a B-47, but not necessarily having full crew competence. If this lower level of skill could be achieved at a lesser number of flying hours, the cost of maintaining minimum crews could be greatly reduced—perhaps to something of the order of $300,000 per pilot on a 3-year basis.* Such a reduction in cost might be achieved by the use of

*The estimate of the cost of flying the B-47 used in the above calculations was $1042 per flying hour. Air Force Letter 150-10, Dept. of the Air Force, Washington, February 2, 1953 (Confidential), calls for 40 flying hours per month per crew (2 pilots) to maintain crew competence. Recent experience with B-47 flying-hour costs has been very much more favorable. This experience enhances the advantage of minimum evacuation crews.

rated non-crew officers, and there are a large number of them in a wing organization.

Fourth, if the personnel assembly bottleneck is eliminated, the rate of take-off may emerge as a bottleneck. With an improved radar net, there may be bases where the number of aircraft evacuable can be increased by the provision of an additional runway usable concurrently with one of the existing runways. The cost of a standard 10,000-ft runway has been estimated at $5 million. Runways of the sort we are discussing need not meet all specifications for permanent peacetime jet-bomber operation, since they are intended primarily for emergency use. Nevertheless, in the analysis which follows, the cost assumed has been that of a standard runway.

Adequacy of Evacuation in the ZI. In the examination of the effects of improved evacuation which follows, no attempt has been made to select either an optimal budget level for such improvements or an optimal collection of measures. To do this would require consideration of the joint effects of the measures taken to improve evacuation, as well as consideration of threats such as the submarine-launched aircraft or missile and later threats such as the intercontinental ballistic missile. It is not necessary to the central subject of this study, the selection of the best strategic air-base system, to make such a choice. This is so because the requirement for a capability of survival against at least initial attacks in the ZI is common to all the systems considered here, although some systems make fuller subsequent use of this capability.

We have made a number of tests of the value of these improvements in the capability for evacuation. The results are shown in Fig. 85, which compares the effects of enemy attacks on a SAC devoting varying amounts of its resources to evacuation. (The comparison is made in the same terms as Fig. 84's comparison of alternative budget allocations to local defense.) The results of the heavier attacks with SU 1956 capabilities (500 TU-4's, 150 Type 31's, and 120 bombs) are repeated for the basic case and are also shown for a situation in which the measures for improved evacuation discussed above have been adopted at the cost of 2 medium-bomber wings.

Improved evacuation has also been tested against the kind of Soviet attack which might be mounted near the end of the 1956–1961 period. The force delivering this late-period attack consists of 750 turbojet bomb-carrying aircraft and 4700 area-defense decoys, of which 150 and 1500, respectively, are allocated to SAC bomber bases. The turbojet aircraft include both medium

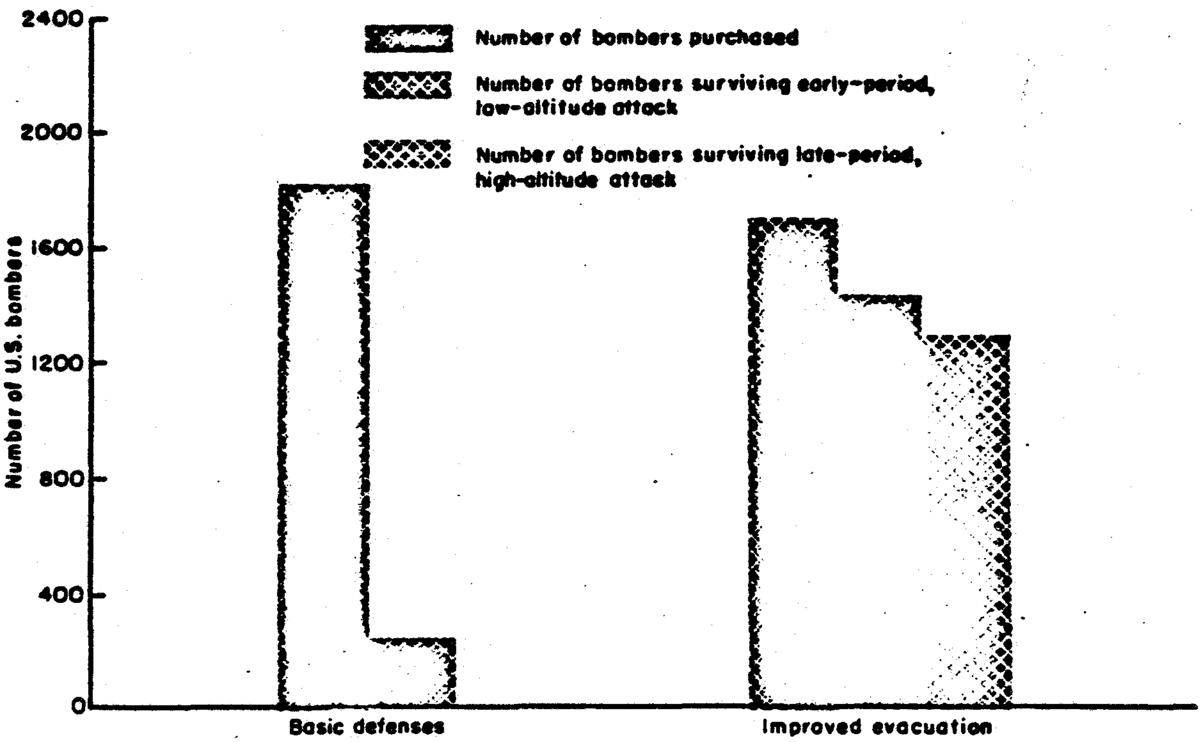

Fig. 85—Improved evacuation for SAC in the ZI (large SU attacking force)

and heavy types. In this attack 150 bombs are assumed to be allocated to SAC targets.

This late-period attack is a high-altitude attack, for several reasons. First, the higher-performance jet aircraft used incur severe range penalties at low altitude. Second, the gaps in the low-altitude radar coverage which place a high premium on low-altitude penetration have been eliminated as one of the measures to improve evacuation by increasing the warning. The third reason is associated with probable changes in our area defenses. It has been assumed that the additions to and improvements in area defenses for the protection of cities, which were proposed for accomplishment by 1960 in the Air Defense Study,* have taken place. Although intended for cities, and therefore properly costless to SAC, these improvements would provide some protection for bomber bases. One effect of these improvements would be an increase in the effectiveness of area-defense weapons at low altitude. This increase also would reduce the attractiveness of a low-altitude attack.

It is evident from Fig. 85 that improved evacuation offers significantly greater protection than the basic defenses. Improved evacuation, under the

* See Barlow, *Active Air Defense of the U.S., 1954–1960.*

1956 attack situation, secures the survival of almost 80 per cent of the bombers procured in the basic case. This may be compared with the results shown in Fig. 84, page 282, for Nike local defenses, where the analogous proportion surviving ranges from approximately 15 to 50 per cent, depending on the amount of warning required. But it will be recalled that some highly important aspects of the comparison are omitted from the results shown in these figures. First, Nike's blind spot may virtually eliminate its effectiveness. Second, if the enemy surprises us by mounting a stronger attack than we expect, the results, with an evacuation scheme, will be insignificantly affected, whereas attrition of our bombers with any active defense will rise appreciably. That is to say, reliance on preventing bombers and bombs from reaching the release line depends for success, with fixed weapon types, on the relation between the numbers of bombs and bombers and the number of defense weapons. Obviously, one element in this relation is subject to control by the enemy—within limits, it is true, but within limits which must appear highly uncertain to us. An evacuation scheme, however, relying on removal of bombers from the base, is, for fixed weapon types, a measure entirely under our control.

But, even within the period considered in this study, Russian weapon types may be expected to change. Figure 85 also shows how the evacuation scheme would perform against a later threat. Even with the reduced warning available when the enemy uses substantially faster bombers, the improved evacuation scheme serves to protect 70 per cent of the bombers programmed.

The analysis so far has been conducted in terms of a fixed budget (the basic budget of Fig. 85). Of course, additional expenditures could serve to increase the number of surviving bombers in the later period. If additional funds are added to the SAC bomber-defense budget considered here, they may be allocated to local defense, further expenditures on the evacuation scheme, or additional bomber wings.

The results have been estimated for two levels of an additional budget: $1 billion and $5 billion. The particular amounts have been chosen solely to illustrate characteristics of the alternative defenses. For each level two allocations have been made. With one allocation, we use these funds for a combination of additional bombers and further improvements in evacuation. With the other, we spend the funds entirely on local-defense missiles. In this time period, it is assumed that an improved local-defense weapon will be available, either Nike B or Talos W. The higher estimates of kill potential, those of Talos W, have been used in the analysis. This kill potential amounts to 5.1 enemy aircraft per battery; and the 3-year cost per battery is $32 million.

The attack in the $1 billion additional-budget case is the same as the later-period attack of Figs. 84 and 85, which has already been described. For the $5 billion additional budget, the total attacking force is the same, but 200 bombs and bombers are allocated to SAC, together with 1500 area-defense decoys.

Figure 86 shows that at neither budget level is there a large difference in the protection afforded by the two kinds of defense. This suggests that, with an already substantial evacuation capability in the face of the attack assumed, the choice between an advanced local-defense missile and a combination of more aircraft and further evacuation effectiveness is a matter of comparative indifference. However, this conclusion must be qualified. It holds only if we are prepared to rule out of consideration the possibility of an unpleasant surprise in the form of an even heavier enemy attack. Otherwise, the less sensitive measure—evacuation—must be preferred.

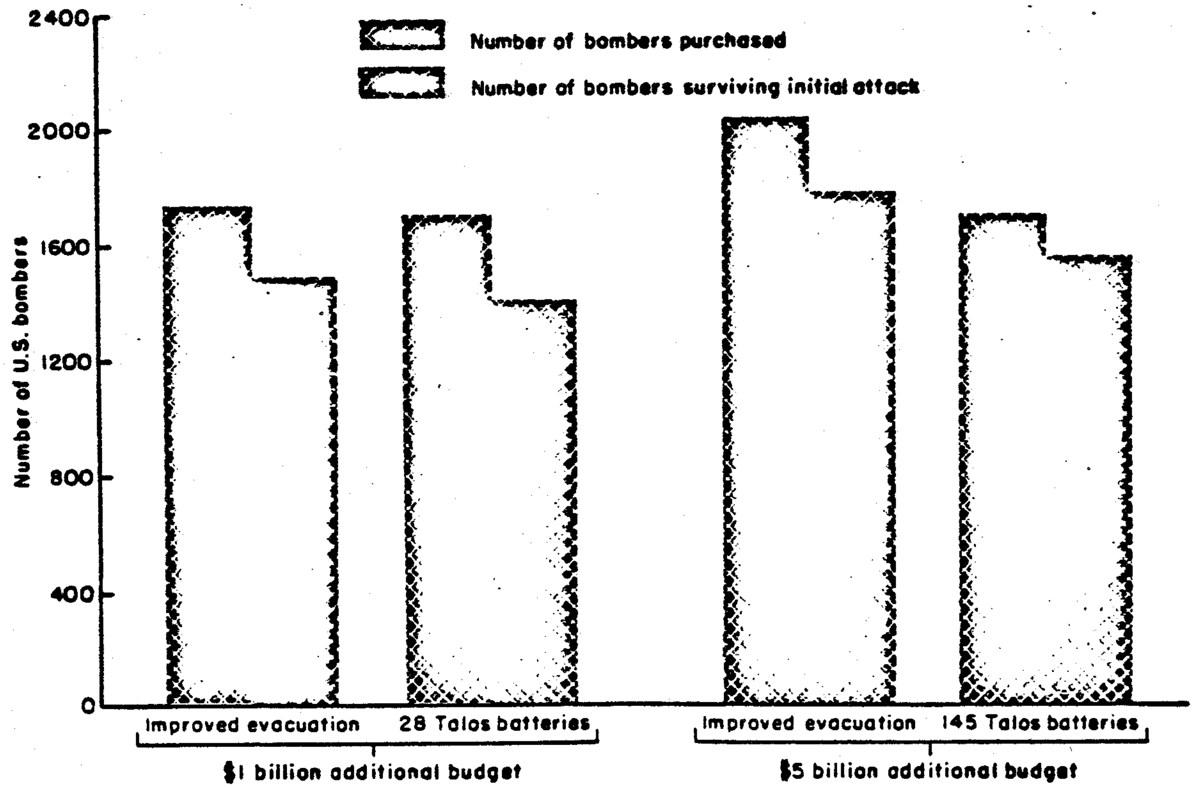

Fig. 86—Improved evacuation vs Talos local defense for SAC in the ZI: two additional budgets (large late-period high-altitude attack)

Soviet possession of advanced aircraft and missiles such as those we have under development now would increase warning requirements still more. A missile with performance equivalent to that of our Snark (520 knots) would require about 760 n mi of radar for 1½ hr of warning; a Navajo type would require 2200 n mi of radar (or, if this is infeasible, a reduction in the amount of warning required to evacuate SAC, using some of the measures discussed above); and a ballistic missile, against the sort of sensing system now planned, would give essentially no warning. If we may estimate operational dates for these weapons from our own progress in missile development, it appears that these missiles will not present a threat before 1961 at the earliest. Even with these advanced threats (excepting the ballistic missile), an advanced radar line would provide sufficient warning. However, as we indicated above, its usefulness could be greatly reduced by appropriate Soviet deceptive tactics.

The maximum frequency of spoofing attacks against the ZI, in sufficient strength to alarm all of SAC, should not be high enough to render evacuation infeasible as a continuing measure for interior bases and most peripheral bases. However, those bases located along our northern border (Fairchild, Rapid City, Limestone, Plattsburg, Westover, and Portsmouth) are not far enough from Russia for frequent penetrations to be excluded.*

A type of defense previously mentioned has evacuation implications. Dispersed operation of units means fewer bombers to be evacuated per base. The time required to evacuate a 1-wing base would be about 30 per cent less than that required to evacuate a 2-wing base, if personnel assembly were not the major limiting factor.

Adequacy of Evacuation Overseas. If evacuation from overseas bases could be accomplished within 1 hr, then 300 n mi of coverage would be required for TU-4 attack and 500 n mi for jet bombers. As we have seen, such coverage is very expensive. Unless we possess a large defense kill potential and can afford to ignore small attacking cells, evacuation overseas appears to be infeasible, even with augmented radar. The commitment to evacuation must be made while enemy bombers are some distance away from our bases; any aircraft identified as hostile within the "evacuation line"—whether aircraft attacking

*There is one other type of threat to be considered in this connection. Recent RAND studies have shown the value of decoys in diluting our defenses. They can be designed to appear to radars as bombers. The use of this type of weapon would make a small raid look like a large one. Interior bases protected by extensive radar and backed up by interceptors would be less affected than would peripheral bases, because decoys would very likely become less convincing as penetration depth increased.

other targets, enemy feints, or reconnaissance aircraft—would require execution of evacuation plans. And where radar cover is not backed up by fighters, repeated deep enemy penetrations can be made at little cost in aircraft lost. Overseas bases are particularly susceptible to submarine-launched atomic attack, since they are almost universally quite close to the sea.

Intermediate operating base systems beyond TU-4 unrefueled radius may have a marginal evacuation capability. It may be possible to provide radar (500 n mi for a jet-bomber attack for evacuation within 1 hr if possible) and interceptor back-up; but, unless active-defense effectiveness is such that attacks less than large ones can be ignored, then feints even at extended ranges or repeated attacks will render evacuation infeasible. Probable intermediate base systems are not much beyond unrefueled TU-4 radius and are within Type 31 radius. Measures permitting evacuation from intermediate bases will, at the very least, have to be backed up by fighters to prevent spoofing. A combination of high active defense as well as adequate radar coverage is essential. Moreover, even if the base is beyond TU-4 radius, a good deal of the radar cover is not. This makes it subject to spoofing, especially with area decoys. Therefore, in the campaigns presented in Part III, *no* evacuation occurs from intermediate bases. If evacuation is assumed to be possible, the position of the intermediate systems improves relative to the advance overseas operating base systems, but it remains distinctly inferior to the ZI ground-refueled system.

Summary of Evacuation Measures. The conclusions on defense of the bombers by means of evacuation are as follows:

1. For the ZI, evacuation measures are the principal component of the best defense of SAC. They are the most effective and reliable of all of the defenses examined.

2. Moreover, such a defense is adequate: a high-confidence protection of a large part of our bomber force in the ZI can be worked out with additional expenditures that are moderate in relation to the total SAC costs.

3. Any moderately large expenditure for protecting bombers in the ZI should, it is clear, be devoted largely to improving our ability to evacuate.

4. If there is to be a much larger additional expenditure to increase the number of bombers surviving the threats considered in the analysis, still further improvements in evacuation capability will be at least as fruitful as expenditures on the various active and passive defense alternatives. However, if large additional sums were to become available (and no need for these is evidenced in this study) it would be better to spend them, at least in part, on preparation

for some of the obscurer Russian threats of which we have no firm evidence now; e.g., on FPS-7 radar for submarine-launched bomb carriers.

5. For protection of bombers overseas, evacuation is not a reliable measure.

Microscopic Passive Defenses

Practically complete coverage of most ZI SAC bases can be obtained with a 40-KT bomb dropped with a 4000 CEP for soft targets such as aircraft. The same sized bomb will do almost as well against most of our overseas bases. Only our large French Moroccan bases present a target for which a bomb as large as 100-KT would be necessary for practically complete destruction of soft elements. The ZI bases and some overseas bases have not been designed against attack at all, while the most serious threat most overseas bases have been designed to meet to any extent is high-explosive attack. It is possible to provide a considerable degree of protection against A-bomb attack on a base, and an examination of ways of protecting the elements which are to be found on an operating base suggests the following conclusions:

1. Many of the elements are intrinsically tough and difficult to damage.
2. Many elements perform no essential or irreplaceable function for a strategic campaign of short duration.
3. Some of the vital elements can achieve a high probability of survival at low cost.
4. The most critical element—bombers—can be protected, while on base, at moderate cost but with low confidence; and can be protected at high cost with greater confidence.

Dispersal. As our bases are now designed, there is generally one ground zero suitable for almost all the vital elements on the base. Our strategic bases in a very real sense present "point" targets. Airfields typically occupy a good deal of ground; and the use of this land, combined with blast-proof construction, would, for some A-bomb sizes, sharply reduce the vulnerability of these bases. Figure 87 compares an aircraft parking scheme designed to achieve greater protection with that currently used at a typical airfield (Goose Bay). Figure 88 compares the expected attrition to aircraft with each of the parking schemes shown. As we change from concentrated apron parking to dispersal against atomic attack with a 40-KT bomb, aircraft attrition is reduced from 80 per cent to 22 per cent. However, microscopic dispersal is sensitive to the size of the enemy bombs committed, just as macroscopic dispersal is sensitive to the number

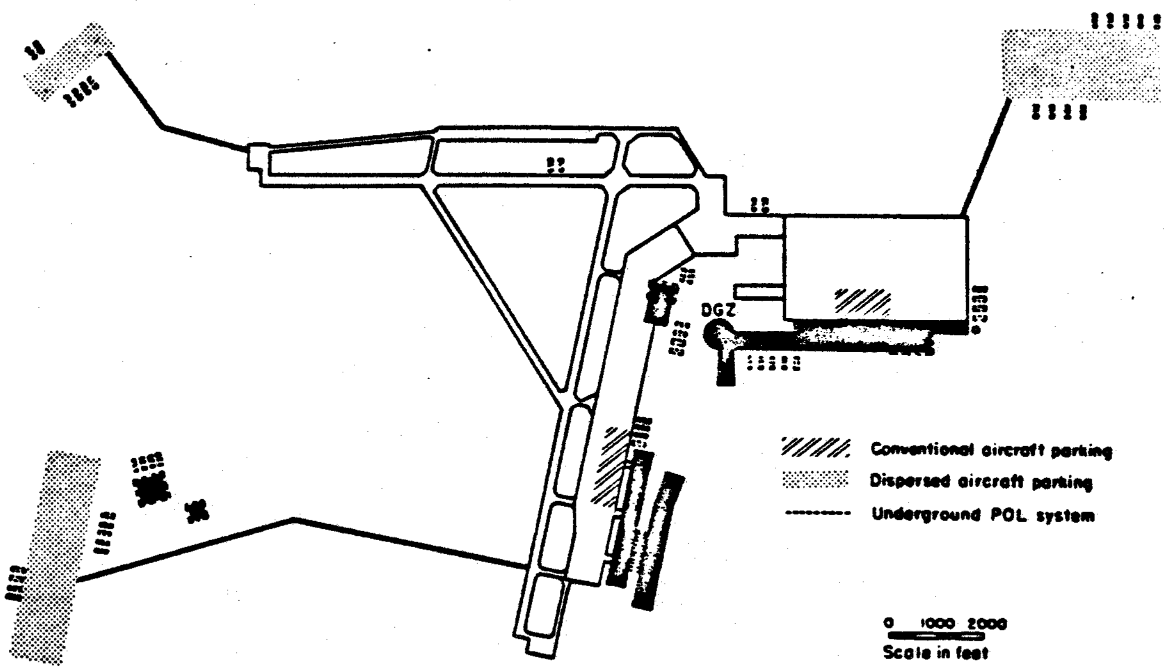

Fig. 87—Dispersed aircraft parking

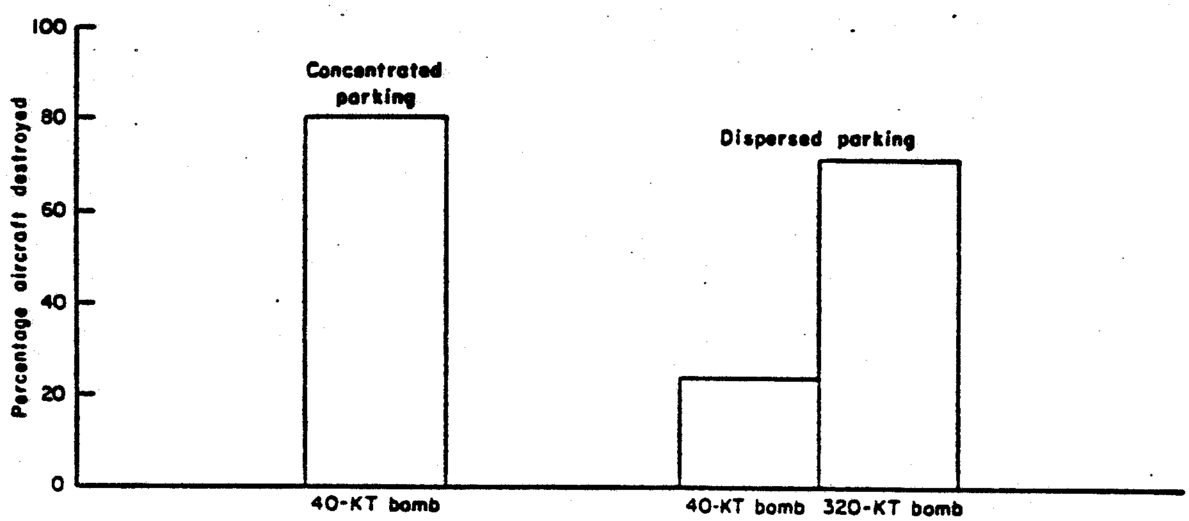

Fig. 88—Dispersed parking and aircraft attrition

of enemy bombs committed. The use of a 320-KT bomb would increase aircraft attrition, even with dispersal, to 70 per cent. Other facilities protected by dispersal and blast-resistant construction would remain relatively unchanged. In both cases the total amount of fissile material required in order to accomplish a given level of destruction is increased. Unfortunately, we cannot generally be confident that Soviet capabilities have been exceeded as long as one large bomb to each of 30 bases will destroy most of the aircraft on these bases.

