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CHASING GRAVITY'S RAINBOW

KWAJALEIN AND US BALLISTIC MISSILE TESTING

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Nautilus Pacific Research

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ABSTRACT

The international regime for controlling the spread of weapons of mass destruction is at a cross-roads. The existing Nuclear Non-Proliferation Treaty regime is inadequate to the task of controlling ballistic missile development, and these missiles are capable of delivering nuclear, as well as chemical and biological weapons. The superpowers are developing their ballistic missiles qualitatively even as they negotiate cuts in numbers in the START 1 agreement. Export controls on ballistic missile technology have not halted missile proliferation: many small and medium-sized states are developing their own ballistic missiles; space is quickly becoming accessible to many states for military purposes.

This report is the product of phase one of a project conducted by Nautilus Pacific Research, to promote a Ballistic Missile Test Ban Treaty and to support international controls on ballistic missile development. It describes how ballistic missiles are tested, earlier ballistic missile testing in the Pacific area, US facilities for testing ballistic missiles (the USAKA installation on Kwajalein Atoll and the Western Test Range), the organisational links, and the implications for other programs, particularly the Strategic Defense Initiative. Finally, it discusses the various missile test ban proposals.

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PREFACE

The further development of ballistic missiles by the superpowers and their adoption by small and medium states threatens international security. The international regime for controlling the spread of weapons of mass destruction is at a cross-roads.

The existing Nuclear Non-Proliferation Treaty regime is inadequate to the task of controlling ballistic missile development. These ballistic missiles are capable of delivering nuclear, as well as chemical and biological weapons. The superpowers are developing qualitatively their ballistic missiles even as they negotiate cuts in numbers in the START 1 agreement. Export controls on ballistic missile technology have also proved incapable of halting rapid missile proliferation and can be only an interim measure until a more universal regime of control is established.

Many small and medium-sized states are developing their own ballistic missiles. Space is quickly becoming accessible to many states for military purposes. Ballistic missiles are the common capabilities that underlie these intersecting trends.

This report is the product of phase one of Nautilus' project to promote a Ballistic Missile Test Ban Treaty and to support international controls on ballistic missile development.

The goals of phase one were to suggest a technical and political approach to achieving a ballistic missile test ban that would be (1) easily monitored and verified, and (2) provide incentives to potential ballistic missile proliferators to commit themselves to a ballistic missile non-proliferation regime.

Phase two of this project will analyze ballistic missile testing by everyone other than the United States; that is, China, the Soviet Union, and medium states (such as the UK, France, India) and small states (such as South Korea, Israel). It will also produce a fully fledged proposal for a Ballistic Missile Test Ban Treaty, including proposed treaty language.

We anticipate that a credible and feasible proposal for a total ballistic missile test ban treaty will be composed of three essential elements. These elements must:

1. define legally permissible launch corridors and re-entry angles that would enable states to distinguish between legitimate space booster rockets and ballistic missile launch rockets on the one hand, and between satellite/shuttle/spacecraft re-entries and military re-entry vehicles on the other;

2. provide incentives for non-ballistic missile capable and space-entry capable states to join in creating a ballistic missile non-proliferation regime; especially via U.S. and Soviet adoption of a total Ballistic Missile Test Ban Treaty;

3. offer access to space entry technology to all states, but especially latent and active ballistic missile proliferating states (such as South Korea and Iraq), in return for ballistic missile non-proliferation commitments.

If phase two is successful, then phase three of the project will seek one or more state sponsors for the Ballistic Missile Test Ban Treaty in the UN General Assembly. These sponsoring states would play the same role as Ireland for the nascent nuclear non-proliferation treaty regime in the sixties, and Malta for the Law of the Seas regime in the seventies.

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PROLOGUE: WHAT IS A BALLISTIC MISSILE?

To define exactly what constitutes a ballistic missile is not easy. Originally, a missile was any kind of weapon that was thrown or otherwise propelled at its target. Arrows, spears, stones and bullets are all missiles in the original meaning of the term. Similarly the word "ballistic" was an adjective meaning "of or pertaining to the throwing of missiles" (*Shorter Oxford Dictionary*). So dictionary definitions are not much help.

What if we say that a ballistic missile is one which follows a ballistic trajectory? A ballistic trajectory is the path taken by a missile after it has been accelerated into flight, and when it is subject only to the downward acceleration of gravity. Classically, over distances short enough that the earth's roundness is not an important factor, a ballistic trajectory is roughly in the form of a parabola - a graceful arc up towards the sky then down toward the earth again. Thomas Pynchon called this shape "Gravity's Rainbow", after the trajectory of the first ballistic missile, the World War II German V-2.

Today a ballistic missile means a largish missile which uses a rocket motor to accelerate into a ballistic trajectory. Ballistic missiles are thus differentiated from other largish missiles in which aerodynamic lift plays a significant role in getting the missile to its target; that is, cruise missiles. Cruise missiles have small wings, and fly like pilotless aircraft.

Ballistic missiles are also distinguished from smaller tactical missiles which follow more or less straight-line trajectories to their target.

Ballistic missiles have three major elements: a booster rocket, a guidance system, and a payload.[1]

Booster. The booster is the rocket part and makes up the bulk of a missile. Earlier missiles were liquid fuelled, but most modern missiles have solid fuel rocket motors, similar to ordinary skyrockets, except that around the nozzle there are steering vanes or other devices

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1 See J. Constant, *Fundamentals of Strategic Weapons, Offense and Defense Systems*, (Martinus Nijhoff Publishers, The Hague, 1981).

to deflect the rocket exhaust and to steer the missile according to commands from the guidance system.[2] The booster boosts the missile up to a certain maximum velocity, then cuts out, and the missile coasts the rest of the way to its target. Many missiles are multi-stage - a first-stage rocket boosts the missile into space, then drops away; then a smaller second-stage rocket boosts the missile to a higher velocity and altitude; and this may be followed perhaps by a third stage. When the last booster stage has dropped away, the post-boost vehicle (PBV or bus) carries the payload and the guidance system.

Guidance. The guidance system consists of a set of gyroscopes to measure changes in orientation and a set of accelerometers to determine the velocity of the missile. Together, these processes constitute inertial guidance. A precalculated trajectory is fed into the memory of the guidance system before launch, and during flight the guidance system detects divergence between this ideal path and the actual trajectory, and sends steering commands to the rocket motors. By the time the last rocket motor is exhausted, the missile is following as closely as possible the optimum path toward the target area. Further guidance commands are sent to very low-thrust "vernier" motors on the PBV for fine adjustment of the trajectory.[3]

Payload. The payload of a missile is under the point, or shroud, at the top, containing the nuclear explosives. When each missile carried only a single warhead, the terminology was quite simple. Now that most missiles can each hit several targets, the terminology has become more complicated. "Warhead" has gone out of fashion, but it has not been replaced by "peacehead".

These days, modern missiles are described as carrying re-entry vehicles, or RVs. As the PBV hurtles through space it points itself in predetermined directions and releases RVs at predetermined times toward their pre-assigned targets. Each RV contains a nuclear explosive device, and a fuse to make that device explode at the right

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2 See G. Sutton, *Rocket Propulsion Elements: An Introduction to the Engineering of Rockets*, (John Wiley and Sons, New York, 1986).