The practice of moving aircraft to the periphery of a base upon warning of a raid, presently practiced by SAC, and the suggestion within the Air Force that aircraft be moved off base where possible involve a combination of evacuation and microscopic dispersal. In the ZI, where some warning is generally available, it will not be necessary to keep aircraft dispersed during peace. If dispersed parking areas are available, aircraft not evacuated to alternate bases can be moved to these areas upon warning of an attack. Overseas, there would not be sufficient warning for even this limited form of "evacuation" on most bases, and permanent parking of aircraft on dispersed parking areas would be required. In order to accomplish this, additional taxiways and aprons would have to be constructed beyond the present confines of our bases; and on overseas bases where permanent, dispersed parking of aircraft would be desirable, additional vehicles would probably be necessary in order to reduce intrabase transportation problems. This can be accomplished at a cost of about $1.6 million per base if minimal pavement construction is used for the emergency dispersal areas ($4 per square yard of pavement).

Blast Protection. An alternative to dispersal is *protection* against blast, thermal, and radiation effects. Recent tests have shown that it is possible to design structures against quite high overpressures. Some of these structures would be suitable for the protection of some critical strategic base functions.

Aircraft. It is possible to protect aircraft by means of covered shelters. Figures 89 and 90 show two such shelters: one for strategic fighters and fighter interceptors, the other for a B-47. These shelters should provide protection against overpressures as high as 60 psi. The protection afforded by aircraft shelters of this type and by some of the other shelters discussed below is limited by the strength of the doors covering the entrance to them. Although no intensive study has been made, a brief consideration indicates that some of these shelters might be hardened to the point where the shelter itself could not be destroyed, except by cratering or earth deformation. The ground shock and crater lip, however, might effectively destroy the contents at greater distances from ground zero.

The cost of sheltering a squadron of F-84F or F-86D aircraft overseas against overpressures in the neighborhood of 60 psi would come to $1.9 million; the cost for a wing of B-47's with its squadron of KC-97's would come to $49 million. A rough estimate of the cost of shelters with the stronger doors mentioned places the cost in the neighborhood of 50 per cent greater than that for the 60 psi shelter. The vulnerability of fighters based overseas can be very sub-

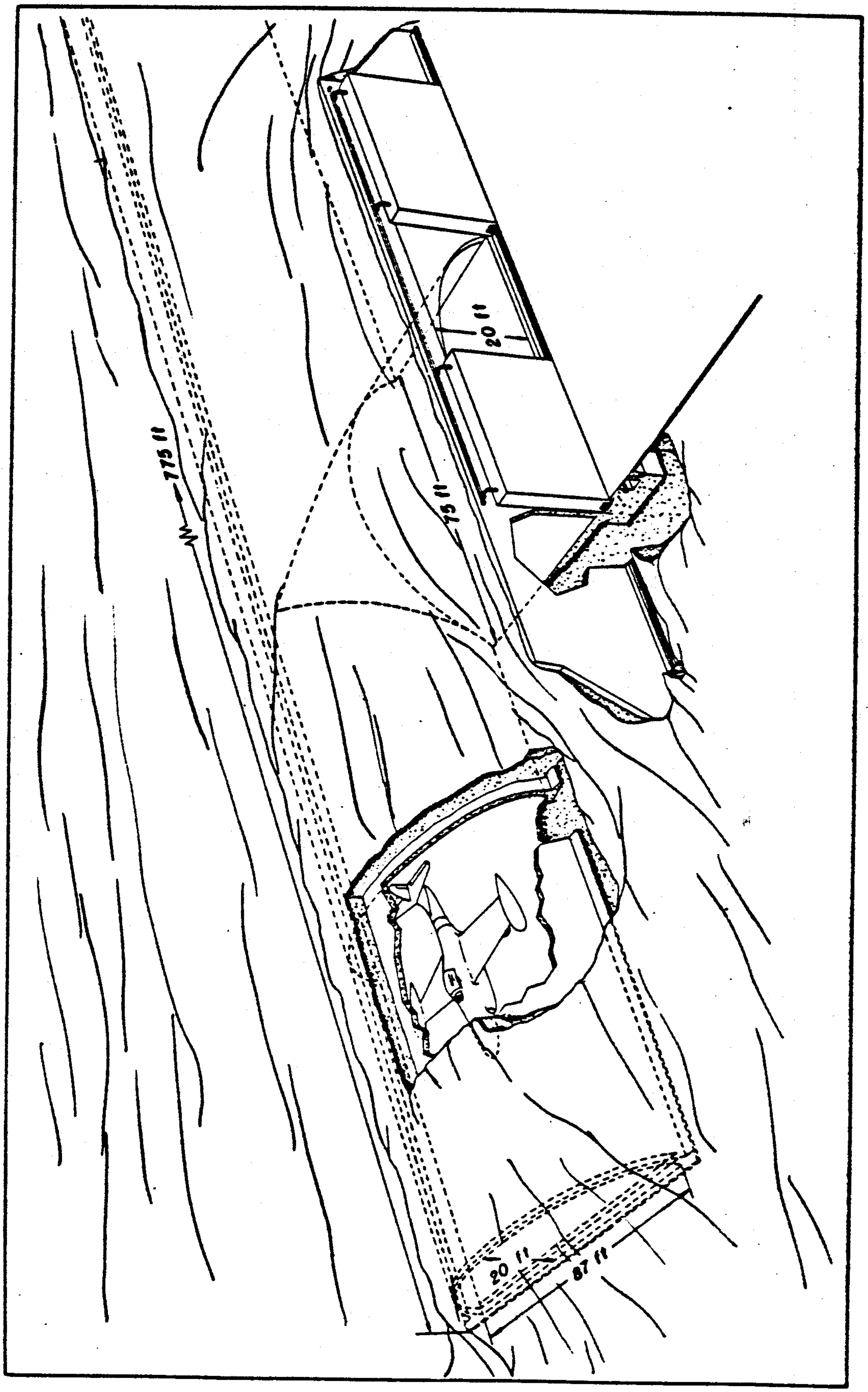

Fig. 89—Underground hangar; F-89

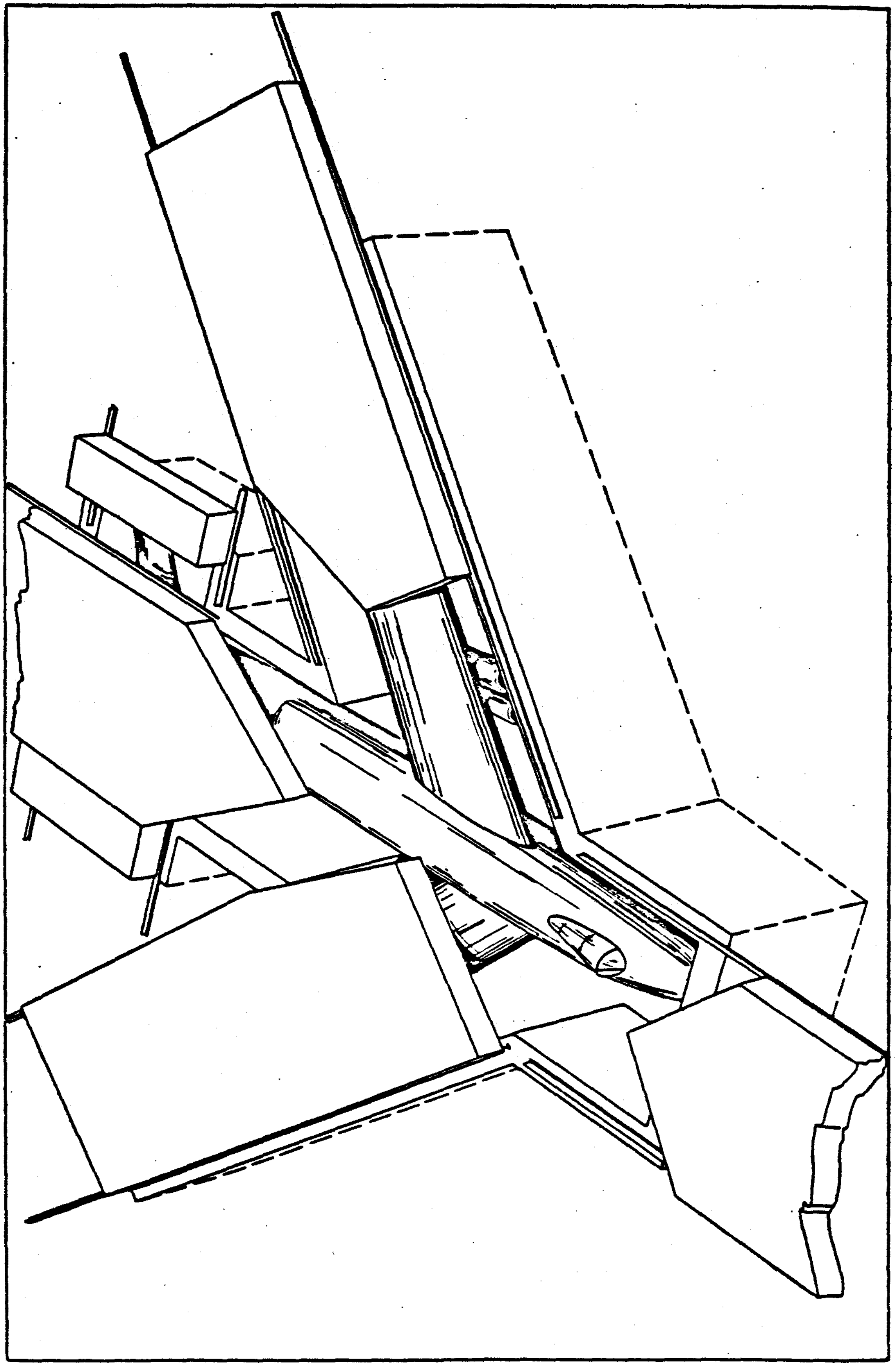

Fig. 90—Underground shelter (elevator-type hangar): B-47

stantially reduced at reasonably low cost. But against an accurately delivered nuclear weapon, the protection of bombers by this method appears to be expensive, especially considering the probable short-life usefulness of this measure, since bombs with yields in the megaton range would reduce the effectiveness of these shelters. Such bombs might be available for use in quantity against overseas bases so protected.

Revetments have some utility against high-explosive attack, but in recent tests they have appeared to have little usefulness against A-bomb attack. Unless later tests show revetments to be of greater value than is presently indicated, they should be considered primarily as protection against high-explosive attack.

Structures. The provision of a high level resistance to blast for most base structures would be extremely costly and in many cases unjustified. Many of these structures make no essential contribution to the bombing mission. Rather than housing, shops, general warehousing, etc., only the most essential facilities—command, communication, bomb storage, fuel distribution and storage, and electric-power generation—would appear to warrant the provision of blast protection. Figures 91 and 92 illustrate two structures that might be used for the protection of fuel pumps and critical items of equipment and supply. While damage to buildings could be reduced sharply, it would be more economic to do without many of these structures rather than to try to protect them or to provide prefabricated structures which could be assembled *after* an attack. For such vital functions as fuel distribution, however, attrition could be kept by protective measures in the neighborhood of 10 per cent for a wide range of bomb sizes.

Personnel. The protection of personnel could be achieved with a high degree of confidence at low cost. Where evacuation would not be feasible or desirable as the primary measure for the defense of personnel, it would be possible to provide protection on the base. The cheapest and most effective defenses appear to be simple concrete boxes or pipe covered with earth or buried in the ground (see Fig. 93). This shelter would reduce personnel casualties as the result of blast from over 60 per cent for a 40-KT bomb to less than 5 per cent for a 320-KT bomb and would cost, at ZI prices, roughly $150 per man.

Fuel. Operating-fuel storage is situated below ground, and on some bases all fuel is stored below ground. This form of storage provides complete protection against air-burst weapons of moderate size. An alternative to underground storage is dispersal, not only against high-explosive attack, as is presently practiced, but wide separation against *both* high-explosive and A-bomb attack.

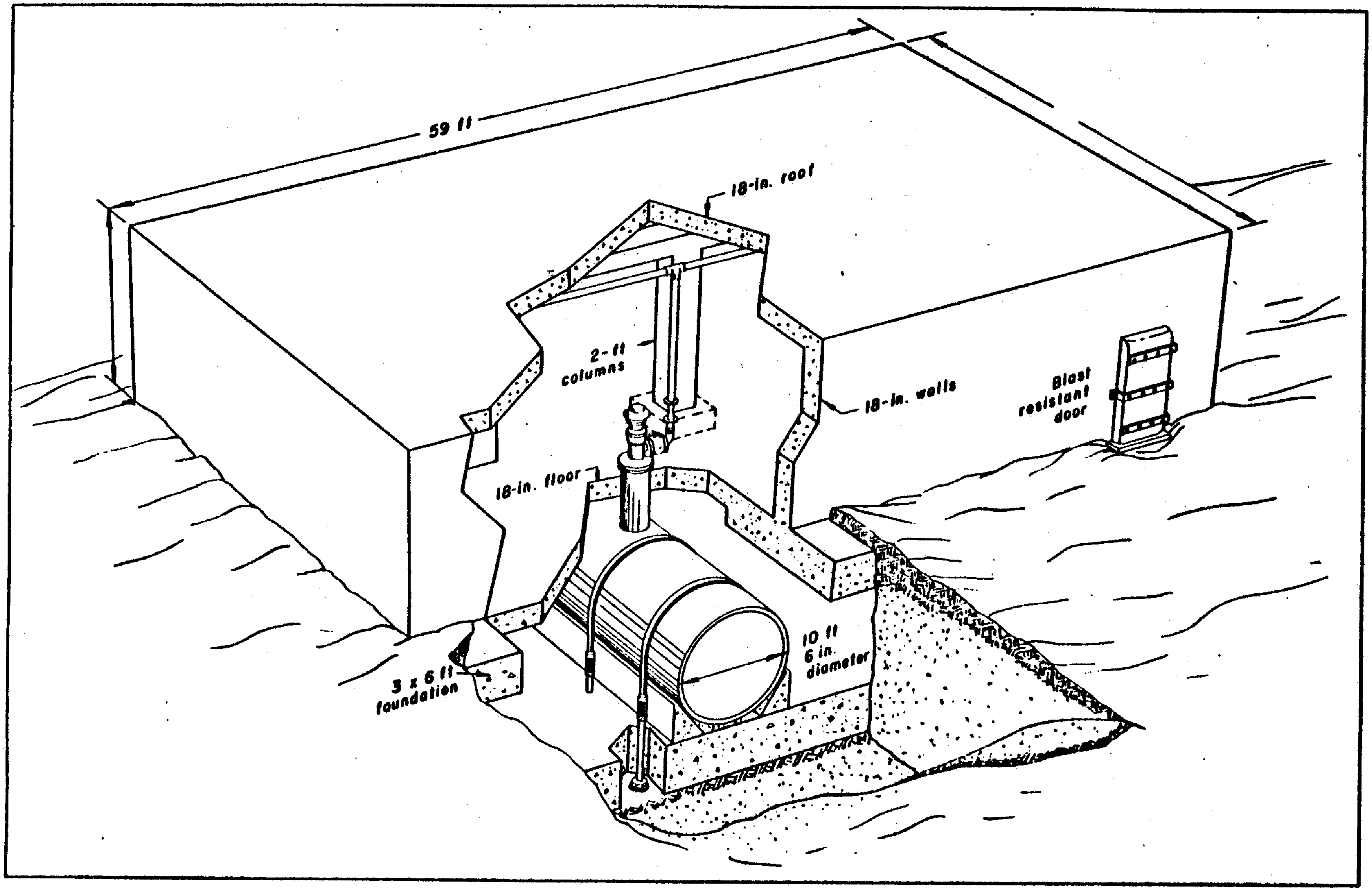

Fig. 91—Blast-resistant pump house

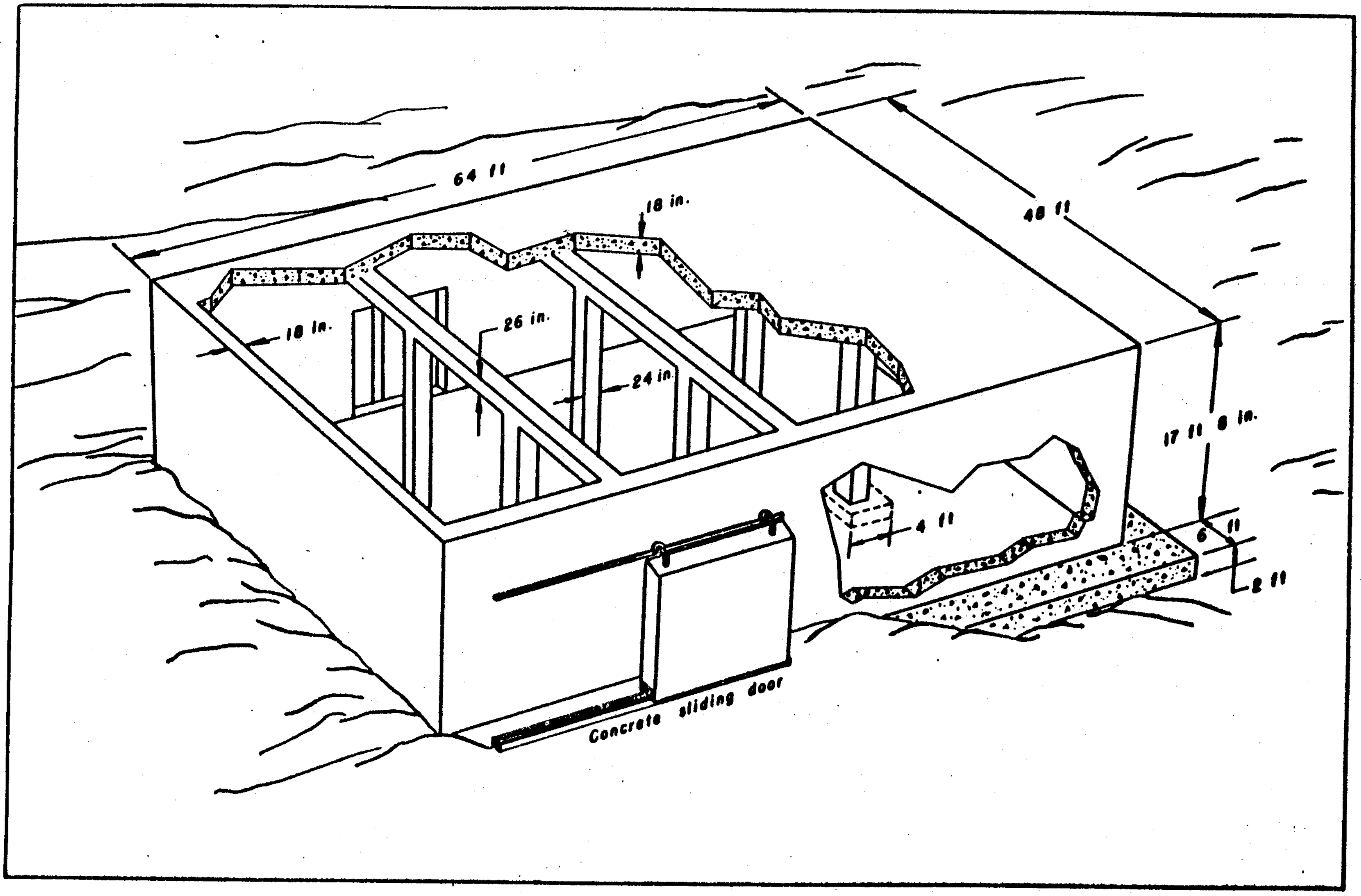

Fig. 92—Blast-resistant warehouse

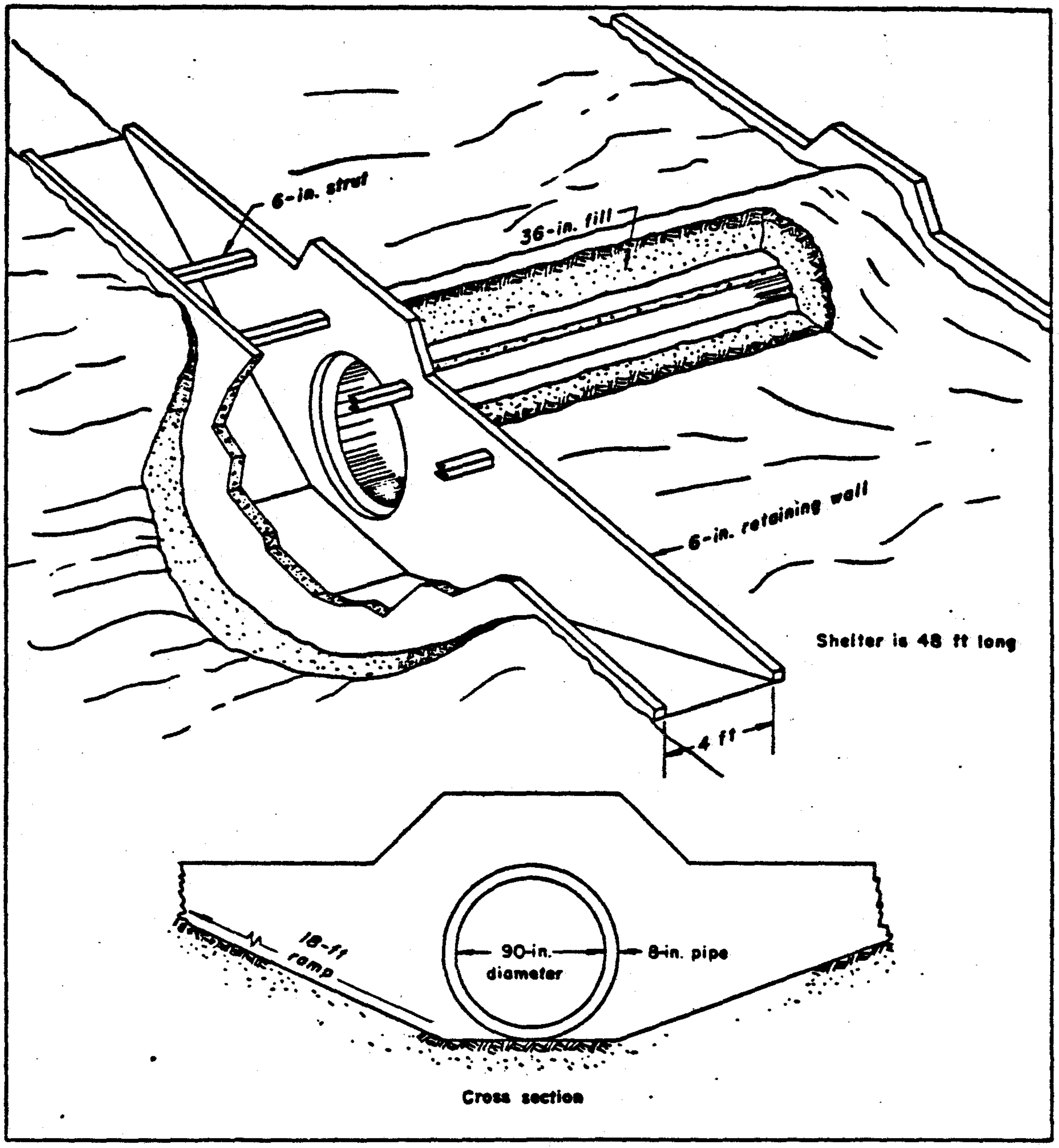

Fig. 93—Concrete-pipe personnel shelter

A comparison of the costs of providing microscopic base defenses shows that many of the measures described above can be achieved at a cost considerably lower than the costs of dispersal to the squadron level. The cost (at ZI prices) of dispersing aircraft, adding minimal blast-resistant structures and personnel shelters, and protecting fuel comes to about $5 million per base, as indicated in Table 44. In our comparisons in Part III, such microscopically defended bases are assumed for the overseas primary-based systems.