3 See D. Mackenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*, (MIT Press, Cambridge, 1990); and C. Cochran *et al.* (eds), *Space Handbook*, (Air University Press, Maxwell Air Force Base, Alabama, 1985), pp.5-1 to 5-22.

moment, both of which are enclosed in a heatshield to protect against the fierce temperatures generated by air-friction as the RV re-enters the atmosphere. Most heatshields are ablative - that is, they are made of material which carries heat away from the RV by gradually vaporizing. These modern, multi-warheaded missiles are said to carry multiple independently targetable re-entry vehicles, or MIRVs. The jargon gets even more excruciating: these missiles are said to be MIRVed.

Trajectory. Intercontinental ballistic missiles (ICBMs) have trajectories of about 10,000 km length. Submarine-launched ballistic missile trajectories are somewhat shorter. Such trajectories will carry the missile about 1,500 km out into space. Every trajectory consists of several phases (illustrated in Figure 1.3). First there is the launch phase, when the missile is ejected from its silo, or breaks the surface of the sea after being ejected from a submarine missile tube. Then there is the boost phase, when the rockets are firing, for a total duration of only a few minutes. After that comes the mid-course phase, lasting for most of the half-hour duration of an intercontinental missile flight, when the PBV is coasting in space. The RV separation takes place during this period. Then there is the re-entry phase, lasting less than a minute, when the RVs make their fiery plunge through the atmosphere toward targets. The booster stages have already made their own separate re-entries along the flight-path.

Flight Testing. This all sounds complex. It is. Flight testing of missiles on a test range is a very serious business. All the minutiae of launching, booster ignition, guidance, steering, booster separation, vernier guidance, RV separation, ablation and fusing have to be tested. The trajectories of all RVs have to be accurately terminated, especially at the target or downrange end of the flight. Booster stages, the PBV, the shroud which covered the RVs during launch, and other bits and pieces have to be tracked for safety purposes. Vast quantities of engineering data have to be relayed as telemetry from all the missile components to waiting ground stations.

Flight testing has many objectives. Optimal designs have to be selected, various sub-assemblies as well as the entire missile have to be shown to work. Reliability and accuracy must be established and improved. Various payloads have to be tested. As *Launch Magazine* put it in 1968:

> The missile, to be accurate about it, is not a weapon itself, but part of a weapon system, which includes a launch facility, combat crew, maintenance crew, ground support equipment, re-entry vehicle, and other components. Operational testing exercises all of these together, trying the system in its entirety.[4]

There is only one component of ballistic missiles that does not normally undergo flight testing - the nuclear device intended for the RV. When we say that nuclear missiles are being tested in the Pacific, we do not mean that nuclear explosions occur as the RVs reach their targets. Test missiles carry only simulated explosive devices of similar weight and size to real ones. The nuclear devices are, with only a few historical exceptions, never subjected to flight testing. They are tested separately, deep underground.

The much-vaunted 1991 US-Soviet START 1 agreement permits both signatories to continue to chase "gravity's rainbow". Both sides are prohibited only from denying the other access to missile test telemetry (with exemptions such as SDI-related tests). They are obliged to broadcast all telemetric information from ICBM and SLBM test flights, and to exchange telemetry tapes, interpretative data, and acceleration profiles for every such test. Each side is also allowed 25 test silo launchers and 20 test mobile launchers at test ranges. They have agreed to not test more re-entry vehicles on a missile than are attributed to it in START 1.[5]

In short, they have adopted rules that enable them to pursue the qualitative arms race while avoiding tripping up. Indeed, sharing test data may help both to race even faster!

The numbers, varieties, accuracies, reliabilities, and payloads of ballistic missiles are arcane concepts for most people. But they are also important for everyone. For ballistic missiles constitute the bulk of the firepower in the nuclear arsenals of both superpowers. It is ballistic missiles which will shape the destiny of the world in the first hours of

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4 *Launch Magazine*, "Launch, the Story of Vandenberg", 1968-1969, p.16.

5 US Arms Control and Disarmament Agency, "Strategic Arms Reduction Talks", (ACDA Issues Brief, Washington DC, 29 July 1991).

World War III, should it ever happen. It is engineering "progress" in ballistic missile technology which has made the prospect of a nuclear "first strike" much more immediate than ever before. The Cold War may be over. Military budgets may be in decline. But the qualitative nuclear arms race is proceeding, even accelerating - especially at Kwajalein.

6 *Chasing Gravity's Rainbow*

INTRODUCTION

This report describes a military installation called US Army, Kwajalein Atoll (USAKA), and a complex missile test range called the Western Test Range (WTR). Kwajalein and the WTR are found in the central Pacific Ocean region. USAKA, on Kwajalein Atoll, consists of a unique collection of tracking, monitoring, research and experimental facilities at the downrange end of the Western Test Range (see Chapter 1).

Some of the most advanced, powerful, accurate and versatile radars in the Western world are located here. One radar will soon be able to track 64 objects alone. Another allows trajectory data on 32 objects to be collected simultaneously. One telemetry station alone is capable of recording 800 kilobits a second of telemetry from as many as 14 objects simultaneously. The data collected can be sent back almost instantaneously to research facilities in the United States.

The Western Test Range begins at Vandenberg Air Force Base in California, which is well equipped with a variety of intercontinental ballistic missile (ICBM) launch facilities and monitoring facilities. Off the coast of California are instrumented launch areas on the seabed from which missile-firing submarines launch submarine-launched ballistic missiles (SLBMs). Mid-course tracking and experimental facilities are scattered along the range.

Toward the down-range end, instrumented "broad ocean areas" (BOAs) offer a wide variety of trajectory lengths and azimuths. For some purposes, re-entry vehicles (RVs) can be recovered after making a reasonably soft landing in Kwajalein Lagoon; for other purposes, they can be targeted on one of the islands of Kwajalein Atoll.

USAKA is a multipurpose facility that does more than just test missiles in a space-age shooting gallery. Space tracking is the next most important activity at Kwajalein after missile testing. Kwajalein's radars are ideal for tracking and identifying foreign satellites because they are perfectly located to detect foreign satellites (mostly Soviet) immediately after launch. By geographical happenstance, the Kwajalein facilities also monitor some Soviet missile launches as well as they do US missile tests.

Kwajalein Atoll was acquired by the United States as booty from World War II. It was first used to support nuclear testing at Bikini and Enewetak Atolls in the Marshalls. About 1960, when the Air Force was about to begin launching ICBMs from California to a target area near Enewetak, the Army decided to establish facilities for testing anti-ballistic missiles at nearby Kwajalein. The Army used the Air Force ICBMs as targets for Nike-Zeus, Spartan and Sprint interceptors (see Chapter 2).

Within a couple of years, the ICBM target zone was shifted from Enewetak to Kwajalein itself. Most of the developmental and operational test flights of the early ICBMs - Atlas and Titan - took place along the Vandenberg-Kwajalein flightpath. Later, the same flightpath served for testing the Minuteman ICBMs. More accurate RVs, MIRVed RVs, manoeuvering RVs, penetration aids that mimicked RVs, radar jammers and clouds of "chaff" were carried aboard other missile flights into Kwajalein. At the same time, the tracking radars measured their accuracy, while research radars assessed their likely effectiveness in penetrating Soviet ballistic missile defenses by avoiding radar detection, overloading radar software, and dodging Soviet anti-ballistic missiles (ABMs). Other missiles carried fake Soviet RVs into the Kwajalein area, while experimental radars on Kwajalein refined US techniques for detecting, identifying and tracking Soviet RVs, and discriminating between RVs with warheads and those that were merely decoys. Most of the technological sophistication that has been built into US ICBMs over the years was developed and tested at Kwajalein. All the developmental and operational testing of the MX missile has been carried out using "broad ocean areas" serviced and monitored from Kwajalein. A substantial amount of the technology for the Trident SLBM was developed on flight tests which terminated at Kwajalein (see Chapter 3).

The United States has one other long-range ballistic missile test range - the Eastern Test Range, stretching from Florida into the South Atlantic - which is used primarily for developmental testing of SLBMs, and shakedown testing of the submarine/SLBM combination. The most important advance in ballistic missile technology, the multiple independently targetable re-entry vehicle (MIRV), was developed more on the Eastern Range than on the Western Test Range. The Eastern Test Range was also better equipped than the WTR for testing IRBMs or intermediate range ballistic missiles (which are no longer part of the US arsenal). Compared with the WTR, however, the Eastern Test Range lacks land-based sophisticated monitoring facilities at the down-range end and is therefore much less useful for studying re-entry phenomena and developing re-entry technology.[1]

US officials have often stated that Kwajalein offers unique facilities for ballistic missile testing which would be almost impossible to duplicate anywhere else. Kwajalein has continued to be the main US test facility for ABM technology since the Nike-Zeus facilities were established there thirty years ago. After the ABM treaty was signed, the work carried on as ballistic missile defense. Since 1983, Kwajalein has become the principal site for testing Strategic Defense Initiative (SDI) or "Star Wars" technology (see Chapter 4).

There are several reasons for this concentration at Kwajalein. First, it is one of only two sites where the United States is allowed by the ABM treaty to do ABM research. Second, SDI tests involve intercepts which send debris plummeting back down to the earth's surface. Kwajalein, out in the middle of the Pacific with only a few thousand Marshallese people nearby, is seen as a much "safer" place to test than the other permitted site, the White Sands Missile Range, which is located in the middle of the United States. Finally, only Kwajalein has the sophisticated monitoring and research facilities, and a constant supply of "targets of opportunity" for SDI in the form of incoming ICBMs.

Why do so many missile and anti-missile tests occur at Kwajalein, especially now that the Cold War is ostensibly over? Six factors combine to explain why the United States continues to develop and test strategic nuclear missiles.

First, it is easy to conduct the tests at Kwajalein. Although the missile tests threaten the safety and livelihood of people who live in the Pacific, the people who own Kwajalein have little power against that of the United States.

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1 The US radar facility for missile test tracking formerly based in South Africa played an important role in Kissinger's diplomacy, but it is no longer operative.

Second, as one defense writer put it, "behind every successful missile there is a missileman".[2] Of course, behind every missileer stands a missile design engineer. In fact, missile tests are increasingly used to identify errors in computer-aided missile design programs rather than the missiles themselves. The missiles embody the thinking of the missile engineers who work in what may be called the missile-labs complex. A typical example is the Lincoln Laboratory, a center for research operated by the Massachusetts Institute of Technology, which manages much of Kwajalein's radar and SDI design work. In turn, Draper Laboratory (also affiliated with MIT) designs the re-entry vehicle guidance and navigation systems used in the missiles.

These exotic technologies are then incorporated into missiles designed by major defense firms under contract to the Pentagon. "As indefensible as it may seem," one report to the Pentagon admitted in 1980, new missiles may be introduced "to keep a designated design group occupied".[3]

Third, missile research, development, production, and deployment represents a huge market for these defense contractors in the missile-industrial complex. In 1982, for example, military sales of

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2 *Launch Magazine,* "Launch, the Story of Vandenberg", 1968-1969, p.2.

3 Martin Marietta Corporation, Aerospace Division, "Analysis of the Effects of Flight Test Limitations", Phase B, Final Report TR-E-80-008 to US Defense Nuclear Agency, Denver, Colorado, December 1980, p. 58. Many studies of the origins of specific missiles testify to the powerful impetus to new missiles that comes from the public weapons laboratories, for example: H. Sapolsky, *The Polaris System Development, Bureaucratic and Programmatic Success in Government,* (Harvard University Press, Cambridge, 1972); F.Ordway and M.Sharpe, *The Rocket Team, From the V-2 to the Saturn Moon Rocket,* (MIT Press, Cambridge, 1982); T.Greenwood, *Making the MIRV: A Study of Defense Decision Making,* (Ballinger, Cambridge, 1975); D.Carter, *The Final Frontier: The Rise and Fall of the American Rocket State,* (Verso, London, 1988); T.Cochran, W.Arkin, R.Norris, M.Hoenig, *U.S. Nuclear Warhead Facility Profiles,* (Ballinger, Cambridge, 1987) and *U.S. Nuclear Warhead Production,* (Ballinger, Cambridge, 1987); W.Broad, *Star Warriors,* (Simon and Schuster, New York, 1985).

missile systems and parts amounted to $US5.2 billion, a market that now exceeds contracting for the US space program and expanded rapidly during the Reagan era.[4] This market is likely to explode in the aftermath of the Patriot-SLCM-Scud war between US and allied forces and Iraq.

As a large proportion of a given missile "buy" is destined for use in testing, the Pacific Test Range is a major opportunity for these firms. Thus, the private companies who make the missiles constitute one side of what US defense analyst Gordon Adams has called the "iron triangle" of defense spending in the United States.[5]

Fourth, both the strategic thinkers who articulate the ideology of nuclear deterrence, and defense policy makers who set the priorities built into budgets, exercises and warplans, exploit the technological and political opportunities presented by the missile-labs and missile-industrial producers. They are particularly concerned with extracting the last drop of political and military advantage that they can see arising from the United States having perceived nuclear superiority.

Hard target kill capability - that is, the ability to promptly and reliably destroy targets such as command posts or missile silos designed to withstand the effects of nuclear attack - is central to gaining nuclear superiority. The hardest, fastest, most lethal form of nuclear superiority is obtained from offensive nuclear missiles tested at Kwajalein.[6]

The fifth factor is the British and French nuclear forces. These forces push the United States to stay technologically ahead of them to justify its alliance leadership. Although the United States has provided to its nuclear allies much of its most advanced missile technology, it often does so on a "black box" basis so that the United States retains its technological advantage. The package denies American technological secrets to buyers.

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4 K.Bertsch and L.Shaw, *The Nuclear Weapons Industry,* (Investor Responsibility Research Center, Washington DC, 1984), p.45.

5 G.Adams, *The Iron Triangle, The Politics of Defense Contracting,* (Council on Economic Priorities, New York, 1981).

6 See S.Kull, "The Perceptual Value of Hard-Target Kill Capability", in *Minds at War, Nuclear Reality and the Inner Conflicts of Defense Policymakers,* (Basic Books, New York, 1988), pp.177-207.

A sixth factor is the countervailing nuclear forces of the Soviet Union and China. These forces stimulate US threat perceptions and rationalize US arms racing. The impact, however, of adversarial programs on US missile testing is complicated. As important as offsetting or emulating adversarial missiles (or anti-missile systems) may be in the battle of perceived capabilities, technological innovation in US missiles is also driven by the mundane factors mentioned earlier and by loftier considerations of pure ideology that affect US foreign policy, regardless of developments in adversarial force structures.