Table 44

OPERATING BASE PASSIVE DEFENSES

	Unit Cost	ZI Base		Overseas Base	
		Requirements	Cost	Requirements	Cost
Pavements					
Emergency taxiways	$34.50/LF	6 mi	$1,100,000	6 mi	$1,100,000
Emergency hardstands	$17,500 ea	65	1,130,000	65	1,130,000
			$2,230,000		$2,230,000
Fuel storage and distribution					
Bulk storage	$0.10/gal, plus $464,000 for piping	...	....	2,300,000 gal added at 4 mi distance; tanks separated by 1000 ft	$ 694,000
Distribution system protection	$4,200 ea	...	....	22 hydrant blockhouses	92,400
					$ 786,400
Operations and communications					
Control center and command (blast resistant)	$21.00/SF	...	....	10,000 SF	$ 210,000
Communications (blast resistant)	$21.00/SF	...	....	10,000 SF	210,000
Fire and crash stations (blast resistant)	$18.00/SF	...	....	11,830 SF	218,000
					$ 638,000
Aircraft maintenance facilities	$18.00/SF	...	....	10,000 SF	$ 180,000
Personnel protection	$150.00	...	....	3,750 men × 1.5	$ 845,000
Utilities (power)	$18.00	...	....	2,000 SF	$ 36,000
Storage facilities (flyaway kit)	$16.00	...	....	10,000 SF	$ 160,000
TOTAL BASE			$2,230,000		$4,875,000
TOTAL OVERSEAS (× 1.5)					$7,300,000

There are constraints in the application of many microdefenses as there are with macromeasures. Terrain in some cases will not permit wide aircraft dispersal. It is not legally possible to obtain the necessary land surrounding various other bases. This has been an obstacle in the expansion of our UK bases. In the Arctic, permafrost may make it difficult and costly to put elements below ground. We have not estimated the feasibility of achieving the very wide degree of dispersal described above, but it does appear that at least moderate degrees of local aircraft dispersal are possible on more than half of the ZI and overseas bases. However, the protection of aircraft by blast-resistant hangars would involve large sums of money difficult to obtain during a period of budget cuts.

The appropriate combination of microscopic defenses for ZI bases will vary with the wartime function of the base and the type of atomic weapons expected. A base to be abandoned immediately after the outbreak of war in accordance with the Mobility Plan would have little need for a type of protection which would make it suitable for continuing operations while under atomic attack. It would, however, require the hardening of all facilities for at least the initial strike (and this would include much of what would be essential for the later strikes). Where a base is intended for continued use, it is apparent that toughening of the essential base functions is indicated. In the case of ZI bases, which are to be occupied during the campaign, such microscopic defenses as egress taxiways, protection of fuel and fuel-distribution systems, and blast-protected, sealed, and air-conditioned shelter for personnel forced to remain on base to evacuate aircraft are indicated.

Reduced Recuperation Time

So far we have discussed changes which affect the physical character of bases, their location, and patterns of use. All these measures have been intended to reduce expected damage to base function. It is not possible to provide complete protection, and in spite of these measures we would still suffer damage. For some levels of enemy attack, this damage, especially on overseas operating bases, would be very considerable. We should, then, anticipate the effects of damage which would occur in spite of our best efforts to prevent it and investigate means for reducing the impact of this damage on strategic operations.

The importance of reducing indirect damage, providing medical assistance, and developing means to measure and reduce the effects of residual contamination are receiving attention within the Air Force. The problem of restoring the complex organization of a strategic operating base to an acceptable level of effectiveness—even when protected by the defenses outlined above—bears on the critical importance of time in the strategic campaign. The preparation of bombers for a strike requires more than the survival undamaged of aircraft and minimal tools, spare parts, ground equipment, and personnel. It requires damage control, damage assessment, rapid assembly of surviving matériel, and provision for resupply. At best an operating base attacked by an A-bomb will be able to perform its essential functions at reduced efficiency. Loss of housing and other personnel facilities, hangars, shops, vehicles, and many of the non-aircraft supplies will mean a degradation in base efficiency. In particular, the after effects of a surface burst will degrade operations.

One type of recuperation which is receiving special attention is the problem of surface contamination after a ground burst. Following such an attack, depending on wind conditions at the time of the attack, a portion of the base will be covered by radioactive material from the crater. While the natural decay rate of this radiation is rapid as compared with decay rates of some types of material that may be spread, it may be long in relation to SAC campaign time requirements.

Since an operating base must be occupied continuously to function, the delay occasioned by residual radiation may be serious. Table 46 (see p. 327) indicates that for a moderate level of residual contamination, continuous occupancy for 1 day might require a delay of 4 days, while a 4-day period of continuous occupancy might require a delay of somewhat less than 2 weeks. Because of these delays and the general disruption of the complex activities of an operating base which would follow an atomic attack, the sortie rate of overseas operating bases might be expected to be reduced sufficiently under a high level of enemy attack to allow him to deliver more than one strike for each of ours. Such a case is examined in one of the campaigns of Part III.

Equipment and techniques for reducing residual radiation are under investigation by the Army Chemical Corps, and some of these appear promising. A simple mask is being developed by the Air Force for protection against biological-warfare (BW) and chemical-warfare (CW) attack, and this mask would provide protection against the inhalation of radioactive dust. With this equipment, protective clothing, meters, etc., and with training in techniques of working in contaminated areas, base recuperation time might be reduced considerably. However, at a time when the enemy might be expected to have a large stockpile of H-bombs and the capacity to deliver them, it appears that he could make the continuous occupancy of operating bases infeasible in a large proportion of our base system. The essential defense against contamination of home bases at the end of the period studied requires:

1. Avoiding the initial large dosage of radiation by evacuation on warning of the attack;
2. Having any of a large number of emergency alternatives to land on, in case the home base has received a surface burst;
3. Keeping a capacity to delay return to home base during a cool-off period which may be shortened by shortening the time of occupancy;
4. Staging through the home base on a strike in order to restrict the period of occupancy, or, if this base is unusable, staging through a prepared alternative base;
5. Preparing plans and equipment for such a policy of flexible base use; i.e., by—
   (*a*) Stocking off base of critical matériel and supplies needed for the major SAC strikes,
   (*b*) Adopting, in case of emergency, methods of landing and take-off which are appropriate to runways of poorer standards or runways more poorly placed with reference to the SAC mission.

   (Assisted take-off is only one of several such devices; another would utilize the capability in emergency of converting bombers to tankers to enable a significant proportion of the bombers to take off light and be fueled over base. This would permit the use of shorter runways. Similarly, both tankers and any extension of the radius capability of the projected bombers would be useful in providing us with a more flexible strategic force. The range-extended B-47E with a taxiing gross weight of about 220,000 lb, extra assistance in take-off, and water injection would all increase the flexibility of the projected medium-bomber force; and retrofit should be considered.)

The home bases in the ZI have the advantage over operating bases overseas in that (1) evacuation is a feasible policy, and (2) the remoteness of these bases from enemy attack and the extensive active defenses minimize the probability of the enemy's staging two-way reconnaissance missions to find and bomb the alternative bases.

Initial airframe spares procurement for the B-47 is about 16 per cent of total airframe procurement by value, and airframe parts are those most likely to be damaged on a B-47 by atomic blast. Except against microscopically defended bases, the proportion of bombers receiving less than total damage would be quite small. With dispersal, as much as 40 per cent of the aircraft on base at the time of attack could be slightly damaged. Without airframe spare parts availability, lightly damaged B-47's would not be available until a large number of replacement parts were available. With these parts and the minimal repair facilities assumed protected on modified overseas primary bases, lightly damaged aircraft could be repaired within a day or two. A doubling of airframe spares procurement for these vulnerable elements would increase total aircraft and spares procurement costs by about 3 per cent and total systems costs by less than 1 per cent.

Other base elements for which replacements can be procured and stored in anticipation of damage include portable hydrant refueling systems, tents and prefabricated housing, portable rubber fuel-storage tanks, prefabricated shops, medical stations, and mobile radars. Many of these facilities can be rapidly assembled. For example, two portable hydrant refueling systems and forty 10,000-gal rubber tanks can be assembled and delivery of fuel started from the hydrants within 2 hr 20 min by a force of 111 men. A damaged hydrant refueling system could be replaced by 308 properly trained and equipped aviation engineers inside of 6 days, if the replacement material were available. This replacement material should not be stored on base where it would very likely suffer damage, nor should it be stored at major depots also likely to be attacked. Some of these conponents are air-transportable (such as the hydrant refueling system) and could be airlifted from the ZI when needed.

Preferred Defense Measures for Operating Bases

Zone of the Interior Bases. The primary measure for the defense of the valuable and mobile elements of SAC in the ZI is evacuation. Measures associated with this defense appear to be economic, reliable, and achievable within a relatively short period. These measures include:

1. Further intensification of the SAC evacuation plan through reduction in personnel assembly time and matériel and facilities bottlenecks; separation of plans for evacuation from plans for deployment and from plans for ADC civilian alerts; triggering evacuation auto-

matically at a tolerable frequency; and, if necessary, retention of some minimum evacuation crews on or near base.

2. Increased warning through a combination of added radar in the south and southwest and transfer of combat-ready bomb wings to interior bases.

Additional measures called for in the ZI are

1. Blast protection of fuel storage and distribution and of communications; requirement that personnel be on base to assist evacuation; off-base storage of flyaway kits.
2. Use of existing roads and construction of minimal strips as egress taxiways for the taxiing and towing of nonflyable aircraft off base upon warning of attack.
3. Preparation of minimal alternate bases with plans and equipment for emergency use as operating bases in the event of enemy use of base-denial weapons on home bases. This will become increasingly important in the later part of the period, when the Russians may have large stockpiles of nuclear weapons.

Overseas Operating Bases. For those units forced to operate from overseas bases—fighter interceptor, strategic fighter, and perhaps some medium-bomber units—the following defenses are indicated:

1. Microscopic dispersal of aircraft, and blast protection for at least some strategic fighters and fighter interceptors.
2. Blast protection for personnel, essential equipment and supplies, fuel storage and distribution, electric power, and operations and communications.
3. Increased active defenses with emphasis on the use of such local-defense weapons as Nike, T 212 rocket guns, Loki, etc., and increased radar coverage.
4. Preparation for recuperation by development of damage-control, decontamination, and medical teams, and prestocking off base of supplies, equipment, and structures.

It should be recognized, however, that all these measures for the overseas operating base system depend for their effectiveness on close limitations in enemy assignment of his offensive power.

OVERSEAS REFUELING-BASE SYSTEMS

The advantages of remote operating bases for our strategic force appear to be clearly indicated. Basing our strategic force outside the United States, and especially within unrefueled radius of Soviet medium and light bombers, is a risky business. However, keeping our strategic force on bases remote from the Soviet Union means increasingly high radius-extension costs if we choose to reach targets by the use of aerial tankers, or it means dependence on forward refueling bases. And even though aerial tankers are expensive, it must be demonstrated that their cost is not offset by the increased vulnerability of a system which depends largely on the use of refueling bases.

It is especially true of overseas refueling bases that their vulnerability cannot be considered separately from that of the bombing system as a whole. Overseas refueling bases are in advanced locations, close to the source of enemy striking power. It is, therefore, undeniable that the enemy can deny us permanently the use of any one or any small number of refueling bases. However, the question which faces him is not one of his capability to do this, but rather one of his capability to injure the over-all striking power of our bombing force. The choice facing the enemy in the case of a refueling-base system is that between attacks on ZI operating bases or on overseas refueling bases. We must assume some fixed level of resources available to him for the over-all job of attacking SAC (although this does not mean that we consider only one such level). We must then evaluate his capability for the injury of SAC's striking power, assuming a good allocation of his resources. Therefore, in our consideration of the vulnerability of overseas refueling bases, what concerns us is their relative vulnerability compared with the ZI-base component of the system.

To the extent that our projected staging bases and the units using them are vulnerable, it is largely because of the way in which it is planned to use them. Some of the contributing causes to their vulnerability are as follows: (1) Our aircraft will remain on many bases long enough for Soviet attacks to be mounted against them while the bases are still occupied; (2) the identity of bases to be used for staging purposes, especially in support of B-36 aircraft, is difficult to conceal, and the total number of such bases is not large with respect to Soviet attack capabilities; (3) the physical vulnerability of many fixed base elements is high, and bases can be put out of action for a considerable period by high-explosive or atomic attack. These deficiencies in the projected base structure point up the must important requirements for a viable refueling-base system to support all or the greater part of our strategic force rather than just the heavy-bomber portion of it:

1. *Reduced and irregular exposure time of aircraft on base;*
2. *Area and local active defenses;*
3. *Low physical vulnerability of critical fixed base elements to atomic and high-explosive attack;*
4. *Damage control and recuperation measures.*

Reduced and Irregular Aircraft Time at Risk

One device for protecting aircraft in the ZI is to see that they are not on base at the time of attack by getting them off base with warning of an approaching attack. The comparable measure overseas is not evacuation, which we have seen is hardly feasible, but making certain that the bombers are practically never to be found on base.

The Soviets may attempt to destroy aircraft on refueling bases by attacks timed and placed on the basis of information available to them, or, in the absence of usable information, by randomly timed and placed attacks. A number of measures are available to a refueling-base system to make both of these attempts unattractive to the enemy. *It should be a central part of our strategy to increase the uncertainty of the Soviets with respect to date, time of day, and place of refueling-base occupancy, and to decrease the payoff to the enemy if he does find us.* The goal which should be approached from the point of view of vulnerability is to force the enemy to attack all of a large number of bases at times selected completely at random and find at most only a small percentage of our total force.

Size of the Force at Risk. The number of our bombers on refueling bases during, say, any 1-hr period can be affected by the strike tactic chosen by us. Two of the strike tactics treated in previous chapters have particular relevance in this connection. The first of these is the tactic of reserving bombers and crews to replace losses on earlier strikes. The second is the tactic of attacking separately regions whose defenses are relatively independent. The occupancy patterns displayed in Figs. 94 through 101 illustrate the effects on the proportion of the force exposed at refueling bases of varying the duration of occupancy uniformly over all bases. However, for reasons which are indicated below (see page 319*f*), maximum occupancy limitations are not uniform from base to base. The patterns shown assume an impact tactic and an attack on

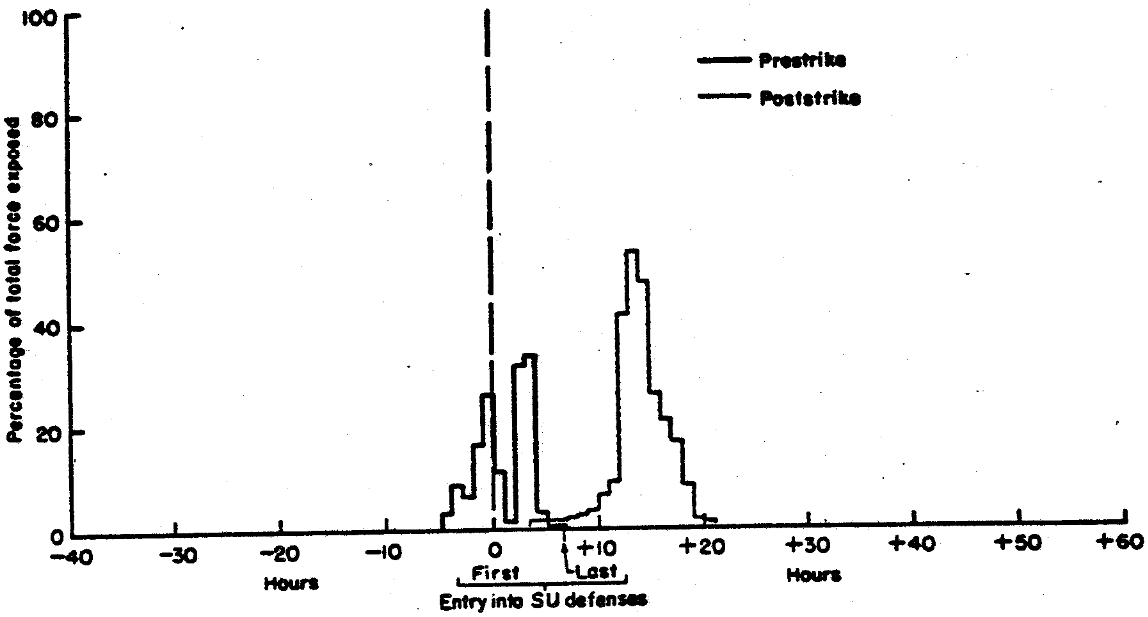

Fig. 94—Two-hr base occupancy, impact tactic, all-region attack (penetration staggered for maximum cover of darkness)

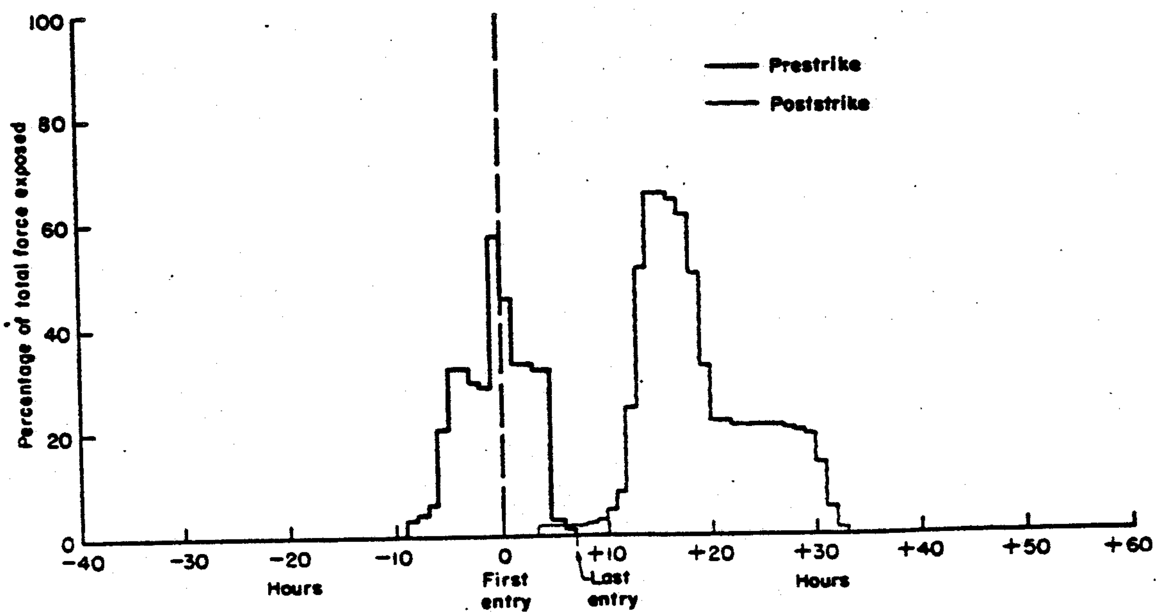

Fig. 95—Six-hr occupancy, impact tactic, all-region attack (penetration staggered for maximum cover of darkness)

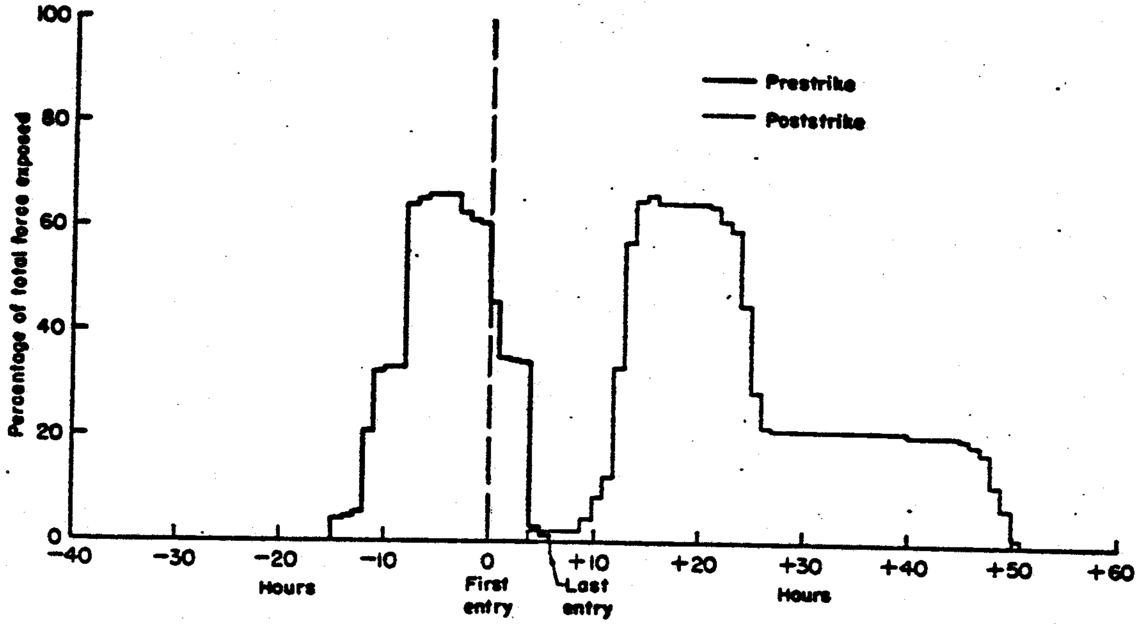

Fig. 96—Twelve-hr occupancy, impact tactic, all-region attack (penetration staggered for maximum cover of darkness)

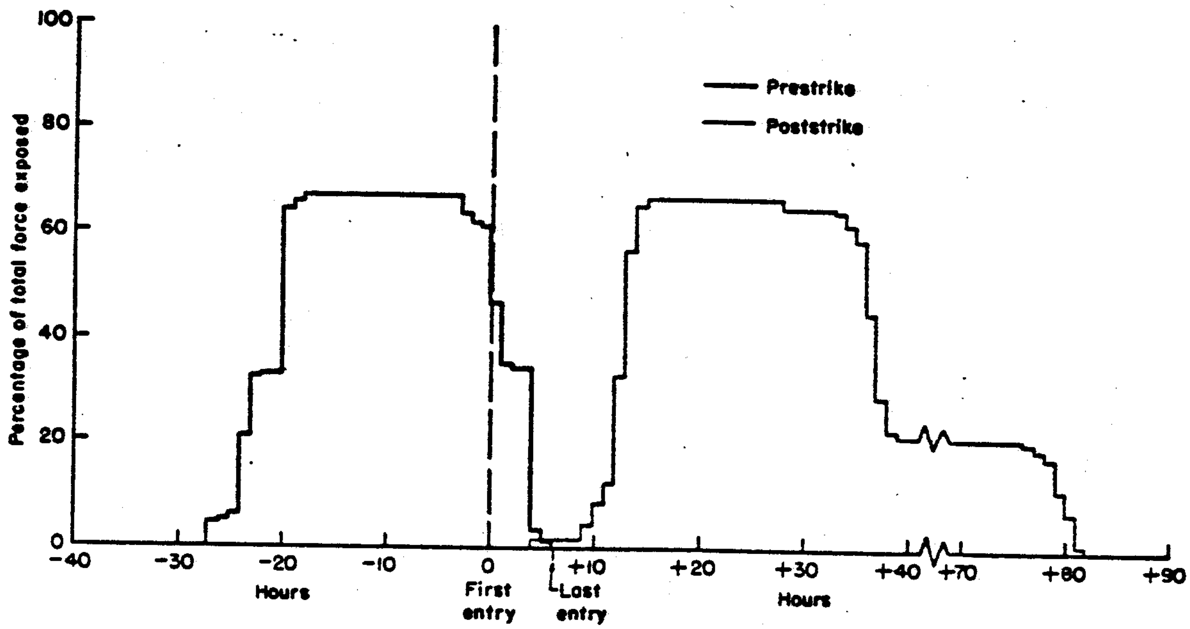

Fig. 97—Twenty-four-hr occupancy, impact tactic, all-region attack (penetration staggered for maximum cover of darkness)