This report deals only with US missile testing programs. Of course, missile testing is part of the overall nuclear standoff between the super and great powers. It is urgent, therefore, to examine in detail the missile testing programs of the other four nuclear states, as well as the missile programs of nuclear-capable or near-nuclear states such as Israel, India, Pakistan, North and South Korea, etc. That task, however, is beyond the scope of this report.

Nonetheless, the US missile testing program at Kwajalein vastly exceeds the activity of any other state in this dimension of nuclear arms racing, except possibly Soviet testing aimed at Kamchatka and the North Pacific. This Soviet activity deserves in-depth investigation that will be the subject of future reports by the authors.

The reader may ask: what do we know as a result of reading this report that we didn't know before? One major insight gained in this study relates to the *synergistic interaction* between the offensive and defensive missile testing programs conducted at Kwajalein.

The US Air Force wields an ICBM sword from Vandenberg that strikes again and again at the US Army's Star Wars shield at Kwajalein. The immense array of measuring devices at Kwajalein, especially the radars, serve as an umpire in each duel between the missile sword wielded against the anti-ballistic missile shield. The KREMS radars measure how successful the sword is at piercing the shield, and how successful the shield is at warding off the sword. But - and this is what is unique about Kwajalein - the shield is also a whetstone against which the sword is continuously honed, and the sword is a forging hammer which hardens the shield. KREMS measures both sharpness of sword and hardness of shield.

At Kwajalein, the United States is arms-racing with itself. The Air Force tries out better RVs, and the Army tries out better ways of shooting them down. The five KREMS radars function as a panel of uniquely alert and sharp-eyed judges who cast an occasional backward glance at the Soviets, to check on how *their* arms race is coming along.

A few thousand Marshallese subsist under the edge of the shield. Offshore, the Soviets have a spy trawler listening to the clang of sword against shield and picking up tips on how they can sharpen their sword and harden their own shield.

In view of its extraordinary contribution to the qualitative arms race, anti-nuclear movements in the Pacific have long sought to close Kwajalein. These movements saw the arms race as being a technological one, pointing out that most of the weaponry "improvements" that were driving the superpowers towards first-strike doctrines were made in the missiles rather than in nuclear explosive devices. Hence, a ban on missile testing might help slow down the arms race far more than a ban on nuclear testing, desirable as the latter is for political and environmental reasons.

This report, therefore, reviews the popular opposition to Kwajalein, including direct actions and the unsuccessful efforts to create a South Pacific ballistic missile test-free zone (see Chapter 5). It examines the pros and cons of partial and comprehensive approaches to obtaining a missile test ban and describes how these ideas have already been incorporated into strategic arms control agreements.

It concludes that symbolic direct actions against missile tests, such as peaceful blockades at sea, on land, and in the air, might put these options much higher on the agenda of the arms control community in the capital cities of great and medium powers. It also suggests that there is an integral link between the provision of access to peaceful uses of space, a missile test ban treaty, and the propensity of missile-proliferating states to join in a ballistic missile non-proliferation regime.

Plate 1: Radar Sites at Kwajalein Atoll (USAF Photo)

CHAPTER 1

USAKA - US ARMY, KWAJALEIN ATOLL

A. Locale

Kwajalein is an ecological wonder of the world. Crescent-shaped, it is about 120 km from 'horn' to 'horn,' making it the world's largest coral atoll. Like all atolls, it consists of a coral reef, awash at low tide, enclosing a lagoon. The lagoon is about 2,850 km^2 in area, and 30-55 m deep. The reef is interrupted at intervals by passages, at least one of which is big enough for ocean-going ships to pass through.

There are about 100 islands scattered along the reef, ranging in size from sand cays of a few hectares and barely above high tide level, to Kwajalein Island, 3.1 km^2 in area. The land area of all the islands totals 14.5 km^2. Kwajalein is located about 9° north of the equator, and 13° west of the international dateline (see Figure 1.1).

Kwajalein is also part of one of the world's most sophisticated and highly instrumented ranges for testing strategic nuclear ballistic missiles and anti-ballistic weapon systems. Between 12 and 20 such missiles per year are targeted on or near Kwajalein. As of June 1989, the United States had one half billion dollars of real property investment alone in Kwajalein Atoll.[1] Replacement cost of the Kwajalein facilities is estimated at about $US2 billion.[2] Kwajalein is being developed as a principal test range for what the US government calls the Strategic Defense Initiative (SDI). SDI is the effort to develop a set of surveillance, tracking, and weapon systems which will supposedly and eventually enable the United States to shoot down or otherwise disable most of the Soviet Union's strategic missiles after they have been launched.

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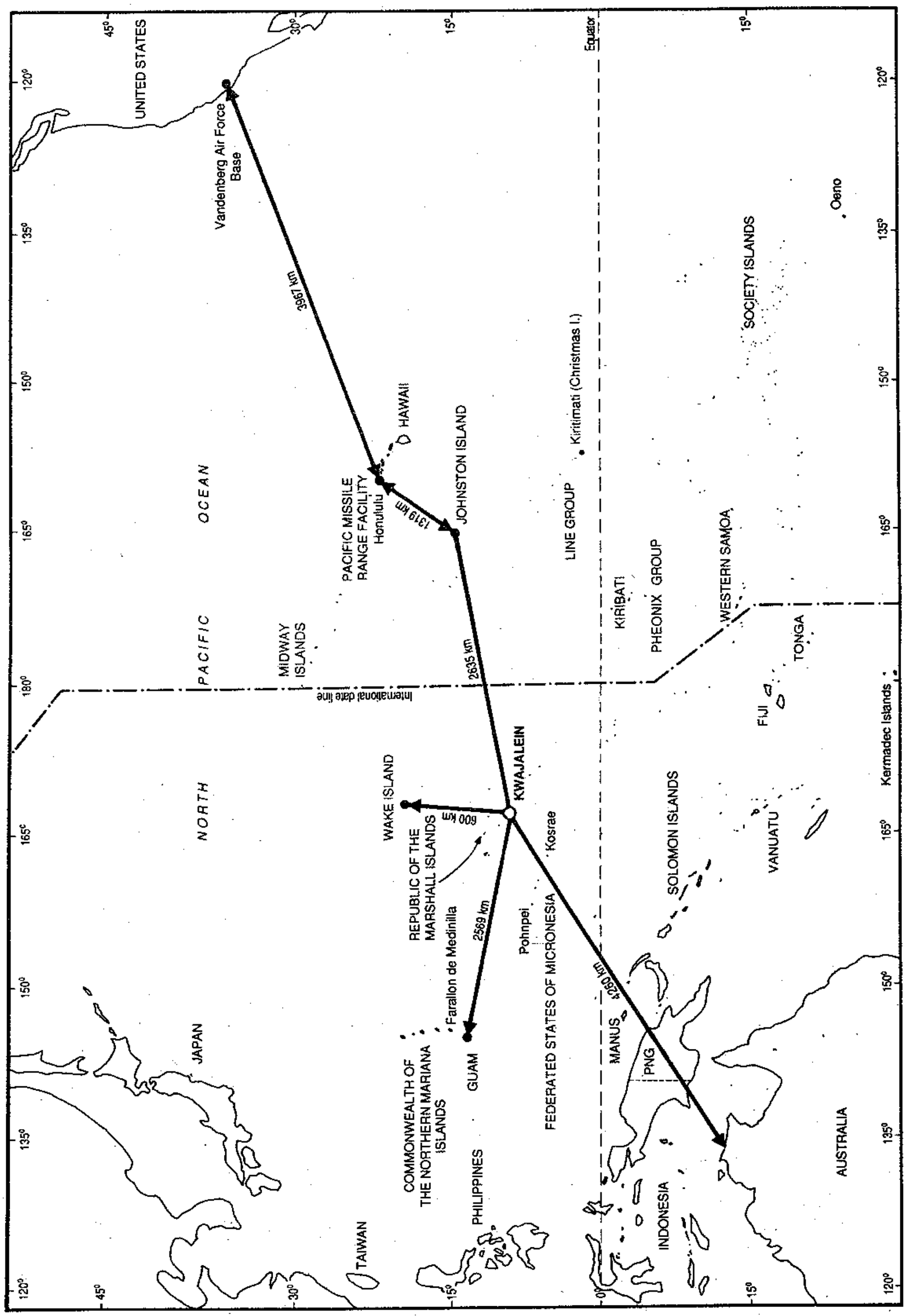
1 *Proposed Actions at US Army Kwajalein Atoll, Draft Environmental Impact Statement*, US Army Strategic Defense Command, June 1989 (henceforth referred to as *DEIS*), p. 2-62. If anything, the figure seems on the low side.

2 J. Gordon, "Kwajalein Settlement Stalls in Senate", *Aviation Week and Space Technology* (henceforth referred to as *AWST*), 28 October 1985, p.82.

Figure 1.1: Location of Kwajalein Atoll and Western Test Range



Eleven of Kwajalein's islands, including most of the larger ones, are occupied and used by what is now called "US Army, Kwajalein Atoll" (USAKA, formerly Kwajalein Missile Range, KMR) (see Figure 1.1). Most missile types now or previously in the US strategic nuclear arsenal have undergone at least some of their development or testing at Kwajalein.

USAKA is operated by a contractor, currently Pan Am World Services, on behalf of the US Army Strategic Defense Command. Currently, there are about 3,000 US personnel, mostly contract or employees, at USAKA. There is also a Marshallese workforce of about 1,000, drawn mostly from the non-USAKA island of Ebeye. Some Marshallese workers at Roi-Namur live on Ennubirr.

This chapter looks briefly at the kind of missile test activities going on today at Kwajalein, and then describes the various facilities at Kwajalein Atoll involved in a missile test. Kwajalein is only the terminal end of a missile testing range that stretches all the way from the coast of California. The other components of this range and its command structure are described, while activities other than missile testing at Kwajalein are simply listed.

B. Current and Typical Operations

A typical missile test involves launching an intercontinental ballistic missile (ICBM) from the Western Space and Missile Center at Vandenberg AFB, California, or a sea-launched ballistic missile (SLBM) from a submarine in the northeastern Pacific. Each missile usually carries three or more warheads, referred to euphemistically[3] as re-entry vehicles (RVs). For test purposes, these RVs are dummies - they carry no nuclear explosives, but are ballasted with depleted uranium so that they have the same weight and balance as a real warhead. They also carry sensors for measuring engineering data during the test; and this data is radioed back to receivers on the ground or in special aircraft. The RVs are targeted at any of three sea areas associated with USAKA: the so-called mid-atoll corridor (MAC) within

3 The euphemism is regretted, but other terms are ambiguous - "warhead", in particular can refer to either the cluster of RVs atop a missile or to the nuclear explosive device inside each of the RVs.

Kwajalein lagoon (see Figures 1.2 and 1.3), a broad ocean area (BOA) lying 140 km north of Kwajalein and known as USAKA North, or the BOA lying 450 km to the east, called USAKA East. For certain purposes, some RVs are targeted for land impacts on Illeginni Island, part of the atoll. There are other BOAs lying further afield - near Guam, the Northern Marianas, Wake Island and Oeno (Pitcairn Islands), all of which are serviced independently of Kwajalein Atoll. A single missile test may require up to 185,000 km^2 of sea and air space.[4]

USAKA is also used for developing and testing weapon and sensor systems intended for destroying or otherwise incapacitating enemy missiles after they have been launched. These systems and programs were originally known as ABM[5] (Anti-Ballistic Missile), later as BMD (Ballistic Missile Defense), and now as SDI (Strategic Defense Initiative), or, to the disrespectful, as "Star Wars".[6] The ABM/BMD/SDI activities at Kwajalein mostly involve testing the abilities of radars, optical trackers, infrared sensors, lasers, and similar devices to detect, identify, and track in-flight missiles and incoming RVs. In most cases the ballistic missiles undergoing routine test flights are used as "targets of opportunity". But in some instances special missiles are launched to serve solely as "dedicated" SDI targets. SDI weapon systems are tested by launching them from the Atoll at incoming missiles or at dedicated targets.

Over the last few years, intercontinental missile warheads have been plummeting down on or close to Kwajalein about once

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4 "Procedures to prevent mutual interference between space and missile center operations and fleet training commitments in Hawaiian fleet operating areas; promulgation of", COMTHIRD FLT Instruction 3120.7B, 1 August 1984.

5 In this report the term ABM, although out of fashion, will be used throughout to include any missile intended for use against strategic ballistic missiles.

6 H.York, first US Director of Defense Research and Engineering, later chief US negotiator in the comprehensive nuclear test ban talks, is amongst those who see "Star Wars" as the more appropriate term. See his *Making Weapons, Talking Peace: A Physicist's Odyssey from Hiroshima to Geneva,* (Basic, New York, 1987), pp. 243-245.