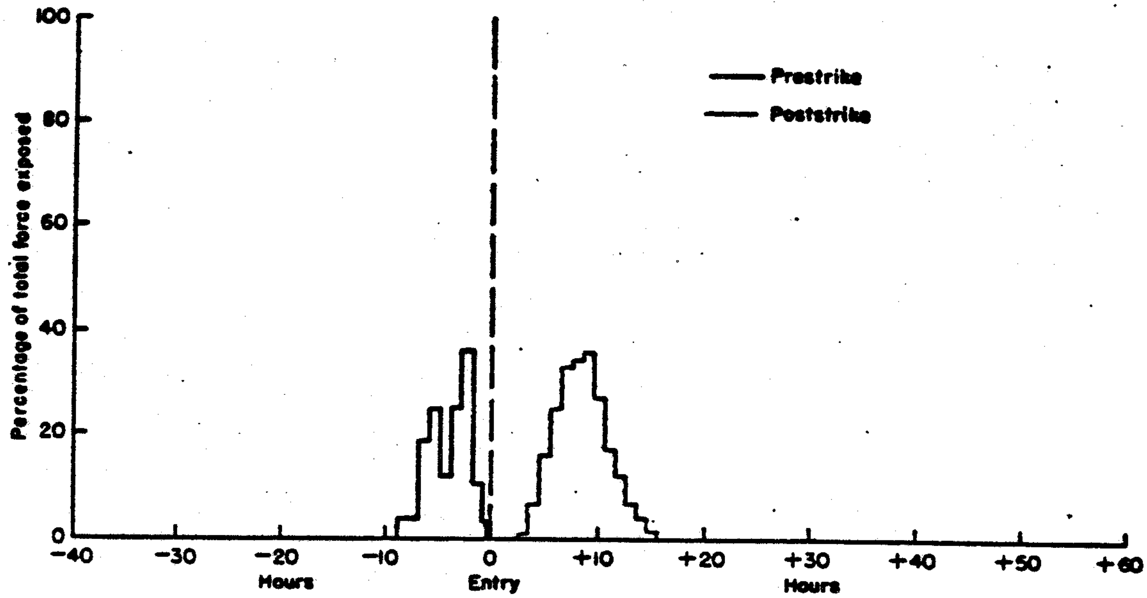

Fig. 98—Two-hr occupancy, impact tactic, all-region attack (simultaneous penetration)

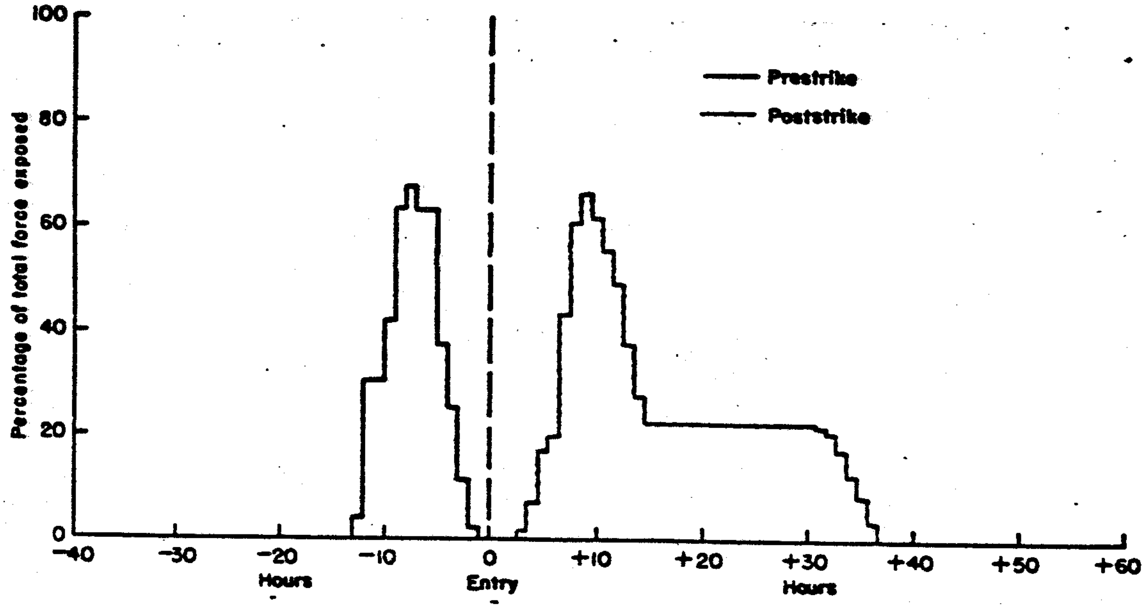

Fig. 99—Six-hr occupancy, impact tactic, all-region attack (simultaneous penetration)

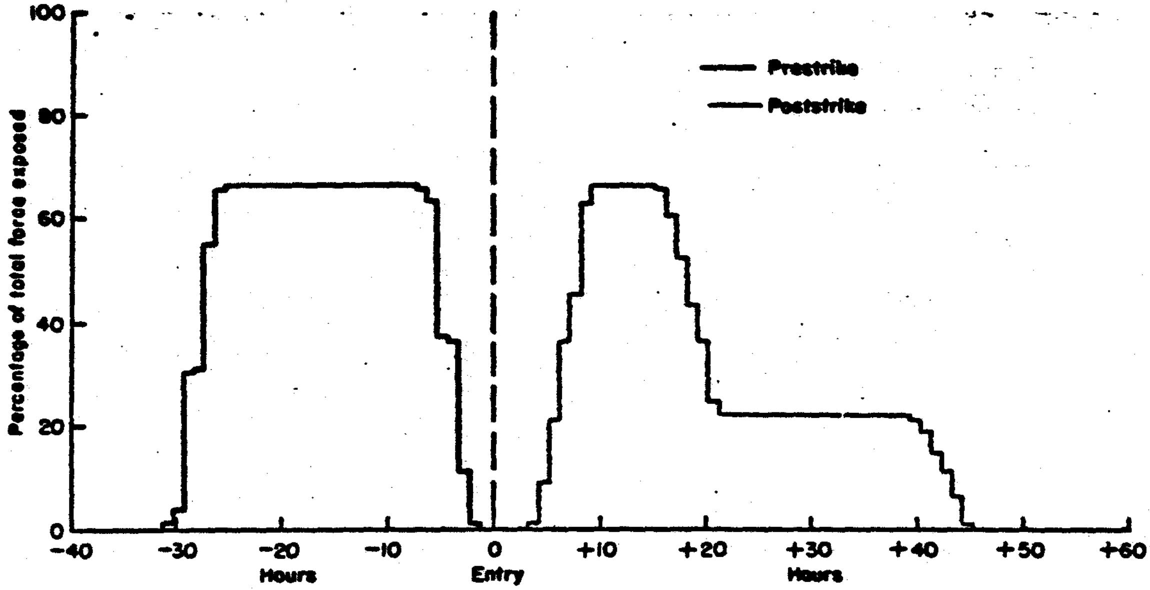

Fig. 100—Twelve-hr occupancy, impact tactic, all-region attack (simultaneous penetration)

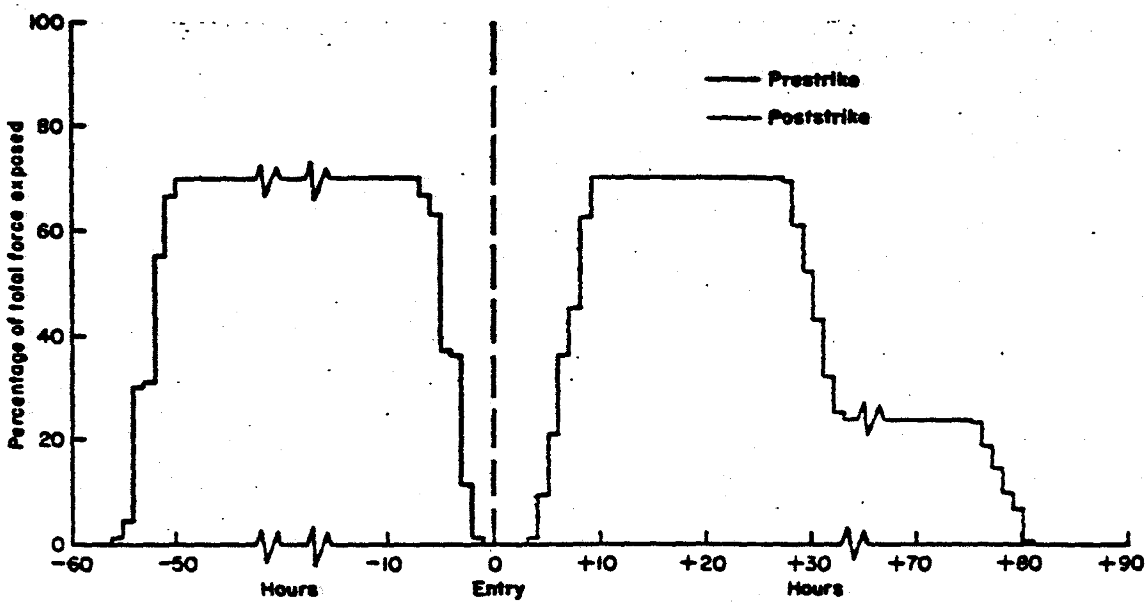

Fig. 101—Twenty-four-hr occupancy, impact tactic, all-region attack (simultaneous penetration)

all regions of the Soviet Union within 1 day timed to achieve maximum cover of darkness for our bombers (see Figs. 94 through 97), or an attack timed to achieve simultaneous penetration (Figs. 98 through 101). Either the tactic of reserving aircraft or that of attacking regions on distinct strikes shows a much smaller relative exposure of the force. Furthermore, these figures do not allow for aborts or attrition.

Brief and Deceptive Occupancy. To execute an effective attack on aircraft at refueling bases, the enemy must estimate or guess the day of the month on which our bases will be occupied, which bases will be occupied, and the time of the day during which they will be occupied. We might, to be on the safe side, suppose an extensive supply of information about aircraft movements on home bases furnished to him by agents on the spot. We might even suppose that some Air Force personnel were prepared to give the enemy strike information. Or we might merely suppose that the enemy was ready to decipher any easily legible strike schedule. The obvious way to counter the last would be to adopt an irregular strike pattern, making, within limits set by operational considerations, some of our choices at random.

The first two kinds of information could be nullified by mixing departures for actual strikes with departures for feints or training missions; and the identity of the individual take-off as a genuine strike might even be kept from the crew members by the use of sealed orders until after departure.

If the enemy guesses correctly that a strike is in progress on a given day, for example, from information to the effect that some of our bombers have landed on refueling bases, he may, given certain strike tactics on our part, make correct inferences on the subsequent pattern of refueling-base occupancy. If we adopt either the plan of simultaneous penetration of all regions, or penetrations of all regions to achieve maximum cover of darkness (restricted to the same day), the irregularity which we can impart to the use of refueling bases is considerably constrained. However, even in these cases we have a range of choice. First, there are a number of ways in which we can match refueling bases, entry points, and targets, even when we limit our consideration to the relatively short radius B-47. Second, the number of ways of matching bases, entry points, and targets, and the enemy's uncertainty in general can both be increased by adding to the number of our refueling bases. Third, the choices open to us increase for the radius-extended B-47E and the B-52, and our fleet of tankers further increases our flexibility. Fourth, by choosing among various routes which enter on one side of the Soviet Union and leave on the other, we enlarge the number of possibilities.

However, we are not constrained to attack all of Russia on the same day by consideration of air attrition (see the section entitled "Bases, Targets, and Penetration Paths," page 135), and this gives us greater opportunities to reduce ground attrition. A regional saturation tactic decreases the number of our bombers at risk, as indicated above, and also offers us the possibility of increasing the enemy's uncertainty as to the time and place of our use of refueling bases.

Even the tactic which attempts to achieve maximum cover of darkness increases the enemy's uncertainty, since there are a number of regions which confer the benefits of darkness during almost any part of the day in some months of the year, and which offer almost no darkness in other months.

Besides providing the foundation for inferences on future occupancy, information that our planes have landed at a certain base also suggests the possibility of attack on these planes at this base. The time required for the Russians to learn of the arrival of our bombers on base, transmit the information to strike bases, launch an attack, and fly to our bases cannot, of course, be unequivocally determined. Table 45 presents an Air Intelligence estimate of the total time and its components for different base regions. It is clear, of

Table 45

EXPECTED SAFE-OCCUPANCY PERIODS FOR OVERSEAS[a] BASE AREAS

(Hours)

Base Area	Total Time		Detection Time	Transmission and Command Time	Flight Preparation Time	Flight Time	
	Min	Max				IL-28	TU-4
United Kingdom	4.5	8.5	0.5 to 1.5	1.0 to 2.0	2.0 to 4.0	1.0	...
Japan-Okinawa	5.0	9.0	0.5 to 1.5	1.0 to 2.0	2.0 to 4.0	1.5	...
Spain	8.5	15.0	0.5 to 2.0	1.0 to 2.0	2.0 to 6.0	...	5.0
French Morocco	10.5	17.5	0.5 to 2.5	1.0 to 2.0	2.0 to 6.0	...	7.0
Iceland	9.0	14.5	0.5 to 2.0	1.0 to 2.0	2.0 to 6.0	...	4.5
Alaska	8.5	14.5	0.5 to 1.5	2.0 to 4.0	2.0 to 6.0	...	3.0
Saudi Arabia	7.5	14.5	0.5 to 1.5	2.0 to 4.0	2.0 to 6.0	...	3.0
Labrador, Newfoundland	15.5	22.5	2.0 to 4.0	2.0 to 4.0	2.0 to 6.0	...	8.5

[a] Directorate of Intelligence, HqUSAF. Later intelligence estimates reduce slightly those shown above.

course, that we can render attacks of this sort ineffective by restricting our periods of occupancy to less than this safe-occupancy time. The time between the arrival of our first bomber at a refueling base and the enemy decision that an attack in force is in progress can be lengthened by the possibility of feints. The disparity in the safe-occupancy periods available to various bases indicates that the uniform occupancy periods implicit in Figs. 94 through 101 are too long for some bases or shorter than necessary for others, or both. Restricting periods of occupancy to those shown in Table 45 will affect the hydrant requirements at refueling bases, as well as the opportunity for crew rest and maintenance. The consequences of this restriction for refueling base-cost, crew requirements, and abort rate have been discussed above in the section entitled "Base to ZI: The Cost of Operations Outside the ZI," page 187.

The enemy may also attempt to eliminate both time and place uncertainty on the poststrike location of our bombers by following our existing bomber stream from Soviet territory to the refueling bases. To do this, aircraft, crews, and bombs would have to be held unevacuated and in readiness throughout our attack. They would have to be based near the borders of the Soviet Union and its satellites and located along our routes of departure. Finally, in spite of the tempting targets they would offer, they would, of course, have to be spared attack by us. If they achieved this conjuncture of circumstances and managed to take off in pursuit of our bombers, the SU bombers would then run the risk of being shot down by their own fighters. Only jet aircraft would be at all capable of following B-47's, and 50 per cent of our refueling-base system is beyond IL-28 radius. If the outbound minimum-penetration routes presented in the section entitled "Bases, Targets, and Penetration Paths," page 135, are followed, only one poststrike refueling base used will be within IL-28 radius. Both night and daylight trailing appears difficult, and if we are aware of being followed, our force can loiter, split up, and use alternate fields. The tanker requirements used here incorporate a reserve capability for this purpose.

Evacuation and Brief Occupancy. The analysis of alternative refueling-base occupancy patterns makes clear that the enemy's expectation of finding our bombers or tankers on refueling bases may be made smaller than the corresponding expectation of finding unevacuated bombers in the ZI. In the ZI there may remain bases at which warning time is insufficient for complete evacuation, and on all bases there will be some bombers which cannot be evacuated because they are unflyable at the time of attack. Furthermore, if there are no units on rotation, the enemy can benefit from surprise only by attacking the ZI.

In using the tactic of deception as a primary means of defense for our bombers overseas, an essential element in its success is the use of active defenses in combination with it. Our area and local defenses make it costly for the enemy to respond automatically to our feints as well as our genuine strikes. They mean he loses bombers and bombs as well. By using other deceptive measures—not mentioned so far, such as B-47 and B-52 dummies—on unoccupied bases we may be able to lead the enemy to waste some of the bombs we do not shoot down.

Active Defenses

Refueling-base defense, like the defense of operating bases, cannot be left to passive means alone. If this were to be done, the enemy could bomb with high accuracy, fly repeated reconnaissance sorties—perhaps while armed—at little cost, and attempt base capture by air. In addition to the need for a continuing defense, the intermittent character of the use of refueling bases suggests a defense, itself intermittent in character, which can be concentrated during strikes.

The objectives of active defense of a refueling-base system differ from those of an operating base system overseas. The latter requires continuous protection for bombers which are continuously present and continuously vulnerable. The object of active defense is the prevention of even a single penetration to bomb release, since, given the softness of the targets, this is enough. Refueling-base active defense, on the other hand, has fourfold objectives. First, it penalizes any automatic enemy response to our strike or feinting movements, and so reduces the likelihood of the enemy's finding our soft elements on base. Second, it constitutes a form of insurance in the unlikely coincidence that he does find our aircraft on base. Third, it prevents the enemy from cumulating damage to the hard fixed base elements by degrading the accuracy of his attacks and exacting some attrition in the event of repeated visits. Fourth, it provides protection for the fixed facilities against air and ground assault.

While different defense levels have a considerable effect on the cost to the enemy of bombing, there is little base damage over the range. Defense in most base areas would presumably be largely "local" in character, since two of its objectives would be a degrading of enemy bombing accuracy and the defense of our bases against air- and ground-troop assault. In the United Kingdom, the considerable resources of the RAF, together with NATO forces on the continent, would also exact payment for repeated high-explosive or reconnaissance sorties against refueling bases. And Soviet transports intending paratroop attack against our interior and western United Kingdom bases would suffer high attrition before reaching our bases.

Having more refueling bases than we intend to occupy on any given strike and selecting different bases on successive strikes suggest the use of interceptor "task forces" in order to obtain high levels of defense while our bombers are exposed on base. This concept involves the stationing of interceptors in each of seven base regions, the deployment of fighters to prestrike and poststrike bases slated for occupancy just before the arrival of bombers on base, and the flying of intensive-cover air patrols while bombers are on base.* The distance over which fighters can be deployed for this purpose has been limited by assumption to 700 n mi (F-86D range), so that the transfer can be carried out rapidly with no intervening refueling stops.

Since it appears that the probability of being caught on the ground can be made low by the measures outlined above, such a mobile defense should be regarded as partial insurance against misfortune (the coincident arrival of Soviet and U.S. bombers jointly at refueling bases) or a superior Soviet attack capability.

Base Denial

We have examined the threat of Soviet attacks directed primarily against bombers on refueling bases. Such attacks might give bonus results in the form of base denial. There is also the possibility of attacks whose goal is the denial of refueling bases. We can discriminate two classes of such attacks. One type of attack consists in an attempt to deny us the use of refueling bases by the physical destruction of these bases. A second type of attack is one which attempts to deny us the bases for a period of time, but not necessarily permanently. This sort of temporary base denial can further be broken down into an attempt to delay for some period of time the mounting of our strikes, and an attempt to disrupt our strikes once they have been mounted.

We have proposed as a primary defense measure for bombers on overseas bases that they have short and irregular periods of occupancy of refueling bases. This is to lower the probability of their being found on base by enemy bombers.

*Here, as with the deployment of maintenance teams, bomb-loading units, etc., it is important not to have too early a convocation at bases scheduled for use.

This defense, by definition, will not work for fixed base elements. These elements may be attacked at the pleasure of the enemy. Therefore, the primary method of defense proposed for fixed base elements is that those which are necessary to operations be made sufficiently hard and numerous to present uninviting targets for enemy attack. These necessary elements consist of the following items:

1. Pavements;
2. Fuel storage and distribution facilities;
3. Fuel and other supplies;
4. Fixed and mobile ground equipment;
5. Housing and personnel facilities;
6. Base personnel.

Some modification of existing or programmed air force overseas bases is necessary to insure sufficiently low vulnerability of the elements listed above. The principal modifications are

1. Location underground and/or dispersal of bulk fuel storage;
2. Additions to the fuel-distribution system to permit the simultaneous refueling of 30 B-47's in a 2-hr period;
3. Protection of the fuel-distribution system by blast-resistant construction;
4. Wide separation of new fuel-distribution facilities from existing facilities;
5. Protection and duplication of power-generation system;
6. Provision of personnel shelters giving protection against blast and gamma radiation, some located as far as possible from probable DGZ's, others at places of work;
7. Protected command posts and communication centers;
8. Augmentation of runway-repair equipment and personnel; provision of blast-protective shelters for communications, decontamination, runway-repair and power-generating equipment, as well as for crash and fire vehicles and tow trucks.

The average costs of protecting overseas bases in this fashion are estimated at approximately $10 million per base. The vulnerability to various kinds of attack of a base so hardened is examined below.

Threats examined that, if successful, would result in base denial for short periods or for the campaign are as follows:

1. Advance of ground forces;
2. Paratroop attack;
3. Surface burst—large-yield bombs;
4. Surface burst—small bombs;
5. Chemical, bacteriological, and radiological agents;
6. High-explosive bombs.

The enemy can use combinations of these threats to take possession of the base, destroy it, or merely remove it from our use for a limited time.

Enemy Seizure of the Base. As Soviet ground forces advance after the outbreak of war, many of our bases will come within range of higher-performance, shorter-range Soviet aircraft. And some will be overrun by Soviet ground forces. An estimate has been made of the probable rates of advance of Soviet ground forces with respect to our base locations. The great majority of our overseas bases will very likely be available for use at the end of a 2-month atomic campaign.

The Russians are expected to have a paratroop force of about 100,000 men. In 1956 they are expected to have a simultaneous airlift capability for approximately 20,000 of these. Perhaps 10,000 additional might be carried in converted TU-4's. These troops might be used against formal airfields in commando-type raids intended to destroy facilities, or, in the case of isolated bases, they might be taken for use. This attack potential is largely limited to a zone within 600 n mi of the Soviet Union, the limit of 5/IL-12 radius. Within this zone troops could be dropped, aided by attacks by IL-28 aircraft but without fighter support. Within 400 n mi fighter support would be available. Beyond the 600 n mi zone, unescorted TU-4 paratroop attacks would be possible.

Plans for defending bases against this form of attack have been developed, especially in the United Kingdom and in Japan, and further development of ground defense methods is expected. Maneuvers for defense of a refueling base against this attack include radar warning, fighter defenses, AAA defenses, and a ground defense force organized around the "strong point" concept.

Physical Destruction of the Base. The vulnerability of pavements to airburst A-bombs is negligible, but the enemy has a choice of other weapons. In particular, he might attempt to crater our airfield pavements by surface- or penetration-burst nuclear weapons or by conventional high explosives. Neither of these alternatives appears promising from his point of view. The extent of the crater produced by nuclear weapons of even very considerable size is small, both in relation to the targets to be hit and to expected Soviet bombing errors. To deny us the use of a runway, it is not sufficient for the enemy merely to crater any portion of it. A B-47 can, under emergency conditions with reduced loading, take off in 6000 ft of runway. Therefore, if the enemy leaves at least this much continuous, undamaged runway, he will not have denied us the use of a base. Furthermore, a number of overseas bases have double runways. To deny us the use of a two-runway base, the enemy must leave no greater length than 6000 ft on either runway. This is a multiplication rather than an addition of his difficulties. To illustrate this point, we have chosen an extreme case.

Suppose that we want to deal with a bomb whose lethal radius against airfield pavements is 1000 ft. An airfield pavement may be destroyed by a bomb crater, by deformation of the earth producing cracks in the pavement, or by being covered by massive quantities of each such as occur near the edge of the crater. The zone of rupture is expected to extend to a distance from ground zero which is equal to 1½ times the crater radius.* Using curves relating crater diameter to bomb yield† and taking into consideration height of burst of the bomb as well as uncertainties attached to these curves, we find that a lethal radius (as defined here) of 1000 ft may imply a bomb ranging in yield from 300 KT to 15 MT, but it is the expected lethal radius of a 5-MT weapon exploding precisely at the surface. We have examined the effects of a weapon with this lethal radius used against runways for 2 CEP's—1500 ft and 4000 ft. Figure 102 gives an estimate of the number of bombs of the lethal radius mentioned which are required in order to have an expectation of knocking out a given proportion of the airfields attacked. The number of bombs referred to in this figure is the number of bombs actually dropped on the airfield rather than those committed to this mission.

Suppose we have a refueling-base system of 60 bases, half of them being two-runway bases and half one-runway bases. (In the campaigns of Part III, we charge the ground-refueled system with the cost of this number of refueling bases. This is roughly twice the requirement, based on traffic considerations, in an impact campaign with simultaneous penetration.) *If the enemy were to take as the goal of his base-denial mission the neutralization of 35 of these bases,*

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* *Capabilities of Atomic Weapons*, Department of the Army, the Navy, and the Air Force, rev. ed., AFOAT-385.2, October 1, 1952, p. 31 (Secret).

† *Ibid.*, Figs. 17 and 24.

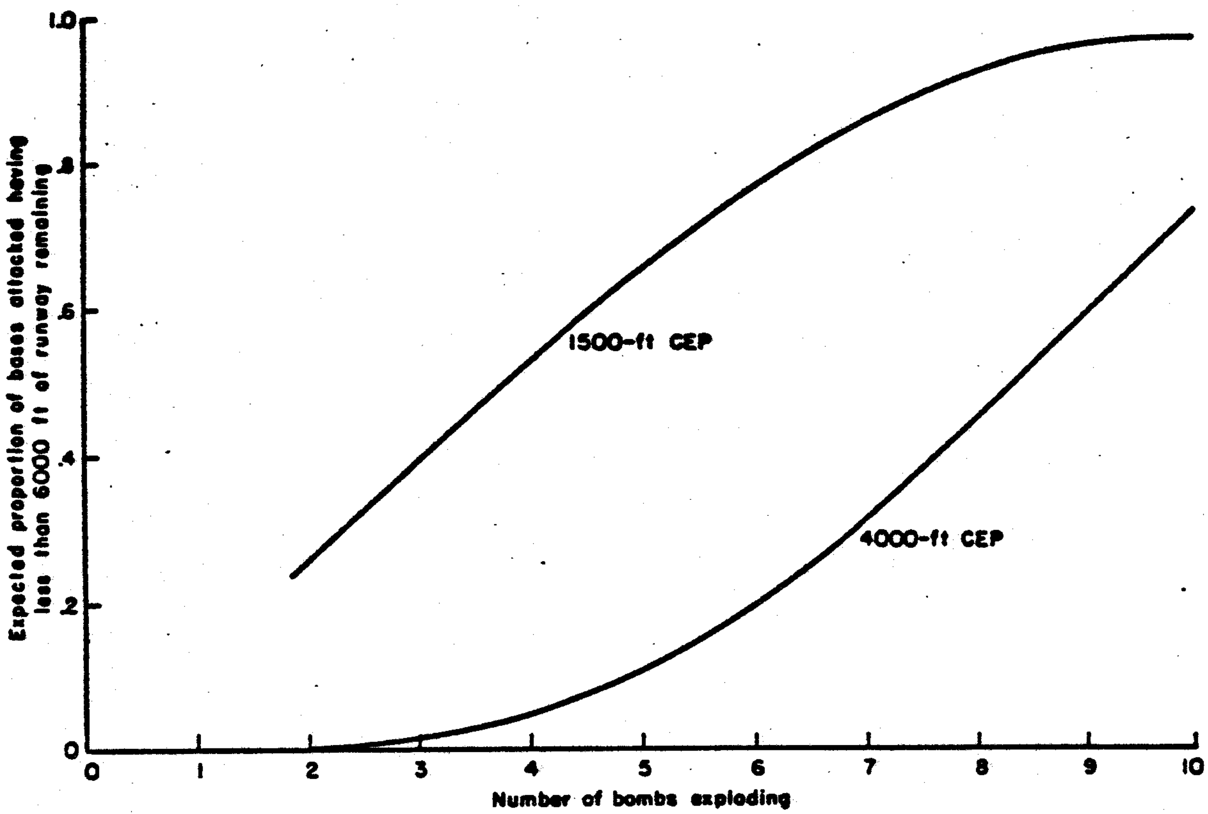

Fig. 102—Effectiveness of a 1000-ft-lethal-radius bomb against bases with two runways

and if he were to require an 80 per cent confidence in his ability to do the job, then with a 1500-ft CEP he would have to commit about 300 bombs of this lethal radius.

But what would this gain him? If we have provided a larger number of bases than are needed on grounds of traffic alone, or if we use a strike plan or a modification of the B-47E which enables us to mount our strikes using a smaller number of fields than we have in total, the destruction of this proportion of our refueling bases need not seriously affect SAC's striking power. At a time when the Soviet stockpile was limited, the allocation of this amount of fissile material to the task of destroying runways would mean foregoing any attempt at the destruction of aircraft in the ZI. It is extremely doubtful that the enemy would undertake such a tactic. But if he did, the damage which he would inflict on SAC's power would be less than that shown in the campaigns of Part III.

Other fixed base elements such as bulk fuel storage, fuel-distribution systems, personnel, and power-generating equipment can also be made difficult to destroy. They can be provided with shelters which approach the level of resistance to blast of the runway. Furthermore, since these, for the most part, are inexpensive and rapidly replaceable relative to the runway, they are not likely to serve as independent desired ground zeros (DGZ's) for atomic attack. Therefore, the likelihood of their being damaged can be greatly decreased by moving them away from probable DGZ's. To reduce even further the probability of a high level of damage, they can be dispersed into independent units, as indicated in Figs. 64 and 65, pages 198 and 199. Under these circumstances the other elements on a refueling base can be made even more elusive targets than the runway.

High explosive presents an alternative means for the destruction of runways. However, since the destruction produced by high explosive is, in general, reparable within a period of time which is short relative to the duration of the campaign, we consider this as a tempororay base-denial measure and include it in the discussion below.

Temporary Base Denial. Denial of a base can occur either as a by-product of an enemy attack seeking to destroy some fixed base element or as the primary result of an attack devised to accomplish this goal. The possibility of denial from residual radioactivity resulting from surface nuclear explosion must be taken into account.

Table 46 shows various lengths of time during which an area is denied operational personnel and at the end of which various periods of work are permissible without exposing this personnel to a total dosage greater than 100 r.

Table 46

LENGTH OF BASE DENIAL TIME

(For varying dosage rates at 1 hr and periods of occupancy accepting a maximum cumulative dosage of 100 r)

Duration of Occupancy	Dosage Rate at 1 hr		
	100 r/hr	1000 r/hr	5000 r/hr
30 min	([a])	3½ hr	15 hr
1 hr	([a])	6½ hr	26 hr
2 hr	1 hr	12 hr	45 hr
8 hr	2½ hr	36 hr	4½ days
1 day	7 hr	4 days	16 days
4 days	17 hr	12 days	2 months

[a] Less than 1 hr delay time.

Three conditions of contamination have been assumed, corresponding to a dose rate of 100, 1000, and 5000 r/hr measured 1 hr after the burst, and the well-known $T^{-1.2}$ decay law was used in the computations. Only surface bursts will create the conditions to which the results of Table 46 refer. An 80-KT burst would likely result in the 100-r/hr rate over a large part of an air base.

Larger-yield weapons would result in larger amounts of fission products, in larger areas with a given intensity of radiation, and in higher probabilities of covering an air base with a given intensity of radiation. We have chosen, in order to represent a very high level of contamination, a dosage rate of 5000 r/hr at 1 hr over the entire base.

What does this mean for the possibility of refueling-base denial by radiation? Table 46 is based on the assumption that personnel are shielded from initial radiation and are subsequently shielded against residual radiation until they occupy the base to perform their refueling function. As planned, personnel shelters will not stop radiation completely. If they are in an area of intense initial or residual radiation, the dosage received while in the shelter may be serious. There appears to be no great difficulty in designing shelters which will give more effective protection against radiation with only a moderate increase in cost. Moreover, there is no compelling reason for putting the shelters close to a probable DGZ on a refueling base. The combination of effective shielding and distance from GZ should provide a high level of protection for personnel while in the shelters.

Table 46 shows that even for the high 1-hr dose rate, a period of occupancy of 2 hr could occur less than 2 days from the time of the explosion. Two hours is the length of time required to refuel a wing of B-47's on the refueling bases recommended here. If an 8-hr period of occupancy is required to perform repairs or clean up debris, the delay for the high 1-hr dosage rate is still considerably less than 1 week. If the attack occurred at a time when there were no aircraft on base or due in at the base, the effect would then be a 2- to 5-day delay in the use of a contaminated base.

This does not mean a delay of this duration in our next strike unless a large proportion of our refueling bases have been contaminated to the extent mentioned. Like the task of runway destruction, base denial by contamination requires a large commitment of high-yield bombs to cause a brief delay in our strike. But, in a situation where the enemy spends a considerable proportion of his resources on such an attack, a short delay need not be crucial to the performance of the SAC mission. Moreover, this appears to be the worst situation having any considerable likelihood of occurrence. In addition to being the result of a large bomb and an unlucky configuration of meteorological conditions, this situation also neglects the possible use, by us, of countermeasures or protective clothing.

A study prepared by USNRDL* indicates that the best present methods and equipment have a capability of reducing the intensity of radioactive fields by a factor of five to ten within a land target complex. The methods which accomplish this reduction are reasonably fast and utilize standard equipment. By these methods, it may be practicable to reclaim a military installation within a period of about a week *for continuous use*, employing only equipment and personnel available at the installation. Reclamation for intermittent use could, of course, be accomplished much more rapidly. Whether a reduction factor of five to ten is sufficient to make decontamination a useful military countermeasure is being investigated at USNRDL. Whether it is necessary at a refueling base, where in any case delay times appear to be quite short, is a matter that can be settled only with an expansion of our knowledge of the effects of contamination and the costs and effects of decontamination.

The situation can be further improved by the proper choice of refueling-base design. For example, the combination of fuel storage, fuel pumps, power-generation facilities, refueling hydrants, and so forth into independent units widely separated can lessen the danger of simultaneous residual contamination of all of them. In sum, the principal defense against residual contamination is analogous to that relied on for the defense of the aircraft. This is the brief and intermittent use of refueling bases.

High explosives may be regarded as a substitute for scarce fissile material in the neutralization of our overseas bases. However, as Table 47 indicates, the enemy may run into another resource limitation in the event that he tries this method. The number of bombers required for simultaneous attacks on a moderate number of refueling bases approaches the total stockpile of Soviet bomber aircraft. Nevertheless, we must examine the possible gain to the enemy from this kind of attack. Table 48 indicates the time required to recuperate from high-explosive attacks on runways for various levels of earth-moving

* *Radiological Recovery of Fixed Military Installations*, Dept. of the Army, Corps of Engineers, Dept. of the Navy, Bureau of Yards and Docks, NAVDOCKS TP-PL-13, prepared by U.S. Naval Radiological Defense Laboratory, August, 1953, p. 16*f*, Tables 3.1 and 3.2.

Table 47

SU FORCE REQUIREMENTS PER RUNWAY FOR RUNWAY CRATERING WITH HIGH EXPLOSIVES

Percentage of Runway Area Cratered[b]	Number of 500-lb GP Bombs on Target	Force Required over Target[a]			
		TU-4		IL-28	
		1000-ft CEP	4000-ft CEP	1000-ft CEP	4000-ft CEP
6	140	41	140	123	420
8	180	53	180	159	540
12	280	82	280	246	840
16	350	103	350	309	1050

[a] Aborts, attrition inbound, and unavailable aircraft should be added to determine total force requirement.

[b] Runway dimensions assumed here are 8000 ft × 200 ft.

Table 48

TIME REQUIRED TO REPAIR RUNWAYS DAMAGED BY HIGH EXPLOSIVES

Percentage of Runway Area Cratered[b]	Number of TU-4's Required per Runway (CEP = 1000 ft)	Repair Time (hr)[a]		
		Low Repair Capability	Moderate Repair Capability	High Repair Capability
6	41	236	90	45
8	53	296	113	56
12	82	475	181	90
16	103	588	225	112

SOURCE: J. J. O'Sullivan, *Time, Equipment, and Costs To Repair Cratered Runways*, The RAND Corporation, Research Memorandum RM-730, November 27, 1951 (Confidential).

[a] The cost and manpower required to effect runway repairs are as follows:

Low repair capability: $145,100 for equipment; 19 men.
Moderate repair capability: $363,700 for equipment; 32 men.
High repair capability: $778,530 for equipment; 57 men.

[b] Runway dimensions assumed here are 8000 ft × 200 ft.

and runway-repair equipment and personnel. The situation shown in these tables is for one-runway bases. Where there are two standard runways, repair time is substantially shortened, since the pattern of bomb hits generally leaves one runway with considerably fewer craters than the other. Where we have, as on some of our bases, two standard runways (200 ft wide), two taxiways usable as emergency runways (100 ft wide), and the high repair capability indicated in Table 48, it is clear that pavement cratering by high explosives is not at all effective as a neutralizing method. In the campaigns of Part III, the cost of the personnel and equipment for the high repair capability has been charged to the ground-refueled system.

For the results of high-explosive attacks directed specifically against the fuel-distribution system, see Table 49. The highest level of damage shown, inflicted by a very heavy attack with low CEP, could be repaired in 6 days or less. Simultaneous attacks of this size on less than 15 refueling bases would fully occupy the expected force of TU-4's.

Table 49

DAMAGE TO A PROTECTED FUEL DISTRIBUTION SYSTEM FROM 250-LB GP BOMBS

Number of TU-4's over Target	Percentage of Vital Area Destroyed	
	CEP = 1000 ft	CEP = 4000 ft
25	8	1
50	17	3

SOURCE: Taken from unpublished material by J. J. O'Sullivan, The RAND Corporation.

If, however, the enemy chooses to employ delayed-fused bombs in large numbers, however extensive the runway repair capability may be there will be a minimum delay dependent on the number and fusing of the bombs dropped. In an area where bombs are exploding at fairly regular intervals, we should expect ground personnel activity to be at a minimum, and we should not care to risk our aircraft and crews on bases where the probability of being hit is high. Table 50 presents bomb requirements for varying periods of base neutralization, assuming average bombing errors derived from past bombing experience. This estimate includes the use of antipersonnel ("butterfly") bombs intended to delay bomb removal and runway repair.

Delayed-action bombs are much more effective than are instantaneous-fused bombs in disrupting airfield activity for considerable periods of time, and the difference lies chiefly in the "lethal radius" differences between the two types of bombs. A contact-fused 500-lb general-purpose (GP) bomb produces a crater 6 *ft* in diameter, and this crater can be filled within a matter of minutes.

Table 50

DELAY-FUSED-BOMB REQUIREMENTS FOR RUNWAY NEUTRALIZATION

Delay Time (hr)	Duration of Neutralization				
	3 to 4 hr	5 to 6 hr	8 to 10 hr	12 to 18 hr	Overnight
	Number of 250-lb GP Bombs on Target				
½ to 1	36	36	30	30	....
¾ to 2	36	36	30	30	....
1½ to 2½	36	36	30	30	....
3 to 6		54	56	60	....
6 to 12			70	80	....
18 to 30				40	....
Type of Bomb	Number of Butterfly Bombs on Target				
Antidisturbance	648	648	648	648	1584
Delayed action	216	216	216	216	144

SOURCE: *Weapons Selection for Neutralization of Airfields*, OEG 438, (LO)623-51, April 25, 1951 (Confidential).

A time-fused 500-lb bomb prevents activity within a circle of about a *300-ft* radius—and possibly over a period of hours. And time fuses are available with delays up to 144 hr. The combination of a large area of interdiction per bomb and time delay periods of up to 6 days raises the possibility of effective enemy neutralization of a refueling-base system. In order for this threat to have an appreciable constraining effect, it is necessary to have bursts occurring (1) at frequent intervals and (2) in essential airfield areas. While the frequency with which bursts must occur in order to prevent base activity cannot be stated unequivocally, it appears that on the average one should occur every 10 to 30 min. With this rate of burst neither bomb disposal nor regular base activities in the neighborhood of the unexploded bombs are likely to be carried out. However, two measures indicated above in connection with reducing refueling-base vulnerability to surface-burst A-weapons seem to mitigate the effects of delayed-action bombs. They are the multiplication and separation of vital base elements and the creation of essentially independent, small areas within a large airfield. Even with heavy attacks there is a considerable variance in the extent to which different parts of a base are likely to be covered, and we should generally find that the briefing, communications, bomb check, fueling, and other servicing functions could be performed on part of the base at a reduced rate. On the other hand, runways *are* likely at some point in their length to intersect with regions of high bomb density. Time-fused bombs *alone* are unlikely to prevent runway use, since contact with hard-surfaced runways generally makes a dud of other than contact-fused bombs, and the cumulative expectation of aircraft's being hit by an off-runway delayed burst is satisfactorily low over the range of bomb densities considered. Where *both* contact and delayed-action bombs are used against runways, the delayed-action bombs prevent the filling of craters, and if all possible "emergency" runway strips of 100 by 10,000 ft are interrupted by unfilled craters, then the base is clearly unusable. But runways, we have seen, present extraordinarily difficult targets.

One other measure for preventing base neutralization is the construction of earth revetments around refueling pavements and other work areas—in order to offset the high "interdiction radius" of delayed-action bombs. The cost of so shielding the major work areas of the refueling base would come to $100,000.

Most of our present overseas bases do not have a configuration resembling that required to reduce out-of-action time, and enemy attempts at periods of delay, say from 12 to 24 hr long, would stand an excellent chance of success. On the other hand, the cost of the modifications required to reduce the effectiveness of this sort of attack is not high in relation to our base investment and, fortunately, most of the measures are suitable *both* for atomic and high-explosive attacks.

The use of small antipersonnel ("butterfly") bombs—antidisturbance and time fused—in combination with larger bombs further retards personnel movement. However, the substitution of large numbers of small antipersonnel bombs for larger bombs in order to reduce high aircraft requirements would not produce the same effect. Antipersonnel bombs can be effectively and rapidly cleared by bulldozers (shielded), unless there are larger bombs in the vicinity inhibiting activity. Their use in order to neutralize a base during the hours of alertness presents a nasty clearing problem, but one that can be successfully met in the opinion of physical-vulnerability authorities.

This threat, like the other alternatives available to the enemy, must be evaluated in terms of its demand on his resources and its result in terms of reduction of our capability. Like other attacks using high explosives, the bomber requirements would be high, and the total number of bases which could be put out of action simultaneously for a period of 24 hr by the Soviet 1956 force would be small relative to the total number of bases available to us.

So far, we have evaluated the duration of base-denial methods in terms of the delay occasioned in mounting our strikes. This threat has not seemed serious, because the level of resources required to cause even brief delays is so high that it is doubtful that the enemy could simultaneously mount a heavy strike against the ZI.

However, instead of attempting to delay our strike, the enemy might choose to try to disrupt it once it had been mounted. The most promising form of this kind of attack would have base denial for poststrike refueling as its object. Once again, because of the resource requirements, this plan must be evaluated as a substitute for attacks on aircraft at our home bases. What can the enemy gain from directing his blow against refueling bases? The U.S. tactic which would be most vulnerable to this sort of attack would be one in which we attacked simultaneously all regions of the Soviet Union and used an impact tactic. Under the assumptions of the campaigns in this report, some 50 per cent of the force enters the Soviet defenses on the first strike of an impact campaign, and some 25 per cent survives the defenses and returns after the first strike. This 25 per cent then constitutes one-third of the total remaining force. This is the total amount of aircraft which is at risk from this type of enemy tactic. Because of operational problems similar to those mentioned on page 320, it is extremely doubtful whether the enemy could succeed in destroying a very large proportion of even this small part of our total force. However, even at best, the attempt at disruption of our strike by base denial offers no protection against the first strike, which in the tactic examined is the most massive one. If, on the other hand, we use another tactic, such as attacking separate regions separately, or holding reserves, then even this small potential payoff is still further reduced.

Refueling-base Vulnerability for a Large Enemy Stockpile of Thermonuclear Weapons. It is possible that the enemy stockpile may grow large relative to the numbers of refueling bases at some time in the period considered. As we have seen, the stockpile would have to be very large relative to the estimates shown on page 231*f* of this Part before base-denial attacks would become attractive to the enemy. The ground-refueling concept of operations, however, is not sensitive even to variations in the enemy stockpile which would make attractive the attempt at base denial. Nevertheless, some measures are called for to meet such a situation. The principal one is the multiplication of alternative bases for take-off and landing in case of an extensive program of base denial by the enemy. This does not mean preparing fields specifically for SAC; it does mean preparing SAC for the use of a very wide class of fields in case of emergency. This involves, beside planning, some minor modifications to the programmed aircraft which will enable such emergency operation with a significant proportion of our capability intact. There are a large number of runways sufficiently long for the take-off of B-47's of about 154,000 lb gross weight that use water-alcohol augmentation and ATO. Later production models of the B-47 will increase this flexibility even further. Another possibility is that of using converted bombers as tankers to top off the bombers over base. These possibilities offer us the opportunity of increasing the number of our refueling bases relative to the Soviet stockpile to the point at which these, once again, appear to the enemy as unattractive targets.

FUTURE EFFECTIVENESS OF RECOMMENDED DEFENSES

By the end of the period considered in this study, the enemy's stockpile of nuclear weapons may be expected to have grown greatly in number and destructiveness. This is indicated in the stockpile projections on page 231*f*. Similarly, the performance of Russian carriers will be greatly improved. Both the increase in carrier performance as well as the increase in bomb destructiveness will make defense of our bombers mainly by active means an even less attractive possibility than earlier. The chance of at least one highly destructive bomb's reaching the bomb-release line will be much greater than in the bomb-limited campaigns presented.