Figure 1.2: Kwajalein Atoll

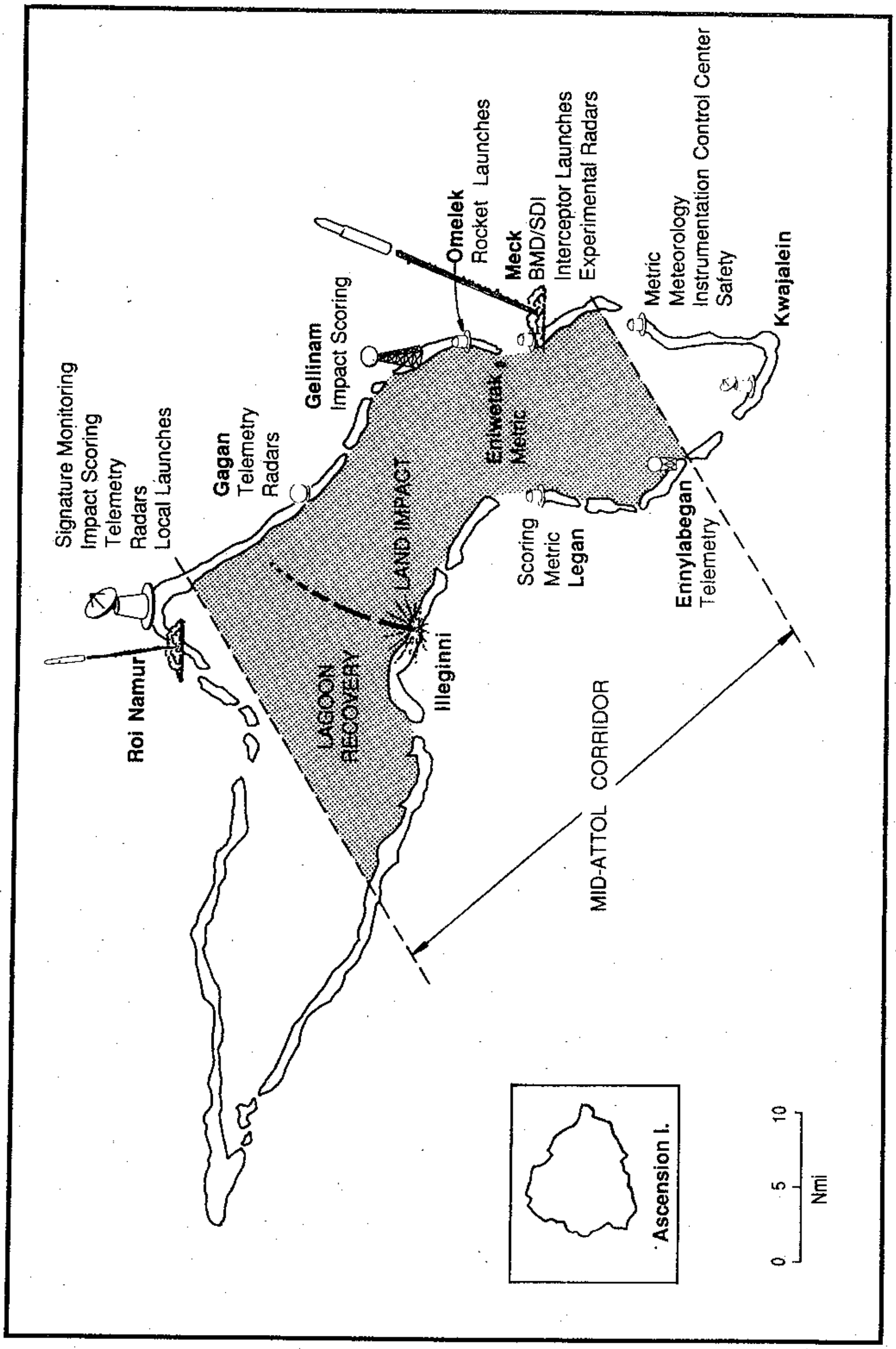
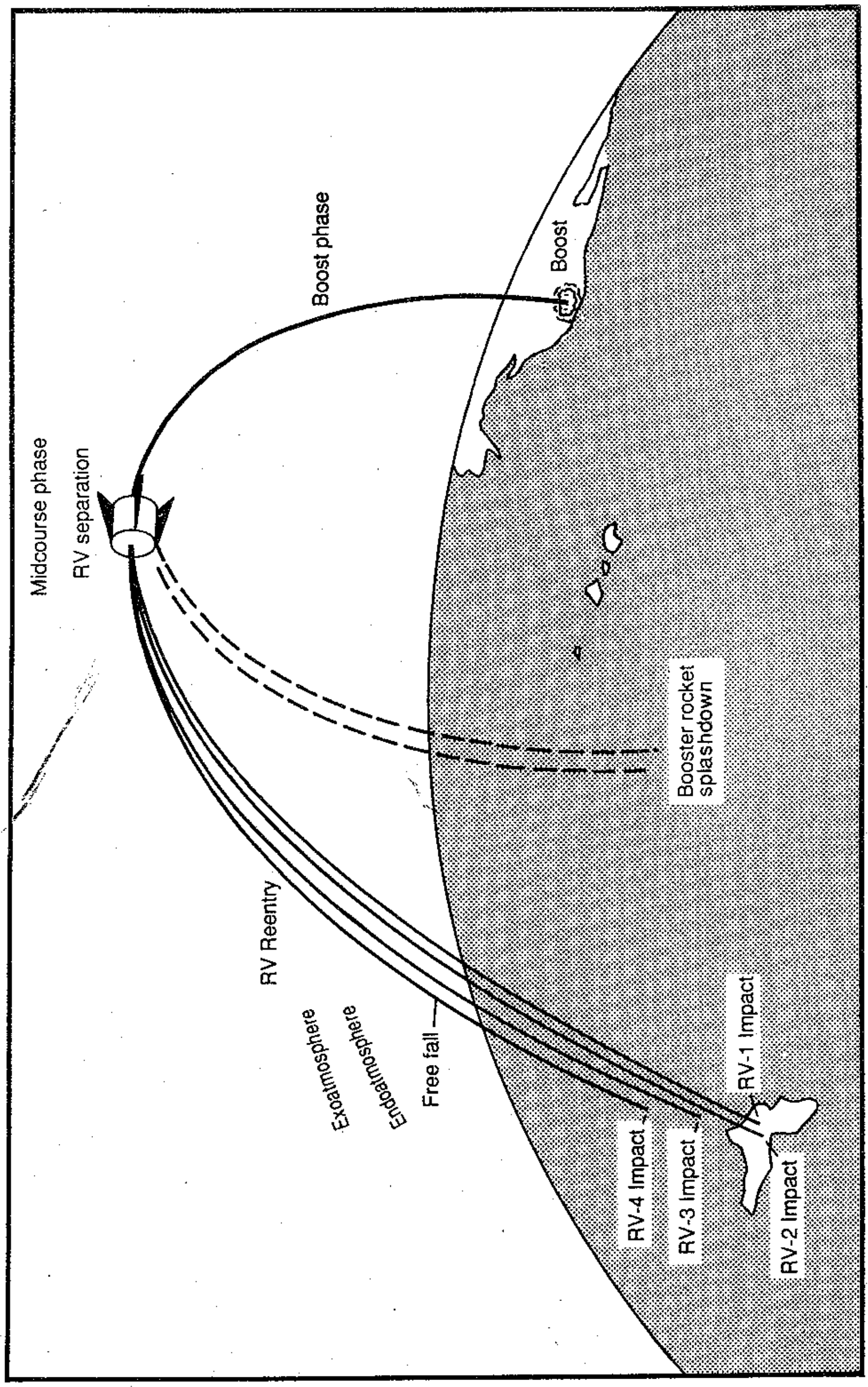


Figure 1.3: Typical Missile Flight Test



every three weeks. Currently two to three rockets per month are launched from Kwajalein itself.

When tests are taking place, all boat traffic and visits to even non-USAKA islands are prohibited in the mid-atoll corridor. Marshallese are not allowed to visit USAKA islands within the corridor, except when the Range is "stood down" and not used for tests.

C. USAKA Facilities at Kwajalein Atoll

A variety of radars, rocket launchers, and other equipment is located on the eleven islands of Kwajalein Atoll used by USAKA. Together, these systems constitute the testing data acquisition system described in Appendix 5. These are listed below more or less in the order in which they function during a missile test.[7]

1. *Support and Housekeeping*

Kwajalein Island, located to the south of the test corridor, is the support base for most activity on the atoll. Most US personnel live on Kwajalein, where bulk fuel and water storage and warehouses are situated. The power plants on Kwajalein alone can generate nearly 31 megawatts. In 1988, 32 million litres of fuel were consumed in electricity generation for the island.[8]

The airfield on Kwajalein has a sealed runway over 2,000 metres long, usable by US military aircraft as big as C-5 Galaxies. During a typical month, there are about 1,500 aircraft movements (that is, landings or takeoffs), half of which are by helicopters flying to other parts of the atoll. MAC C-141 Starlifters come in about 16 times per month. Other US military aircraft also transit through Kwajalein. Australian P-3 Orions and C-130 Hercules occasionally visit, as do

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7 Appendix 1 describes the facilities according to which island they are located on and shows their location in the atoll as a whole.