How do the defenses recommended fare? With the increasing stockpile of bombs, the possibility of waging a base-denial campaign gains the prospect of inflicting significant damage. For the entire period of this study, however, the analyses of such campaigns indicated that, *provided* we took the necessary steps to harden our facilities, both in the ZI and overseas, and to develop the flexibility for exploiting a wider class of bases in time of an emergency, such damage, while significant, could be held within bounds. In fact, the analyses indicated that base-denial tactics would, even under these circumstances, diminish our destructive power less than attacks on the fleeting targets offered by our evacuating and staging bombers.

How about the defenses recommended for the bombers? The increase in performance of enemy carriers might decrease the warning available, and this would diminish the effectiveness of the evacuation program. However, for the period of the fifties, at any rate, it appears that the warning that could be made available would be adequate for an intensive evacuation program. In the sixties this situation might very well deteriorate drastically. In the limit, a practically warningless carrier like the IBM might be achieved by the enemy.

For this case, evacuation from the home bases would no longer suffice as the keystone element in the defense. This defense against manned aircraft would need a supplement dealing with a warningless carrier. The analysis of such a defense is beyond the limits of the present study.

SUMMARY: THE EFFECTS OF DISTANCE FROM BASE TO ENEMY BORDER

It is clear that consideration of vulnerability alone dictates operations from bases as far from the sources of enemy striking power as possible. However, vulnerability does not lessen continuously with increasing distance from enemy borders. Edging away does not help. It is only when bases of operation have been moved well within the radar network of the ZI that a significant and reliable reduction in vulnerability occurs. But if any component of a bombing system is to be left forward, it has been shown that a system which leaves the refueling function forward is least vulnerable.

Various defense measures have been tested for each of the base systems considered. Of those surviving the test of savings versus cost, some are common to all systems considered. These are the measures for hardening critical facilities, both in the ZI and overseas, and for protecting aircraft on the ground in the ZI. Since all systems have a ZI component, at least before D-day, all have the requirement for this defense. The principal measure for the defense of aircraft in the ZI was found to be evacuation.

However, the most critical problem (except for the intercontinental air-refueled system) is the protection of aircraft overseas. The preferred method of achieving this is the adoption of brief and irregular periods of occupancy on overseas bases. This is the method of the ground-refueled system.

PART III: THE JOINT EFFECTS

A. Least-cost Campaigns against Enemy Industry in the Face of Enemy Bombing Attack

So far we have treated separately the effects of various operational distances (base to target, base to favorable points of entering enemy defense, base to logistic support in the Zone of the Interior (ZI), and base to enemy border). In reality these operational distance variables interact. To display their joint effect, we have examined campaigns with an alternative base system from which the United States launches strikes against a defended Russian industry-target system, while its base system is concurrently under Russian bombing attack. In campaigns to be presented, we have compared the three basically contrasting systems, which we have taken as standards. The first set of campaigns compares the B-47 air-refueled, ground-refueled, and overseas-based systems. The second compares the two intercontinental methods for basing the B-52. The third does the same for the B-36.

CAMPAIGN CONDITIONS AND STRATEGIES

The conditions and strategies of U.S. attack and base defense and the enemy's strategies of attacks on our bases and defense of his industry can be outlined as follows:

Conditions of Enemy Offense

Enemy Offense Capability. We have tested several widely varied assumptions as to the level of enemy offensive capability. The lowest level corresponds to a commitment against the Strategic Air Command (SAC) of 30 A-bombs of sufficient yield for high coverage against unsheltered aircraft; a commitment of 50 TU-4's and 500 IL-28's (against overseas operating bases) for the duration of our strategic campaign; and an inability to use countermeasures against our area and local defense, with resulting high effectiveness for our defense weapons. The highest level assumes a commitment of 240 bombs against SAC, a commitment of 500 TU-4's and 1000 IL-28's, and credits the enemy with the ability to use countermeasures lowering our defense effectiveness.

Enemy Offense Strategy for Assigning Bombs. We have assumed that the enemy will stage strikes as rapidly and as large in size as is compatible with the efficient use of his bomb stockpile. At each level of capability he is supposed to make the best use of his bombs against each of our alternative base systems. He will assign the smallest number of bombs per cell consistent with the expenditure of his entire stockpile prior to the completion of our strikes.

Enemy Strike Timing. The enemy is assumed to get in the first strike. After the first strike it is assumed as a first approximation that the rate of exchange between our strikes and his is on a one-for-one basis;* and we have also tested other rates of exchange.

Conditions of U.S. Defense

U.S. Base Defense in the ZI. All three of the base systems compared have home bases in the United States. This is true of the overseas operating base system, which will move from its U.S. bases overseas after the outbreak of war. For all three systems it is assumed that the home bases are well within the coverage areas of the early warning network, and that the evacuation measures outlined in the section entitled "Base to Border: The Effect of Base Vulnerability," page 225, are practiced. Other microscopic passive-defense measures for the U.S. bases described in that section are assumed in all three cases. Planes are distributed one wing to a ZI base.

Active and Passive Defenses for Overseas Refueling Bases. These are the measures described in the section entitled "Base to Border: The Effect of Base Vulnerability," under "Defense Measures," page 269, and "Overseas Refueling-base Systems," page 312. They involve expenditure on active defense and on a considerable microscopic and macroscopic passive defense. The defense cost per bomber is $5.5 million.

Overseas Operating Base Defense. The overseas operating base defense cost per bomber amounts to $8.5 million. These measures have been described in detail under "Defense Measures," page 269.

Enemy Defense Strategy. The enemy is assumed to concentrate his day fighters largely in the northwest and his night fighters in the southwest. This is the area Defense Distribution III for a summer campaign described in the

*With the exception of the campaign assuming high enemy capabilities (see Table 53, p. 344, and pp. 342*ff*, below).

section entitled "Bases, Targets, and Penetration Paths," page 135. The MiG commitment is limited to a 150-mi corridor half-width. The local defenses are assumed to be distributed evenly among the target cities according to the number of specified aiming points (RGZ's) they contain. The higher levels of defense effectiveness are assumed.

United States Offense Strategy. Each base system has been assigned the route which minimizes its cost. For the overseas operating and intercontinental ground-refueled system, these routes consist of minimum-tanker paths; for the air-refueled system, they comprise minimum-penetration paths. Each system is permitted a choice between a reserve and an impact policy for the employment of its bombers. The operating costs of the air-refueled system are very high: $43.4 million per bomber. The operating costs of the overseas operating base system are smaller than those of the air-refueled system, but including defense costs they are still quite high: $27.3 million per bomber. The costs per operating bomber in the ground-refueled system are $17.9 million; this amount also includes defense costs. As a consequence of their high operating costs, the reserve policy is preferred for the air-refueled and overseas operating systems. For the ground-refueled system, the difference in tactics is relatively insignificant. Each base system selects the optimal strike size and number of strikes in the light of both anticipated air and ground losses.

RESULTS OF LEAST-COST CAMPAIGN

Tables 51 through 55 and Fig. 103 (page 346) present the campaign results for the three methods of basing the B-47 and for each of the heavy bombers. The reader is cautioned here, as earlier, that these comparisons concern decisions among the base alternatives and not the decision among bomber types.

The results in the case of each of the bombers show a distinct advantage for the ground-refueled method of operation. The exclusively air-refueled system is decidedly inferior to the intercontinental ground-refueled system. The overseas operating base system, assuming the low level of enemy offense capability, is intermediate in effectiveness between the two intercontinental systems. This might be the case, for example, if we succeeded in destroying the Soviet Air Force on the ground early in the campaign. However, for moderate or high levels of enemy offense, its cost reaches the level of that of the air-refueled system.

Table 51

B-47 COST TO DESTROY AN ENEMY INDUSTRY-TARGET SYSTEM IN THE FACE OF ENEMY ATTACK—INTERCONTINENTAL AND OVERSEAS-BASED CAMPAIGNS[a]

Low Enemy Offensive Capabilities

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System	Advanced Overseas Operating-base System
	Minimum-penetration Routes	Minimum-tanker Routes	Minimum-tanker Routes
Tactic	Reserve	Impact	Reserve
Number of strikes	6	3	4
Number of B-47's in operating force	717	1230	754
Number of B-47's in reserve for air losses	860	0	603
Number of B-47's in reserve for ground losses	22	40	580
Total number of B-47's	1599	1270	1937
Number of B-36-type tankers	1090	44	47
Number of KC-97's	873	242	254
Three-year cost of bomber force	15.7	12.4	19.0
Three-year cost of radius extension[b]	24.4	10.0	13.5
THREE-YEAR TOTAL SYSTEM COST, NEW	40.1	22.4	32.5
Inheritance	4.1	4.1	4.1
THREE-YEAR TOTAL SYSTEM COST, INCREMENTAL	36.0	18.3	28.4

[a] Defense Distribution III.

[b] Includes costs of tankers, en route bases, overseas operating bases, and refueling bases and defense cost for overseas bases.

Sensitivity of Overseas Operating Base System to Expected Level of Enemy Offense

The comparative effectiveness of the overseas system depends not only on the level of enemy offense assumed, but also on a number of factors having to do with the rate of execution of enemy strikes and the measurement of the damage done by these strikes. The campaign costs shown do not include numerous indirect effects of enemy bombing attack, which are most serious for the overseas operating base system. The partial or total destruction of base facilities

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Table 52

B-47 COST TO DESTROY AN ENEMY INDUSTRY-TARGET SYSTEM IN THE FACE OF ENEMY ATTACK—INTERCONTINENTAL AND OVERSEAS-BASED CAMPAIGNS[a]

Moderate Enemy Offensive Capabilities

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System	Advanced Overseas Operating-base System
	Minimum-penetration Routes	Minimum-tanker Routes	Minimum-tanker Routes
Tactic	Reserve	Impact	Reserve
Number of strikes	6	3	2
Number of B-47's in operating force	717	1230	1020
Number of B-47's in reserve for air losses	860	0	273
Number of B-47's in reserve for ground losses	256	395	1500
Total number of B-47's	1833	1625	2793
Number of B-36-type tankers	1250	57	88
Number of KC-97's	1000	309	480
Three-year cost of bomber force	18.0	15.9	27.4
Three-year cost of radius extension[b]	27.9	10.5	19.7
THREE-YEAR TOTAL SYSTEM COST, NEW	45.9	26.4	47.1
Inheritance	4.1	4.1	4.6
THREE-YEAR TOTAL SYSTEM COST, INCREMENTAL	41.8	22.3	42.5

[a] Defense Distribution III.

[b] Includes costs of tankers, en route bases, overseas operating bases, and refueling bases and defense cost for overseas bases.

and the effect of repeated high-explosive as well as A-bomb attack on this system would add a significant amount to the costs incurred through the damage of the bombers themselves.

Similarly, the rate of exchange of strikes between the United States and the enemy affects the comparison. If the Russians can get in more than a single strike for each of our first strikes, and can do this against all base systems, this raises the importance of ground attrition, and therefore the overseas operating base system increases in cost by comparison with the others. Moreover, there is

Table 53

B-47 COST TO DESTROY AN ENEMY INDUSTRY-TARGET SYSTEM IN THE FACE OF ENEMY ATTACK—INTERCONTINENTAL AND OVERSEAS-BASED CAMPAIGNS[a]

High Enemy Offensive Capabilities

(Three-year cost in billions of dollars)

	Air-refueled System	Ground-refueled System	Advanced Overseas Operating-base System[b]
	Minimum-penetration Routes	Minimum-tanker Routes	Minimum-tanker Routes
Tactic	Reserve	Impact	Reserve
Number of strikes	6	2	2
Number of B-47's in operating force	717	1350	1020
Number of B-47's in reserve for air losses	860	0	273
Number of B-47's in reserve for ground losses	977	913	3020
Total number of B-47's	2554	2263	4313
Number of B-36-type tankers	1740	79	141
Number of KC-97's	1390	430	767
Three-year cost of bomber force	25.0	22.2	42.3
Three-year cost of radius extension[c]	38.7	12.1	22.1
THREE-YEAR TOTAL SYSTEM COST, NEW	63.7	34.3	64.4
Inheritance	4.1	4.1	4.6
THREE-YEAR TOTAL SYSTEM COST, INCREMENTAL	59.6	30.2	59.8

[a] Defense Distribution III.

[b] It is assumed here that the enemy delivers two strikes for every one by the overseas operating base system.

[c] Includes costs of tankers, en route bases, overseas operating bases, and refueling bases and defense cost for overseas bases.

some correlation between the expected damage and the vulnerability to a single enemy strike and the likelihood that the enemy will be able to increase his strike rate in comparison with our own. For it is apparent that extensive damage from enemy bombing attack is likely to delay seriously the launching of one of our strikes. The rate of exchange is therefore likely to worsen, specifically, for the overseas operating base system. The effects of a moderate worsening

Table 54

B-52 COST TO DESTROY AN ENEMY INDUSTRY-TARGET SYSTEM IN THE FACE OF ENEMY ATTACK[a]—INTERCONTINENTAL AIR- AND GROUND-REFUELED SYSTEMS

Air-refueled System Costs and Requirements Are Presented as a Percentage of Ground-refueled System Costs and Requirements[b]

	Enemy Offense Capability	
	Low (%)	Moderate (%)
Number of strikes	100	100
Number of B-52's in operating force	89	89
Number of B-52's in reserve for ground losses	49	72
Total number of B-52's	142	136
Cost of bomber force	146	136
Cost of radius extension[c]	284	309
COST OF COMPLETE SYSTEM, NEW	175	168
Inheritance	138	138
COST OF COMPLETE SYSTEM, INCREMENTAL	178	170

[a] Including the effects of flight-profile differences with SU Defense Distribution III.

[b] Air-refueled system uses reserve tactics and follows minimum penetration routes; ground-refueled system uses impact tactics and follows minimum-tanker routes.

[c] Includes cost of tankers and overseas refueling bases and defense cost for overseas refueling bases.

in this exchange rate for the overseas operating base system are included in the campaign which assumes a high level of enemy capability.

The overseas operating base system can reduce its losses on the ground by following a policy of deployment overseas which limits the time that bombers are on the ground overseas before a strike. For example, as shown by the analysis of the section entitled "Base to Border: The Effect of Base Vulnerability," page 225, ground attrition before the first strike can be reduced by this method. If, each time the ground and air losses were replaced out of the U.S. reserve, reserve bombers were merely staged through on their way to the target, losses could be further reduced. It is clear that insofar as the overseas operating base system adopts such devices, it approaches the ground-refueled system in principle.

In effect, our campaign calculations have assumed such reduced vulnerability in the deployment for half the overseas operating base strikes. If we were to assume that each deployment of the reserves was as vulnerable to the succeeding

Table 55

B-36 COST TO DESTROY AN ENEMY INDUSTRY-TARGET SYSTEM IN THE FACE OF ENEMY ATTACK[a]

Air-refueled System Costs and Requirements Are Presented as a Percentage of Ground-refueled System Costs and Requirements[b]

	Enemy Offense Capability	
	Low (%)	Moderate (%)
Number of strikes	100	100
Number of B-36's in operating force	106	106
Number of B-36's in reserve for ground losses	45	62
Total number of B-36's	151	141
Cost of bomber force	151	141
Cost of radius extension[c]	216	229
COST OF COMPLETE SYSTEM, NEW	187	162
Inheritance	93	93
COST OF COMPLETE SYSTEM, INCREMENTAL	176	170

[a] Including the effects of flight-profile differences with SU Defense Distribution III.

[b] Air-refueled system uses reserve tactics and follows minimum-penetration routes; ground-refueled system uses impact tactics and follows minimum-tanker routes.

[c] Includes cost of tankers and overseas refueling bases and defense cost for overseas refueling bases.

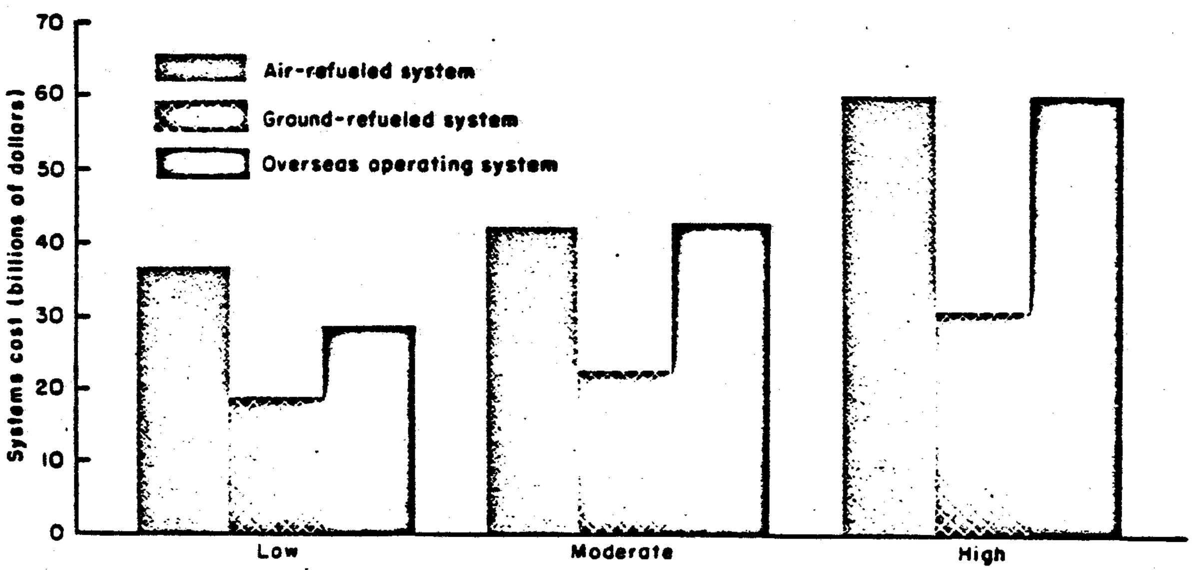

Fig. 103—B-47 cost to destroy an enemy industry-target system in the face of alternate levels of enemy attack: intercontinental and overseas-based systems (incremental 3-year cost)

enemy strikes as the first, the cost of doing a fixed job with the overseas operating base system would increase very rapidly with increases in the enemy stockpile. In the face of very large stockpiles of enemy bombs and bombers, the overseas operating base system would tend to explode. Its costs would rise without limit.

At one end of the scale, then, the campaign costs of the overseas operating base system increase out of bounds. At the other end, the costs decrease as the method of operation approaches that of the ground-refueled system.

B. Feasibility of Comparative Systems

In order to examine the fundamental character of the broadly different base systems considered, we have largely set aside questions of the feasibility of achieving certain postures in this time period. Rather, we have been concerned with the *requirements* and *costs* of the alternative systems. There are substantial differences in the feasibility with which different systems requirements can be met, due to over-all and specific budget, aircraft production, and operations constraints.

POLITICAL FEASIBILITY

Additional base rights for overseas operating base systems which involve the construction of many additional large bases in areas suitable for operating base locations are difficult to obtain. More land surrounding our existing bases for aircraft dispersal and the right to station more personnel overseas for the operation of the local- and area-defense weapons desirable would also be difficult to obtain, in view of the attitude of most of our Allies toward each of these irritants. A system of refueling bases would involve additional bases, but more isolated locations would be suitable for this minimal type of base, so that rights for such bases would be more readily granted. The ground-refueled system would also involve fewer personnel (about 50 per cent as many) stationed overseas than the operating base system. Of course, in the matter of overseas political limitations, the intercontinental air-refueled system comes out on top.

AIRCRAFT REQUIREMENTS

An intercontinental air-refueled system would require the availability of many more tankers than are presently scheduled. In some campaigns as many as 1400 B-36-type tankers would be necessary. Clearly these requirements, budget limitations aside, could hardly be met in the time period considered without a major conversion and acceleration of our aircraft industry. Both the overseas operating base system, which would lose a considerable proportion of bombers on the ground, and the air-refueled system, which would lose more bombers to Soviet air defenses, would require more bombers than the ground-refueled system. In some campaigns the overseas operating base system would lose as many as 3000 B-47's on the ground. While the added bomber requirements for these systems would not present an impossible production task within the period considered, it would mean a major acceleration in the aircraft production program.

BASE CONSTRUCTION

Although the intercontinental air-refueled system has no overseas base components charged to it, it has *larger* additional base costs than do the other systems. The ZI base requirements for a larger tanker and bomber force offsets the elimination of overseas bases. Overseas operating base systems also involve large base-construction sums in the ZI for bombers held in reserve to replace high ground losses (unless a means of storing bombers and having them quickly available for use can be developed). A moderate amount of construction is required overseas for microscopic dispersal, for the basing of interceptors and antiaircraft artillery, and for radar stations. Minimal-refueling base systems require the *least* additional base construction.

DEFENSE WEAPONS

The provision of a high level of active defense overseas, as we have seen, will require extremely large forces of fighters, airborne-early-warning (AEW) aircraft, and ground radars. The availability of this equipment will be limited by present production schedules; and the newer, more effective weapons, such as the Nike, will probably not be available in quantity for overseas use until the late fifties.

OPERATIONAL FEASIBILITY

As has been stressed, the intercontinental air-refueled system can be feasible only if problems of rendezvous and multiple refueling can be solved. The ground-refueled system involves multiple landings on each strike, which fact introduces problems of increased abort rate and the effect of aircraft battle damage on poststrike staging.

C. Strike Rate and Campaign Time

The intercontinental air-refueled system involves not only higher costs than the other systems, but also more strikes, low sortie rates, and—therefore—evidently longer time periods for the destruction of the targets.

In comparison with the ground-refueled system, the sortie-rate advantages of the overseas operating base system are qualified by the following considerations. First, the overseas operating base system has, in the various campaigns, generally adopted a policy of reserving bombers to limit operating costs. These reserve bombers are not usable without the expanding of the overseas base system. For the ground-refueled system, a reserve policy does not exclude the possibility of using its intermittently needed radius-extension apparatus for a second strike with the reserve bombers before the bombers used in the first strike are ready for re-use. This means that, for the ground-refueled system, the interval between strikes, when a policy of reserve is used, may be smaller than the interval between sorties for individual bombers. Second, the strike rate of the overseas operating base system can be expected to be seriously influenced, not only by normal maintenance requirements and air damage, but also by the continuing A-bomb and high-explosive attacks which the Russians can mount against these bases. This is one of the indirect effects of enemy bombing for which we have not made a quantitative estimate. It clearly affects the advanced overseas operating base system more than the others.

Finally, we have made tests in which the ground-refueled system has been constrained to complete the job of destruction in half the number of strikes used by the overseas operating base system (neglecting the indirect effects of bombing attack on the latter system). Even with this constraint, the ground-refueled system can complete a fixed job of destruction at lower cost. It can do the job more cheaply in a period of no longer duration than the other systems. The ground-refueled system depends in large part on the ability to spend relatively short periods on base, and the achievement of short aircraft exposure times has implications for strike timing and coordination, crew exchange, and bomb-loading and testing procedures.

D. Intermediate Systems

Table 56 shows the result of campaigns which combine the logistics, flight radius to target, and vulnerability effects of intermediate systems. It appears that an intermediate base system confined to Labrador and Newfoundland is not superior to the ZI-based air-refueled system, and it is clearly inferior to the ZI-based ground-refueled system. The high costs of logistics, of increased active defenses, and of ground loss more than offset the reduction in the number and size of tankers. One of the major disadvantages of the intermediate basing as compared with ZI basing is the difficulty of using evacuation as a defense measure.

The Labrador-Newfoundland base system is significantly inferior to more advanced operating bases around the periphery of the Soviet Union. A peripheral intermediate base system, discussed in the section entitled "Base to ZI: The Cost of Operations Outside the ZI," page 187, which has bases to the south of Russia is better than the North American intermediate system, but is still inferior to the advanced overseas operating base system.