8 *DEIS*, table 3.12-2, p. 3-170.

Japanese military aircraft.[9] In 1988, 50 million litres of aviation fuel were supplied to aircraft at Kwajalein.[10]

2. *Weather and Environmental Monitoring*

Before a missile is launched toward Kwajalein or a missile interceptor is launched from Kwajalein, it is important to know the weather conditions over the target area. Wind will deflect an RV from its intended course, and raindrops erode the surface of an RV, changing its aerodynamic characteristics. The ice crystals in cirrus clouds can cause even more damage, because they are harder, and because the RV meets them at higher altitudes where it is travelling at very high speeds. To determine weather conditions in the upper atmosphere, meteorological rockets are launched about 25 times a year. There are two AN/WF100-4/2 wind-finding radars at Roi-Namur, as well as a sounding antenna for receiving high-altitude data from weather balloons. A weather radar on Kwajalein is used particularly for monitoring cirrus clouds. There are also two antennae for receiving data from weather satellites.

3. *Communication Links*

Inter-range communication links. A variety of voice, telex, and data links connect all facilities within the atoll, as well as all aircraft and vessels participating in tests. Other links connect the atoll to the places from which the test missiles are launched to ensure co-ordination of all range facilities when a launch is about to take place. There are systems which will send "destruct" messages to any missile which starts to veer off course, or in any other way poses a hazard. There are communications arrangements via satellites for transferring very precise time signals and frequency standards from the US Naval Observatory in Washington, DC to all sensors on the atoll. These arrangements are backed up by an extremely precise caesium beam clock which is flown from the observatory to the missile range and back to Washington, DC for calibration at regular intervals.

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9 *DEIS*, table 3.11-1, p. 3-149.

10 *DEIS*, table 3.12-3, p. 3-171.

Intra-range communication links are used to co-ordinate missile launches at Vandenberg and elsewhere with operations at Kwajalein.

4. *Radars*

The incoming RVs heading toward Kwajalein are first detected and tracked by radars. There are three distinct kinds of radars involved.

Range radars, mostly on Kwajalein Island, are for the actual monitoring and control of the missile tests, measuring the accuracy of RV impacts, etc. These radars are also known as metric radars, because they measure distances, heights, angles, and velocities.

Experimental radars, located primarily on Meck at the north end of the atoll, are tested against incoming missiles to develop new technology for ABM or early warning radars. Meck Island also hosts an experimental "Missile Site Radar". This radar is a prototype of the hardened phased array radars planned for installation at future ABM installations. It is a tenant on USAKA, rather than part of it.

Other radars are for research purposes, studying the phenomenology of ballistic re-entry. They measure the radar reflection of the RV, and of its plume or wake of ionised gas, so that better ways of penetrating Soviet ABM defenses (penetration aids, or penaids) can be developed for US missiles, and better ways of defeating Soviet penaids can be developed for US ABM systems. They also collect information on the aerodynamic performance of the RV, which can help in the design of RVs which will suffer less deflection from their intended trajectories.

Some of the radars are protected within more or less spherical radomes. Others are exposed and visible as parabolic dish antennae. The most important are five radars located on Roi-Namur, and known collectively as the Kiernan Re-entry Measurements Site (KREMS). The KREMS radars are all multi-functional, and serve various range and research purposes. They include:

Altair. An enormous radar, with an antenna dish diameter of nearly 50 metres, and a peak power output of 17 megawatts.

Altair can easily detect an RV as it comes up over the radar horizon, 4,000 km away. It can also track satellites in geosynchronous orbit, 35,000 km above the Pacific and far beyond the range of most satellite tracking radars.

Alcor. A less powerful and long-range radar than Altair, but one which is correspondingly more accurate. In the later part of an RV trajectory, it can measure an RV's instantaneous position to within half a metre.

Tradex. The ability to produce a wide variety of waveforms enables Tradex to make high-resolution images of the incoming RVs. Tradex is also particularly good at imitating the waveforms, frequencies, and scanning modes of Soviet radars, so that it "sees" US RVs the way a Soviet radar would in wartime. This capability helps the United States to design RVs which are less visible to Soviet radars.

MMS. This is a multistatic measurements radar, with receivers located on other islands, enabling very accurate distance measurements to be made using interferometry. It can measure trajectories to within 4 metres at the "pierce point" where an RV first enters the uppermost reaches of the atmosphere, up to 250 km away.

MMW. A millimetre wave radar which allows very accurate determination of RV distances and velocities. It can measure the position of an RV to 28 cm, and measure velocity to an accuracy of 8 cm per second. Operated in a different mode, it can produce two-dimensional images of RVs and satellites. It is also used to passively gather microwave signature data - that is, the characteristics of rocket exhausts and RV plumes which can be used to distinguish between RVs containing warheads and those which are merely decoys.

More radars are found on other islands of the atoll, including two general-purpose AN/MPS-36 tracking radars on Kwajalein and Illeginni, and an AN/FPQ-19 high-accuracy long-range radar on Kwajalein.

A sounding rocket is launched from Kwajalein before each incoming missile arrives. This provides a "target" for checking and calibrating all the radars and optical sensors.

5. *Optical Sensors*

As an RV comes closer to Kwajalein, it comes within the range of optical devices. In general, these are more accurate and sensitive than radars, especially in the last few critical seconds before an RV hits the ground or splashes into the lagoon. Optical sensors provide both metric and signature data.

The main optical installations are called RADOTs (recording automatic digital optical trackers). These are large instrument mounts which can swing rapidly on both a vertical and a horizontal axis to follow an RV. On each mount is fixed a varying assemblage of telescopes, video cameras, film cameras (movie and still), and related devices, all protected from the weather inside an astronomical observatory-type dome. There are 3 RADOTs and 4 Super RADOTs. The Super RADOT can track RVs at up to 3,000 km range.

Ballistic cameras give the most accurate observations of all. Painstaking measurements are made afterwards of their centimetre-thick photographic plates to provide trajectory measurements to within a few centimetres.

For more general surveillance, there are camera towers and closed-circuit TV towers. These record the last few seconds before splashdown, including the small explosion which indicates that arming and fusing of the RV has occurred.

An aircraft functions also as a sort of flying RADOT, operating above cloud cover. When RVs are targeted on the BOAs, other aircraft may be brought to Kwajalein to collect radar, optical and telemetry data beyond the range of the equipment on Kwajalein.

On Roi-Namur an infrared laser tracker with peak power of 50 megawatts is used to develop a database of laser cross-sections of RVs and their wakes. There are also two passive infrared sensors at Roi-Namur for collecting infrared signature data.

6. Telemetry Recording

As the RVs approach, radio transmitters on board broadcast data about such things as temperatures, accelerations and stresses. Aircraft involved in monitoring the tests also transmit monitoring information back to USAKA. All this data, called "telemetry", is monitored at USAKA by some 12 telemetry reception antennae that look like the range radars.

Equipment to allow extremely accurate pinpointing of RVs by use of the Navstar satellite Global Positioning System (GPS) was installed at USAKA in 1989. This system of multiple satellites allows a user to pin-point position and velocity with great precision.