Staging operations beginning at intermediate bases would reduce tanker costs substantially for intermediate operating base systems, and this system of basing might be put forth on grounds of higher sortie rates and fewer en route landings as compared with the ZI operating overseas refueling base combination. As we have seen, the penalty in sortie-rate reduction and in aborts with landings for fuel is not likely to have a major effect and hardly warrants the large increased costs of defense, logistics, and especially expected damage.

One other intermediate case which has been suggested at various times involves operating the bombers from the continental United States, but basing some of the tankers overseas. In this case the combat elements can avoid touching down outside the United States, and, at the same time, tanker requirements for such intercontinental operation are reduced, since the tankers need not fly all the way from the interior. However, the reduction in tanker costs is moderate. Considering the costs of overseas basing, it amounts, approximately, to only 25 per cent of the very high costs for a system using ZI-based tankers along minimum-penetration paths. Most important, tankers based overseas are extremely vulnerable; insofar as they are an essential element in the system, our capability to operate this system is reduced by the destruction of tankers just as much as by the destruction of the bombers they refuel. The results of campaigns conducted with such a system are shown in Fig. 104 and Table 56, which illustrate the fact that this intermediate system also combines the defects of both major rejected alternatives.

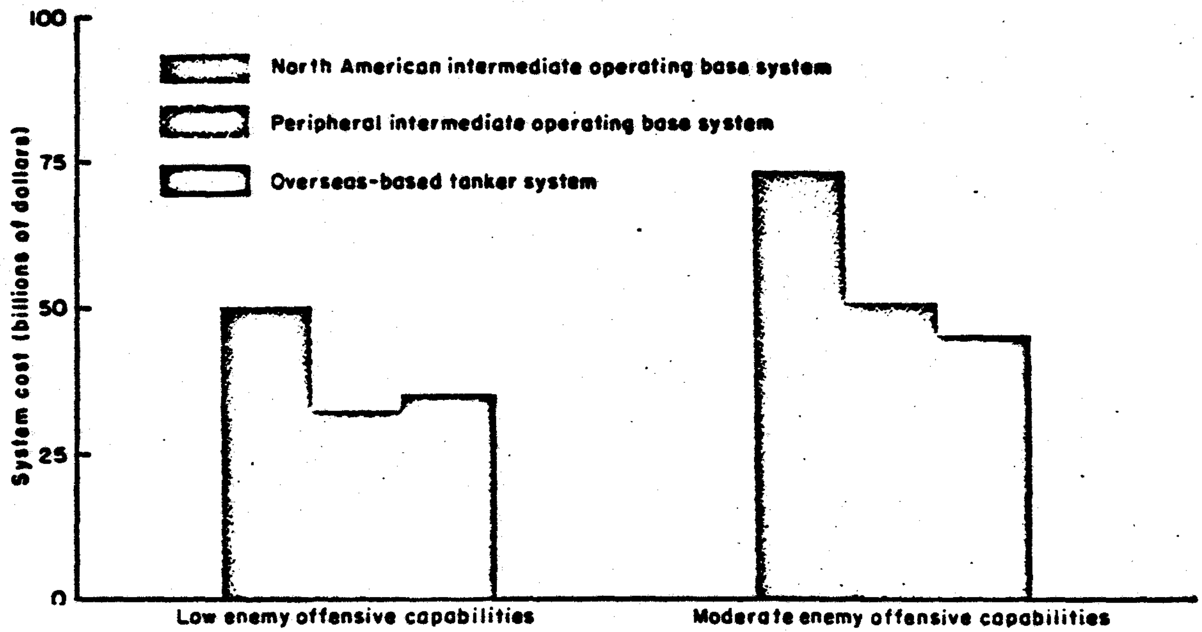

Fig. 104—B-47 cost to destroy an enemy industry-target system in the face of alternate levels of enemy attack: intermediate systems (incremental 3-year cost)

Other intermediate systems which approach the ground-refueled system—e.g., systems that mingle ground-refueling with some missions from overseas operating bases—are lower in cost and vulnerability than the pure overseas operating base system, but higher than the ground-refueled system. Similarly, mixtures of ground-refueling with the extreme case of intercontinental air-refueling approach the performance of the ground-refueled system, and the higher the proportion of the ground-refueled system in the mixture the closer the approach. So a system which air-refuels prestrike and ground-refuels poststrike is superior to the exclusively air-refueled case. And perhaps the closest approach to the ground-refueled system we have analyzed would be a system involving ZI basing of both tankers and bombers, with no advanced ground-refueling of the bombers, but staging of all tankers. The ZI home basing of both tankers and bombers with extensive reliance on ground-refueling, however, is an essential of all the low-cost systems.

Table 56

B-47 INTERMEDIATE SYSTEMS—COST TO DESTROY AN INDUSTRY-TARGET SYSTEM IN THE FACE OF ENEMY ATTACK[a]

(Three-year cost in billions of dollars)

	Operating Bases					
	North American		Peripheral		Overseas-based Tankers	
	Low Enemy Offensive Capability	Moderate Enemy Offensive Capability	Low Enemy Offensive Capability	Moderate Enemy Offensive Capability	Low Enemy Offensive Capability	Moderate Enemy Offensive Capability
	Minimum-penetration Routes	Minimum-penetration Routes	Minimum-penetration Routes	Minimum-penetration Routes	Minimum-tanker Routes	Minimum-tanker Routes
Tactic	Reserve	Reserve	Reserve	Reserve	Reserve	Reserve
Number of strikes	6	6	6	6	5	2
Number of B-47's in operating force	645	645	645	645	778	1030
Number of B-47's in reserve for air losses	860	860	860	860	750	270
Number of B-47's in reserve for ground losses	105	720	140	980	0	0
Total number of B-47's	1610	2225	1645	2485	1528	1300
Number of B-36-type tankers	1125	2050	0	0	0	0
Number of KC-97's	900	1640	1330	2760	2170	3690
Three-year cost of bomber force	15.8	21.8	16.1	24.3	15.0	12.7
Three-year cost of radius extension[b]	36.8	55.9	20.0	30.0	23.9	36.9
THREE-YEAR TOTAL SYSTEMS COST, NEW	54.6	77.7	36.1	54.3	38.9	49.6
Inheritance	4.1	4.1	4.1	4.1	4.3	4.7
THREE-YEAR TOTAL SYSTEMS COST, INCREMENTAL	50.5	73.6	32.0	50.2	34.6	44.9

[a] Defense Distribution III.

[b] Includes cost of overseas operating bases and tankers and cost for defense of overseas bases.

E. Comparative Effectiveness for a Fixed Budget

In all the campaign comparisons so far, we have fixed the mission—the destruction of a 100-point or a 250-point target system—and have compared the cost of providing aircraft, bases, defenses, etc., required in order to accomplish the mission within a given time period. While measuring the cost of accomplishing a fixed objective provides a perfectly sound basis for comparing systems, the realities of the budget allocation method employed by the United States suggests that it would be worth while to examine the target-destruction job done with a fixed budget. Table 57 compares the number of targets killed by three base-aircraft systems procured, operated, and supported for 3 years with a total budget, excluding 1953 inheritances, of $40 billion.

The differences shown in targets killed are considerably increased over cost differences resulting from the accomplishments of a fixed mission. The ground-

Table 57

TARGETS KILLED IN THE FACE OF ENEMY ATTACK FOR A $40 BILLION MEDIUM BOMBER BUDGET—B-47 INTERCONTINENTAL AND OVERSEAS-BASED CAMPAIGNS[a]

Moderate Enemy Capabilities

	Air-refueled System	Ground-refueled System	Advanced Overseas Operating-base System
Tactic	Reserve	Impact	Reserve
Number of B-47's in operating force	655	3137	1000
Number of B-47's in reserve for air losses	892	0	817
Number of B-47's in reserve for ground losses	650	650	1950
Total number of B-47's	2197	3787	3767
Maximum number of targets killed	88	501	165
Number of strikes	7	7	5
Number of targets killed in six strikes or fewer	84	495	165

[a] Defense Distribution III.

refueled system kills *3 times* as many targets as the overseas operating base system and *5 times* as many targets as the intercontinental air-refueled system. These wide differences result mostly from the effect of saturating enemy defenses.

The $40 billion allocated to the ground-refueled system is optimally spent largely on B-47's, and this big force is able to completely saturate Soviet defenses repeatedly. The overseas operating base system must spend much of its money on an overseas logistics and active-defense system, and it must hold back large reserves of bombers as replacements for ground loss. Saturation resulting from its attacks is must less complete, and many more B-47's are lost to Soviet defenses for each target killed on each strike. The intercontinental air-refueled system must spend a large part of its budget on tankers; the strike force it sends is still less able to saturate defenses, and a large number of strikes must be mounted.

F. Uncertainties and Comparative Systems Performance

ENEMY MILITARY CAPABILITIES

In the campaigns presented so far, we have assumed that it would be possible to anticipate, step by step, our losses to enemy air defenses and to enemy attacks on our bases. In each situation we adopted strike tactics and a reserve policy optimal for these known conditions. Such accuracy is unlikely, and we shall probably receive some surprises.

Soviet defenses and offense may be much higher, or lower, than anticipated, and adequate knowledge of Soviet capabilities may have to await the completion of our first attacks. In the campaign results presented in Table 58, we compare the systems purchased with a fixed budget. Each is designed to meet a given level of Soviet offense and defense. On the first strike, however, each system finds itself confronted with a higher or lower enemy defense capability than expected. On subsequent strikes, tactics are altered to conform with the now presumably known Soviet capability.

If Soviet capabilities prove to be higher than anticipated in the design and operation of each base-aircraft combination, all systems kill fewer targets. But the air-refueled system, carefully optimized in order to reduce the number of expensive tankers, suffers most from the surprise of a high defense. Since it is limited in the size of the maximum strike it can mount, its failure to saturate Soviet defenses produces a disproportionate reduction in the number of targets killed.* The overseas-based system is less sensitive to unexpectedly high Soviet capabilities, and the ground-system is still less so. Overseas refueling bases permit the mounting of all the strategic force in comparative safety, and a system using them can more easily adjust to unexpectedly high Soviet capabilities.

If these capabilities are lower than expected, then all systems improve. In this case, it might be that all systems succeeded in destroying all targets called for, but a large difference among systems remains. The air-refueled and overseas operating base systems improve relative to the ground-refueled system. However, tanker limitations on the one and forward-base limitations on the

*The situation of the air-refueled system is made critical by the constraint of attacking all target regions, and a policy of successive regional attacks would somewhat improve its position.

Table 58

THE CASE OF IMPERFECT INFORMATION: TARGETS KILLED FOR $40 BILLION MEDIUM-BOMBER BUDGET—B-47 INTERCONTINENTAL AND OVERSEAS-BASED SYSTEMS

	Air-refueled System		Ground-refueled System		Advanced Overseas Operating-base System	
	Higher than Anticipated Enemy Capabilities	Lower than Anticipated Enemy Capabilities	Higher than Anticipated Enemy Capabilities	Lower than Anticipated Enemy Capabilities	Higher than Anticipated Enemy Capabilities	Lower than Anticipated Enemy Capabilities
Tactic	Reserve	Reserve	Impact	Impact	Reserve	Reserve
Maximum number of targets killed	13	395	265	1291	67	606
Number of strikes	1	10	5	10	3	9
Number of targets killed in six strikes or fewer	13	284	265	1160	67	549

other prevent both of these systems from taking full advantage of low Soviet capabilities.

POLITICAL CATASTROPHE

The loss, if widespread, of some or all of our overseas base rights through a change in political alignment or through atomic blackmail would rightly be regarded as a catastrophic eventuality. The implications for the conduct of a ground war are apparent. And it would not make easier the task of conducting a strategic air offensive if we depended on overseas refueling bases for range extension to targets. It is possible, however, that we shall lose some advanced bases before the completion of the strategic campaign; and while the possibility of large-scale defection of the Allies appears quite remote, its implications for strategic operations are worth considering. The possibility of a successful base-denial campaign by the enemy has been evaluated in the section entitled "Base to Border: The Effect of Base Vulnerability" (pages 225*ff*). It was indicated there that, for very large enemy stockpiles, such a campaign had some chance of success if the United States did not prepare for the eventuality (page 335*f*). Therefore, the base-loss situations discussed below may also be interpreted as being the result of insufficient preparation for an enemy base-denial campaign.

We have tested three degrees of refueling-base loss through political reversal or from other causes: first, the loss of all bases closer than 1000 mi from the Soviet Union; second, the loss of all bases to the south of Russia within about 2000 mi; and third, the loss of all allies, even the Canadians, necessitating complete withdrawal to the ZI. The first of these is in fact the case we have already considered, since in making our estimates of tanker requirements we have excluded bases within 1000 n mi of the Soviet or satellite borders.

In each case the ground-refueled systems procured for a $40 billion fixed budget is made to operate through the successively more remote base system. In these campaigns it is provided, as insurance against just this type of catastrophe, that B-47's are capable of being converted to tanker operations, and vice versa. Figure 105 compares the effectiveness of convertible tanker-bombers with specific tankers, in terms of campaign costs to kill 100 targets. The use of a ground-refueling concept is assumed, but the distance of the refueling bases to enemy targets is varied. For short radii the convertible tanker-bomber is actually slightly cheaper, but it increases in cost very rapidly in the neighborhood of 3200 n mi. In the extreme case of all-overseas-base loss, bombers are sent on

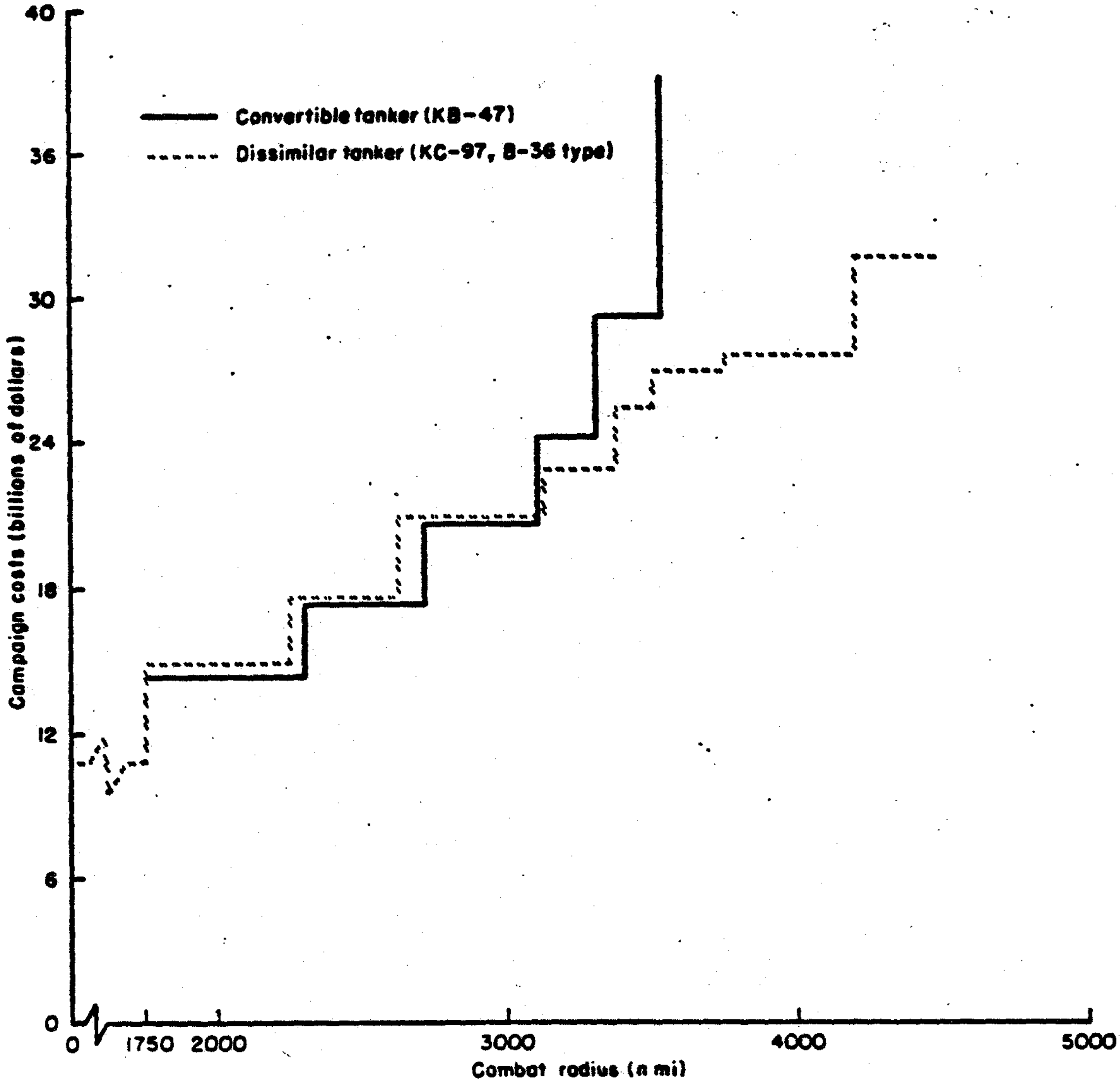

Fig. 105—Campaigns with dissimilar vs convertible tankers

one-way missions. They are refueled on way to target by tankers procured with the intention of aiding operations from forward bases and by converted B-47's. They follow minimum-tanker routes inbound, and withdraw outbound to the nearest neutral country. The results of the campaigns are presented in Table 59. Even on one-way missions from the ZI, the force procured for ground-refueled operations would kill more targets than the system designed for air-all-the-way operations that would, of course, be unaffected by overseas base loss. This does not, of course, mean in general that one-way missions are preferred; for one thing, the accomplishment of strategic objectives might require a good many round-trip flights for reconnaissance. While the probability of such a catastrophic loss of bases appears to be quite low, the insurance of refueling bases in depth and convertible tanker-bomber B-47 capability would cost little. As insurance devices, they appear to be eminently worth their cost.

Table 59

OVERSEAS-REFUELING-BASE LOSS: TARGETS KILLED FOR $40 BILLION MEDIUM BOMBER BUDGET—B-47 INTERCONTINENTAL GROUND-REFUELED SYSTEM

	No Base Loss	Loss of All Bases within 200 Mi of Soviet Union	Loss of All Overseas Refueling Bases
Tactic	Impact	Impact	One-way mission
Maximum number of targets killed	501	478	206
Number of strikes	7	7	4
Maximum number of targets killed in six strikes or fewer	495	471	206

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G. Other Strategic Objectives

Our campaign comparisons have been largely based on the Russian industrial targets. The Strategic Air Command has ou targets and other strategic objectives besides the hitting of Russian ...ustry. What effect might these other objectives have on the base systems we have presented?

Counterair or "blunting" targets must be hit early and they must be hit often. Both of these requirements, other things being equal, favor the peacetime rotation of bombers to overseas bases to mount as early an attack as possible. During wartime, the same requirements dictate that bombers be available "on call" for attacks on such targets as SU staging bases. The difference among systems in the speed with which initial attacks are delivered may not be significant if the rapidity of overseas deployment of ZI-based bombers is increased. However, at the present time nuclear cores are not stored overseas, and the attack cannot be started in any case until they have been delivered from the ZI. Most important is the fact that overseas-based bombers would be incapable of performing the counterair mission in the face of attacks such as those discussed in this report. The attrition resulting from these attacks would reduce to an unacceptably low level SAC's capability to perform any of its missions.

Retardation targets in Europe and western Russia require shorter missions, on the average, from the ZI. Consequently, the intercontinental air-refueled system is improved by the inclusion of these targets. Attacks on satellite industry targets also shift the center of gravity of the full target system in favor of the air-refueled system. However, the bombing of retardation targets might require close strike coordination with tactical fighters and fighter-bombers, so that operating from bases closer than the United States might be desirable. It was pointed out earlier that, as a possible substitute for the rotating of aircraft to vulnerable overseas bases during peacetime for the rapid delivery of bombs to predesignated targets, the basing of some wings on alert in the ZI might be considered. As long as nuclear capsules must be ferried to units on rotation overseas, a wing of B-47's on alert at Limestone could have bombs on target at least as soon as a wing on rotation in the United Kingdom. For this one wing, special measures to insure a high degree of alertness might enable take-off in

Bravo with sufficient speed to avoid a surprise attack. Rapid attacks ets of opportunity, if SAC is to be used against this type of target, could be mounted from forward bases. Also, any use of conventional high-xplosive bombs, whether in all-out war or a Korean-type war, would require operation from forward bases. In a peripheral-type war, where there would be little danger of enemy atomic attack on our overseas bases, the widespread system of refueling bases would provide us with a number of the long-lead items required to set up operating bases. They would, therefore, perform a valuable function even in this kind of high-explosive campaign.

It can also be argued that the benefits of operation from overseas bases can be obtained in safety by transferring operations to these bases after the destruction of the enemy's offensive capability against them. The force of this argument depends on the feasibility, the cost, and the desirability of completing the destruction of the enemy's offensive capability well in advance of finishing the major part of the strategic task; but, in the process of developing a workable defense which promises to keep our own strategic force largely intact, much of the foregoing analysis suggests a similar line of defense open to the enemy. In consequence, it suggests that the job of destroying the Soviet strategic force may be as difficult for us as we can make the job of destroying SAC for the Russians. In fact, in several important respects our Bravo task is more difficult than that of the Russians. To be specific, the Russians may adopt methods of defending their strategic force symmetrical to the one we have found good for defending ours. First, they can adopt the following defenses:

1. They can adopt a policy of evacuating aircraft based deep within their radar network.
2. They can use peripheral bases for staging only.
3. They can harden the critical facilities on all their bases.
4. They can develop a capability for using any of a large number of emergency-base alternatives in case we attempt a base-denial campaign with large numbers of large-yield weapons.

Second, they can benefit from some advantages we do not have:

1. While their knowledge of the exact location, plan, and mission of our strategic air bases may be presumed to be virtually complete, our intelligence on the Soviet strategic-base system is fragmentary, in part based on World War II German photographs, and is, if anything, becoming worse with the passage of time and possible new base construction.

2. While they will very likely have the considerable advantage of striking the first blow and so achieving the maximum strategic surprise of our SAC, our own counterblow will by the same token most likely be aimed at a force that is alerted in advance to evade it.
3. While the U.S. force whose defense we have treated of has been limited to the bombers and strategic fighters of our SAC, the Russian force we must destroy to make our overseas bases safe for continuous occupancy is much more extensive. To accomplish this we must destroy much more than the mediums and heavies of the Russian long-range air force. Half of our operating bases are within IL-28 radius and one-way MiG range. And these carriers would be well used to deliver small A-bombs against SAC bases. Blunting a Soviet attack against our overseas bases is, then, a much more extensive mission than the "Bravo" mission as originally conceived. And it appears to be more difficult than the Soviet task of destroying a rationally defended U.S. strategic force.

Nothing we have said implies that the Bravo mission (in either this extended sense of blunting the attack against our overseas bases or in the narrower sense, given to it earlier, of blunting the attack against the ZI) is not of vital importance, worth trying in spite of its difficulty. For one thing, much of the difficulty presupposes an intelligent base-defense policy on the enemy's part; and, while it is not safe to rely on his lack of rationality, we must have the capability of exploiting any important deficiency, should there be one. Furthermore, it is always at least possible that, even if he exploits the advantages we have outlined, we may hit on some method of acquiring reconnaissance information on his bases, as well as some force of bomb carriers that will either penetrate with little or no warning and so catch his aircraft unprotected on the ground, or that will deliver large numbers of weapons of such lethal effect as to deny him even hardened facilities.

The implication of this analysis is merely that the task of destroying the enemy's capability to attack our overseas bases is very much more difficult than the task of destroying his major Delta targets, and therefore is not likely to be completed before it. In fact, this is the result indicated by the joint Bravo and Delta campaigns we have tried. Figure 106 indicates that, at a time when the Delta mission has been substantially completed, the enemy's offensive force is still to a large extent intact. This result is based on assumptions about the counterair mission which are quite optimistic, as indicated in the figure. We

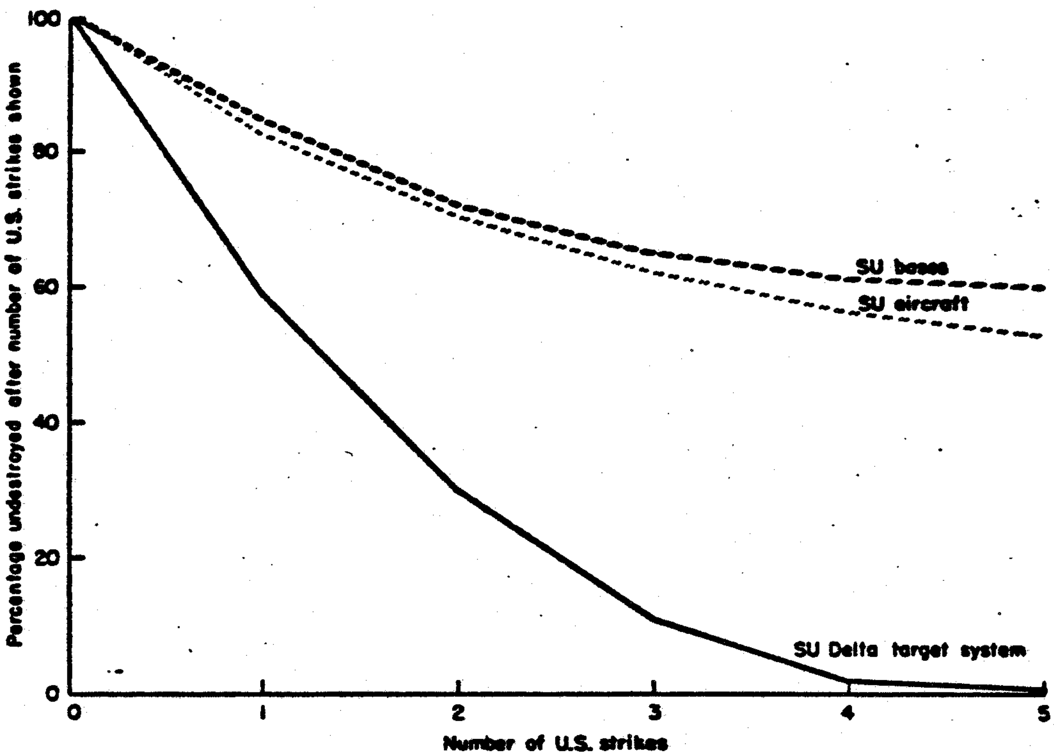

Fig. 106—Joint Bravo and Delta campaign (complete intelligence on base location; H-bombs used for base denial)

have assumed that we shall have in use weapons that will literally be base-busters with a high probability of completely destroying a base—though, in fact as the analysis on pages 324*ff* shows, against a base properly designed and with an appropriate policy of base use, a very large-yield thermonuclear weapon delivered with a rather low CEP will have a fairly low probability of destroying critical facilities or denying their use for any considerable period. We have assumed further that we know in advance precisely the location of all the bases to be bombed, and that no poststrike reconnaissance or bomb-damage assessment is required; that evacuation is only moderate—some 50 per cent—and we have taken into account the dissipation of enemy aircraft in one-way missions and attrition by our air defenses during attacks against theater targets and against our cities. In spite of this, the results show the major disruption targets largely destroyed before the elimination of a major segment in the enemy's own offensive capability. The explanation of the result shown is to be found, on the one hand, in the small number of Delta targets which contain a large proportion of both population and industry, and, on the other hand, in the very wide range of weapons available to the enemy for offensive use against

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overseas bases. Destruction of his power to inflict high attrition on overseas-based bombers means the destruction of a very large proportion of his air force. If we cannot move overseas until we substantially finish the job of destroying the enemy's offensive capability, we very probably cannot move overseas before we have completed the bulk of both the Bravo and the Delta missions—that is to say, the major part of SAC's task.

Even if, as far as the Romeo and Bravo objectives are concerned, the preferred method of basing the strategic force were not an intercontinental ground-refueled system, the major deterrent possessed by our strategic force would be the threat of attack on industry and population, and any base system we might choose must have the *capability* of effectively mounting attacks on these targets. Achieving this capability can be accomplished most efficiently by the preferred system.

H. Limitations and Adaptability

The results presented in this study have been derived from campaign comparisons in which many elements were varied and some were fixed. We have tested the superiority of the preferred system in strategic campaigns in which we varied, among other things, the number of visits required per target, the number and identity of the targets, their value weighting, the routes followed through enemy defenses, the minimum crew-survival-probability constraints, the level and deployment of enemy area and local defense, the level of enemy offense, our ability to anticipate attrition levels, and the political or other circumstances of base loss. However, the study analyzed, in the context of strategic campaigns, only the programmed medium and heavy bombers. While we have examined some joint Bravo and Delta campaigns, only one type of target system was used in most of the detailed analysis. In no case did we attempt to choose an optimal target system. It is natural to ask whether the demonstrated superiority of a ground-refueled, home-based system would be confirmed by additional analyses in which these other fixed elements were also varied simultaneously. The composition of our potential bombing force becomes increasingly variable when later time periods are considered. And although Russian industry is the most familiar target postulated for our strategic force, we have seen that it is not the only objective.

However, one of the merits of the recommended system is its adaptability. Refueling bases could be converted into operating bases if desired and might be combined with a certain number of overseas operating bases used in connection with the retardation targets. Similarly, the ground-refueled system is quite flexible when considered in connection with possible alternative compositions of our bombing force. The ground-refueled system would permit the economic use of smaller aircraft against some strategic targets. This would hardly be feasible for the air-refueled case considered. And for high-performance bombers, it would provide great flexibility in the choice of routes, speeds, and altitudes of penetration, and the possibly large payloads demanded in connection with the advent of H-bombs.

A growing Russian defense has forced us to the use of high-performance, short-radius bombers. At the same time an increasing Russian offensive power will compel us to keep as much as we can of the vulnerable part of our strategic complex a long distance from the enemy's borders. In such a world, a system for basing our bombers at home within the cover of our radar network and extending radius to target by means of dispersed overseas refueling stations appears to be important for a large part of our strategic task. Moreover, it is capable of combination with methods suited to accomplish the rest.

APPENDIX

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WARNING AVAILABLE TO SAC IN 1956

Our purpose in writing this appendix is to explain the basis for our estimates of the length of time which the Strategic Air Command (SAC) will have to evacuate its bases, and to suggest improvements that will extend this period of time. Since these estimates were derived by considering the set of procedures currently employed, estimating transmission time lags involved, and assessing the probable changes that will be introduced by procedure and equipment modifications in 1956, each of those topics will be discussed in sequence here.

There are three distinct possible sequences of events, all linked to the procedures and/or communication system of the Air Defense Command (ADC), that must be examined in the estimation of warning times for SAC bases against an enemy attack of the type specified. Each sequence could provide SAC with a different amount of warning, and the sequence of events that might be generated by enemy attack would depend largely on his planning and execution of the strike. In the first of these sequences, transmission of warning to HqSAC would be precipated by *the identification of an aircraft as "hostile"* (a definition will be supplied subsequently). In the second, *a group of aircraft* would be regarded by either the commander of an Air Defense Force (ADF) or the Commander, ADC, as *manifestly hostile in intent* (also subject to later definition). In the third, transmission of warning would be initiated by the explosion of one or more atomic bombs at one or more SAC bases. Clearly, transmission of warning in the latter case would be more rapid than in either of the former cases.

If the identification of an aircraft as "hostile" is the trigger for the warning system, the sequence of events which preceded this one must have been somewhat as follows: the aircraft in question must have been detected and tracked by radar (we neglect the possible role of a ground observer here) at one of the radar sites, declared to have been an unknown by an Air Defense Direction Center (ADDC), intercepted by an ADC interceptor, and observed to commit an overt hostile act or to be a USSR aircraft not in obvious distress, making an unscheduled appearance. This overt act could take the form of a threatening gesture toward the interceptor. It could be the unloading of bombs over the countryside. We shall neither dwell upon the obvious defects of such a scheme and the possibilities of its interruption nor suggest improvements. These are subjects which have received a great deal of attention from ADC, RAND and other study groups.* It suffices to say here that Soviet attacks, of the kind described in the body of the text, presumably would be intelligently planned and competently executed, at least to the degree compatible with the risk involved in the failure of the operation. Thus, this identification would probably occur so late, if at all, that the process would be short-circuited by one of the other two processes we will describe.

As conditions precedent, determination that a group of aircraft are "manifestly hostile in intent" requires the prior occurrence of the following two events. Specifically, each of the aircraft must have been detected and declared to be unknown. Further, the fact that this has happened must have been passed from the ADDC to the ADCC (Air Defense Control Center), to the ADF Headquarters concerned, and finally, to HqADC. At the headquarters of either an ADF or ADC, an evaluation can be made which leads to the determination in question. If an ADF Headquarters reaches this conclusion, only the region within the purview of that Force Commander is bound to respond to the ensuing Red alert. If the decision is made by HqADC, then a nationwide Red alert is ordered. In either case, HqSAC and the SAC bases affected are notified, the latter by Military Flight Service. As we understand it, no aircraft evacuation of SAC bases can begin under these circumstances until after HqSAC has ordered it.

Assuming for the moment that aircraft penetrating the perimeter of the radar cover are always detected, it is clear that the probability of correctly identifying an enemy strike as such depends critically on the probability of correct identification of individual aircraft. If the chance of a false alert is to be reduced to an acceptable minimum, then the likelihood of identifying friendly aircraft as unknowns must be compensated for in the evaluation process outlined above. A technique known as statistical raid recognition† has been utilized by ADC to provide such compensation and to assist in the process of raid assessment and evaluation. We will not discuss this technique in detail here. Furthermore, it suffices to explain that, based on the air traffic history in the United States,

*See L. D. Attaway and E. J. Barlow, *Identification Procedures for Air Defense*, The RAND Corporation, Research Memorandum RM-1078, May 1, 1953 (Secret), for a discussion of these subjects. The study includes a number of referencs to the substantial effort applied by Operations Analysis, HqADC, to improve aircraft identification procedures.

†Richard H. Blythe, Jr., and W. F. Blaylock, *Numerical Techniques for Raid Recognition*, HqADC, Operations Analysis Technical Memorandum 7, February 27, 1952 (Secret).

certain tolerance limits for the number of unknowns in the air defense system have been established. These limits vary as a function of the time of day and day of the month. If the total number of unknowns in any air defense region at any one time exceeds the threshold limit set for that region, or if the total number of unknowns in the air defense system country wide exceeds the limit set for it at any instant, then this evaluation process is started at the appropriate headquarters.

For the purpose of estimating how long a period of time might be required for the recognition of an incoming enemy strike and for the transmission of warning to SAC, consider the following case. Suppose that the enemy force size is sufficiently large so that, even though certain enemy aircraft are not detected and others, although detected, are incorrectly identified as friendly, the raid is identified because the threshold limits for unknowns are exceeded, say, at HqADC. To make our estimate easier to obtain, assume that all enemy aircraft begin their penetrations of the radar net simultaneously, and that this occurs at some moment during duty hours. Under these circumstances we have been advised that the accumulation of the requisite data at HqADC on which to base an evaluation would normally require between *10* and *15 min*, depending on the amount of traffic in the air. During certain hours of the day, when the volume of air traffic is quite small, the time required may be somewhat less. At other times, particularly during the periods when the traffic load reaches its peak, delays in communicating the information may extend this period of 10 to 15 min appreciably. Since we have taken the case where this raid occurs during duty hours, presumably either the Commander or the Vice-Commander, ADC, would be able to declare this pattern of aircraft "manifestly hostile in intent" very quickly after being advised of the situation. Suppose that the time required for this evaluation and decision is *5 min*. The next step in the sequence which culminates in the evacuation of SAC bases is the transmission of the alert to HqSAC, where, according to our knowledge, another evaluation must take place. It should be observed that the transmission to SAC and the SAC evaluation follow the ADC evaluation of the aircraft pattern as manifestly hostile. Like the decision which occurs at HqADC, the SAC decision involves the Commander or his deputy. The question to be resolved in this case is which units shall evacuate the aircraft from their bases in Condition Alpha (minimum flyaway condition), and which in Condition Bravo (combat-loaded for subsequent deployment). Again, if this decision-making process occurs during duty hours, presumably either the SAC Commander or his deputy will be readily available to participate. We reckon (optimistically, we feel) that 10 min might provide sufficient time for this transmission, evaluation, and decision. Thus, the total time consumed has been estimated to be roughly 30 min. If the reader is familiar with these or similar evaluation and decision-making procedures, he will probably agree that these estimates are optimistic.

Now it is appropriate to complicate the case described by the introduction of two elements of realism. First of all, penetrations of the U.S. radar net by enemy bombers would not all occur simultaneously. Even an expertly designed and executed strike plan would involve a spread in enemy aircraft penetrations. (Recall that we assumed from 30 to 60 min on page 234.) Thus the event which triggers the evaluation and decision-making processes takes time to occur. This introduces delay. (All too often we find those who contemplate and plan for such attacks thinking of the lack of coordination of penetrating enemy aircraft as an asset for the defense. In the extreme, it is. However, a moderate amount of spread in the penetrations in the present circumstances is a positive liability for the defense.) Second, the enemy attacks considered in this study may occur during off-duty hours. While this strike timing would operate to the advantage of the defense in that it would simplify the raid recognition problem (less air traffic and thus a lower aircraft-unknown threshold limit), it would disproportionately lengthen the time required for completion of the evaluation and decision-making processes. (The Commanders or Vice-Commanders of ADC and SAC would have to be summoned to their respective headquarters to make a decision.) Thus, our previous estimate would be increased, perhaps from 30 to 60 min or more.

A great many of the steps in this process which begins with the detection of enemy aircraft and culminates with the evacuation of SAC bases have been subjects for scrutiny. Modifications directed toward the reduction of time required to accomplish each have been proposed. In particular, ADC has intensified its efforts to improve the detection, identification, communication, and raid-recognition features of its air defense system. Similarly, SAC exerts a continuing effort to improve the efficacy of its evacuation plans. Thus, by 1956 we can expect that improvements will have been made. Advances in aircraft identification procedures will have been implemented. These will reduce the probability of aircraft misidentification and will thus decrease the time required for recognition of enemy strikes. Communication links and procedures between HqADC and its lower echelons will have been more fully developed. This will decrease the time required for data transmission. By 1956, SAC will have reduced the time required for evacuation of B-47's from its bases. All these improvements, while noteworthy, will not have decreased the time required for the total process to occur by an amount which will permit complete evacuation of the majority of SAC aircraft from most SAC bases.

Indeed, as we emphasized earlier in the text, the penetration times for some bases are so short that it is clear that improvements in warning-transmission procedures alone will not significantly increase the degree of SAC aircraft evacuation. More radar warning must be provided. However, for other bases with longer penetration times, warning-time deficiencies can be ameliorated by drastically reducing the time consumed in the evaluation and decision-making phases of the warning-transmission process, especially during off-duty hours. We will indicate further on in this appendix how this may be accomplished.

The last of the transmission-of-warning initiators which we shall consider is an actual attack directed at one or more of the many SAC bases which are programmed for location in areas with little or no low-altitude radar cover. As we have previously stated, the enemy using southern approach routes could attack bases in New Mexico, Texas, Oklahoma, Arkansas, Georgia, and Florida without passing through any peripheral low-altitude radar cover. Obviously the only warning those bases would receive, if any, would be that supplied by the radars located at or near bases like Davis-Monthan. It is extremely dubious that enemy aircraft could be identified as hostile prior to delivering their bombs. To assume even 10 minutes' warning for bases like Davis-Monthan may be optimistic.

Whether or not notice that an A-bomb has been delivered on a SAC base will be our first indication that we are under attack is clearly a function of enemy tactics. If he should elect to strike these more exposed bases within, say, 30 min of the time enemy aircraft attacking other SAC bases began to penetrate the U.S. ZI radar net, it is probable that bomb delivery would be our first notice of attack during off-duty hours. If, on the other hand, the enemy decided to hold back the aircraft attacking these more exposed bases in order to force defense utilization of the statistical raid-recognition technique, our first warning would come through the other channels described above. It should be clear that proper timing and execution of this latter tactic would confer an enormous advantage upon the enemy. He would destroy many more aircraft on the less exposed bases (less time for aircraft evacuation) while suffering no penalty with respect to the more exposed bases. (Proper timing implies hitting these latter bases about the time that they receive notice that a Red alert is in effect.)

Upon the basis of the preceding description, it is clear that more than half the total time consumed in alerting SAC in the face of an impending attack would be spent during the evaluation and decision-making phases of the alerting process. The notable exception is the case where bomb delivery at one or more SAC bases would be the trigger for SAC evacuation. As aircraft identification procedures are improved and message transmission times are shortened, these phases of the alerting process will consume an even larger fraction of the total time. We can conclude, therefore, that to make significant reductions in the process time, the periods required for evaluation and decision must be drastically shortened.

In present practice, as we understand it, HqSAC attempts to answer two questions prior to ordering execution of the evacuation plan: Is the situation serious enough to warrant evacuation of any SAC tactical units? If so, which units shall evacuate in Condition Alpha and which in Condition Bravo? We have already concluded (pages 245*ff*) that the second question should not be posed. Owing to the short warning times expected to be available to SAC with the programmed and planned radar network, SAC should plan to evacuate in Condition Alpha. Indeed, to increase the rate of aircraft evacuation from a base, we concluded that the evacuation plan should be modified so that evacuation of aircraft would mean evacuation in minimum flyaway condition. In this context the modification of the evacuation plan has another payoff. It reduces the period of time required for evacuation and decision-making, thus expediting transmission of warning to the SAC bases.

To further shorten the evaluation and decision-making periods will require the introduction of fairly automatic responses to potentially dangerous situations. These situations must be better defined so as to be susceptible to more quantitative measurement than is now the case. At the present time, it appears that a Red alert is a necessary condition (but not a sufficient one) for SAC to evacuate the aircraft from its bases. Since the penalties inflicted on the national economy as a result of a declaration of Red alert are great, the inhibitions which deter this action are also great. Thus there is a tendency to defer taking this action until the probability of a false alert is small indeed. This is understandable and necessary. However, by comparison, the penalties associated with an evacuation of SAC bases as a result of a false alert seem markedly smaller. To be sure, there are losses in operational readiness, etc., but these are compensated for to a degree by the benefits of the operations as an exercise. We have stressed before this that the random occurrence of some alarms every year is a positive benefit, provided that it is kept within the tolerance limits. In view of the disparity in penalties attached to the SAC and the ADC alert actions, there is no apparent reason why the actions have been correlated, except that the same response machinery is employed in reacting to both. Further, for the reasons set forth above and in the body of the text, it is clear that the time has come to dissociate these two alert actions. This can be done in a manner that will provide more automatic responses to potentially dangerous air situations for SAC and will markedly decrease the time required for SAC aircraft evacuation.

An acceptable scheme for accomplishing this objective seems to involve taking the following steps:

1. Establish a number such that if the number of unknown aircraft in a certain region exceeds this specified number, SAC will respond by evacuating the aircraft from the bases in that region. This could be done for regions containing a number of geographically proximate SAC bases. It could also be done for regions corresponding to those under the Eastern Air Defense Force (EADF), the Central Air Defense Force (CADF), and the Western Air Defense Force (WADF). It could, and probably should, be done on a national level as well. These unknown limits could be established in much the same way as those presently employed by ADC. There are a few essential differences. For one thing, the limits on unknowns in the system might be set not only on an hourly basis, but also (to guard against the cumulative drift of unknowns into areas not covered by our radar) on a 12-hr basis. And some test to detect significant drift in the hourly unknowns might also be imposed. The important difference would be that the unknown limits would be lower than the corresponding ADC limits for the same region. These limits should be as low as SAC could tolerate without incurring extreme penalties in reduced operational readiness. This means, of course, that SAC would be responding to some false alarms. This is inherent in the nature of such a scheme. If an alert system is to be sufficiently sensitive so that the probability is great that SAC will have evacuated its bases prior to the arrival of enemy aircraft over target, then the probability that some alerts are false alarms will be significant. With only equivocal indicators to go on, there can be no other solution. However, a small number of "false alarms" at unpredictable random intervals should not be regarded as a drawback. Such infrequent alarms would have a positive value

in the exercise of SAC in the evacuation plan. The requirement is to develop a statistical test and a triggering level which will insure with a high degree of confidence that the major part of SAC will be evacuated in case of an actual enemy attack, and which will trip evacuation at a tolerable and, if possible, a useful frequency. To achieve this, we have made clear, will require not only a refinement in the statistical analysis of U.S. traffic patterns, but an augmentation of our primary sensing system, i.e., the radars, and an improvement of SAC's ability to evacuate. The latter involves both alterations in both the location and character of the facilities employed in evacuation and in the procedure itself. One direction in which the procedures might be developed would lessen the costs of one class of alarms and increase SAC's tolerance for exercise by limiting SAC's response to minimum crew assembly and the like. The losses in operational readiness may be reduced if we discriminate at least two varieties of SAC alert, one in which SAC takes the planes off the ground and goes through essentially all the evacuation procedure, and one in which SAC goes through all the initial phases of crew assembly, etc., perhaps up to the actual take-off of planes. This would mean two triggering levels for SAC. (In the case of an actual attack involving near-simultaneous penetration, the weaker alarm might precede the stronger alarm for evacuation by only a comparatively short time; however, if the attack were one involving a cumulative sneaking across of enemy carriers, there might be a very significant difference in the time at which these two actions were undertaken. And this would also be true in the case of a poorly executed simultaneous-penetration attack.) A second direction in which the procedures might be developed is the one we have stressed at several points in the body of the text, namely, the detachment of the evacuation plan from the plan of deploying our forces for our own attack. This would not only permit speedier evacuation response by our forces; it would also make the identification of the enemy attack as a hostile pattern more rapid, since a false alarm followed by evacuation would carry a very much smaller penalty than a false alarm followed by our starting on our way to bomb Russian targets.

2. Transmit the information on unknown aircraft from an ADCC directly to subordinate headquarters of SAC, or, if necessary, directly to the SAC bases in question. If untimely delays in relaying this information are to be avoided, the channel should be as direct as is compatible with a complete description of the air situation in a particular region. Of course, there must be multiple com-

munication channels to insure reliable and secure transmission of the data. Obviously, authentication procedures must be developed.

3. Delegate authority to SAC units or subordinate echelons to act upon receipt of this information. It appears now that, except under conditions of an extreme emergency requiring immediate action, authority to order evacuation is reserved to the Commander of SAC or his deputy. According to our information, this class of emergencies does not extend to the case where the threshold unknown limits at ADC have been exceeded.

We do not pretend to have solved the difficult problem of formulating a workable scheme. It does seem, however, that the three steps outlined above are basic prerequisites for any procedure that will satisfy the requirements developed in our analysis of the problem.