7. Rocket and Missile Launchers

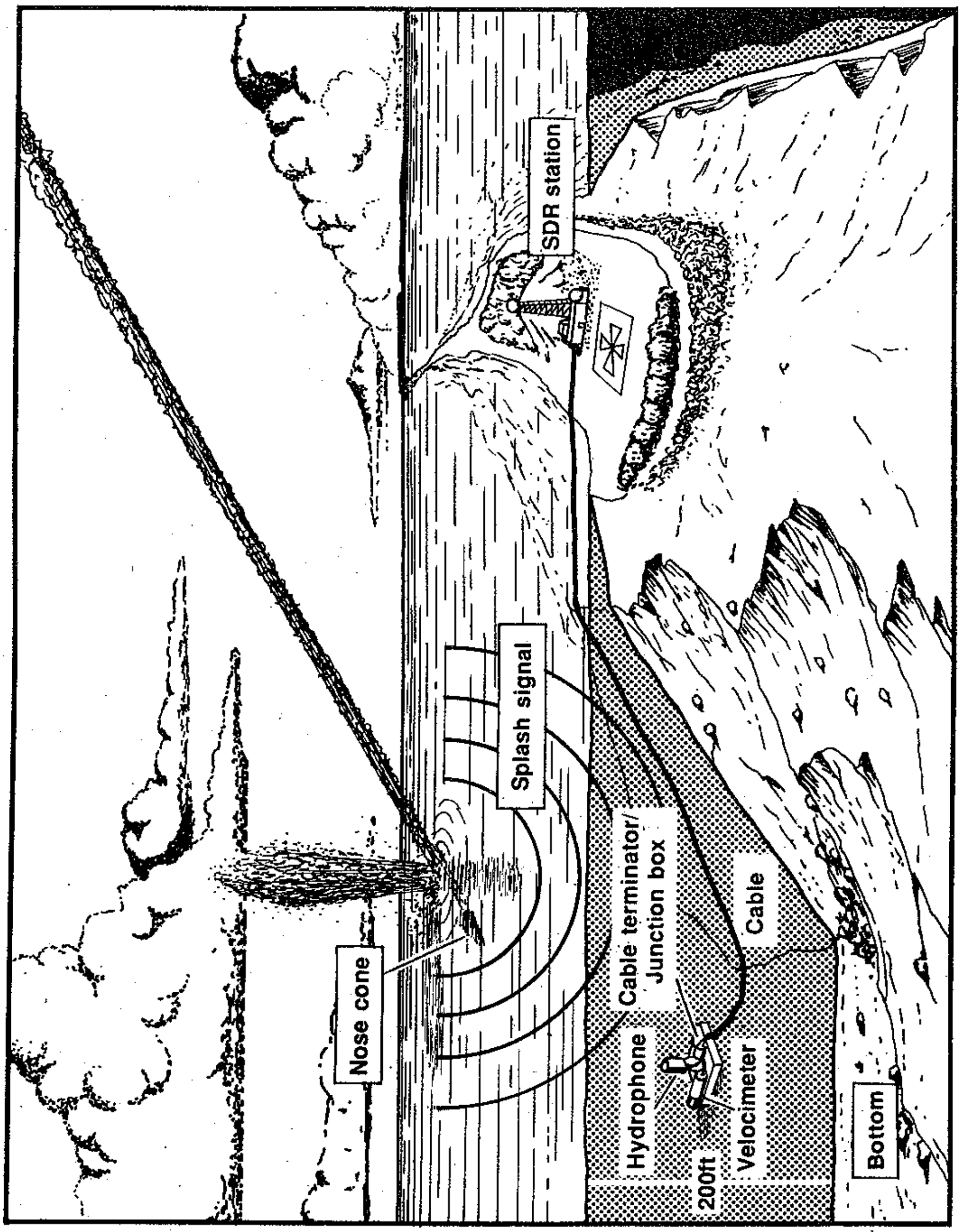
Seven launchers are dispersed around the atoll for launching meteorological and other rockets to measure environmental conditions during re-entries. In addition, various launch pads and silos for launching SDI interceptor and target missiles are planned or under construction.

8. Impact-Locating or "Scoring" Devices

At the down-range end of a missile test, the military are interested above all in knowing how accurate each RV is. In addition to all the tracking equipment, therefore, there is special equipment for determining precisely the impact point of every RV. When an RV hits the lagoon, it creates a 30-60-metre high splash, and small splash-detection radars on towers take a 12-metre accuracy fix on each splash. The Hydro-acoustic Impact Timing System (HITS) is even more precise, consisting of hydrophones on the lagoon bottom, which determine impacts to within about 5 metres (see Figure 1.4).

Many RVs are aimed at the BOAs located east and north of Kwajalein Atoll. Impact points here are measured by sonobuoys dropped beforehand by P-3 Orion aircraft. The sonobuoys in turn locate their own positions by interrogating permanent transponders on

Figure 1.4: HITS Shore Station



SDR Splash Detection Radar

the sea-floor called deep ocean transponders (DOTs). The DOTs, together with the sonobuoys, make up the Sonobuoy Missile Impact Location System (SMILS), which is accurate to within 12 metres.[11] More recently, sonobuoys have become capable of receiving Navstar signals that obviate the need for DOTs.

9. RV Recovery

USAKA has a two-person (yellow!) submarine and a team of divers for recovering RVs from the floor of the lagoon. For part of the re-entry, radio telemetry may be "blacked out" by an ionization sheath ("plasma") surrounding the RV. Some RVs contain flight recorders to preserve data which would otherwise be lost at this time. All RVs change shape during re-entry because they are covered by a heat shield which vaporises and carries heat away from the delicate electronics inside. Some RVs are designed to make "soft" splashdowns, so that these shape changes can be studied.[12] Other RVs are retrieved because of environmental concern about the depleted uranium ballast they contain, as well as to deny the Soviet Union any opportunity of retrieving the RVs for intelligence purposes.

10. Data Processing and Communications

A microwave communication network links all the instrumented islands on the atoll. This system allows all the instrumentation to be synchronized and co-ordinated during a mission

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11 *Strategic Systems Test Support Study: Final Report*, prepared by SIR International for the SSTSS Ad Hoc Executive Committee, November 1981, 3 vols. Released under the US Freedom of Information Act (FOIA) in October 1984. From here on referred to as *SSTSS*. For a brief summary of the *SSTSS* report, see J. Means, "Strategic Systems Test Support Reconfiguration", AIAA First Flight Testing Conference, AIAA-81-2483, November 1981.

12 M.Bunn, "Technology of Ballistic Missile Re-entry Vehicles", Chapter 6 in K.Tsipis and P.Janeway (eds), *Review of U.S. Military Research and Development*, (Pergamon-Brassey's, Washington, 1984).

countdown, and facilitates the rapid assembly of the enormous amounts of data accumulated by all the sensors and telemetry receivers (see Figure 1.5).

A substantial amount of data processing and reduction can be done on the atoll, particularly for "quick look" results. The bulk of the processing, however, is done elsewhere, with the data being sent either electronically or on magnetic tapes.

A big 20-metre AN/FSC-78 satellite dish antenna on Kwajalein Island relays data through the East Pacific Defense Satellite Communications System (DSCS) satellite to similar FSC-78 terminals located at:

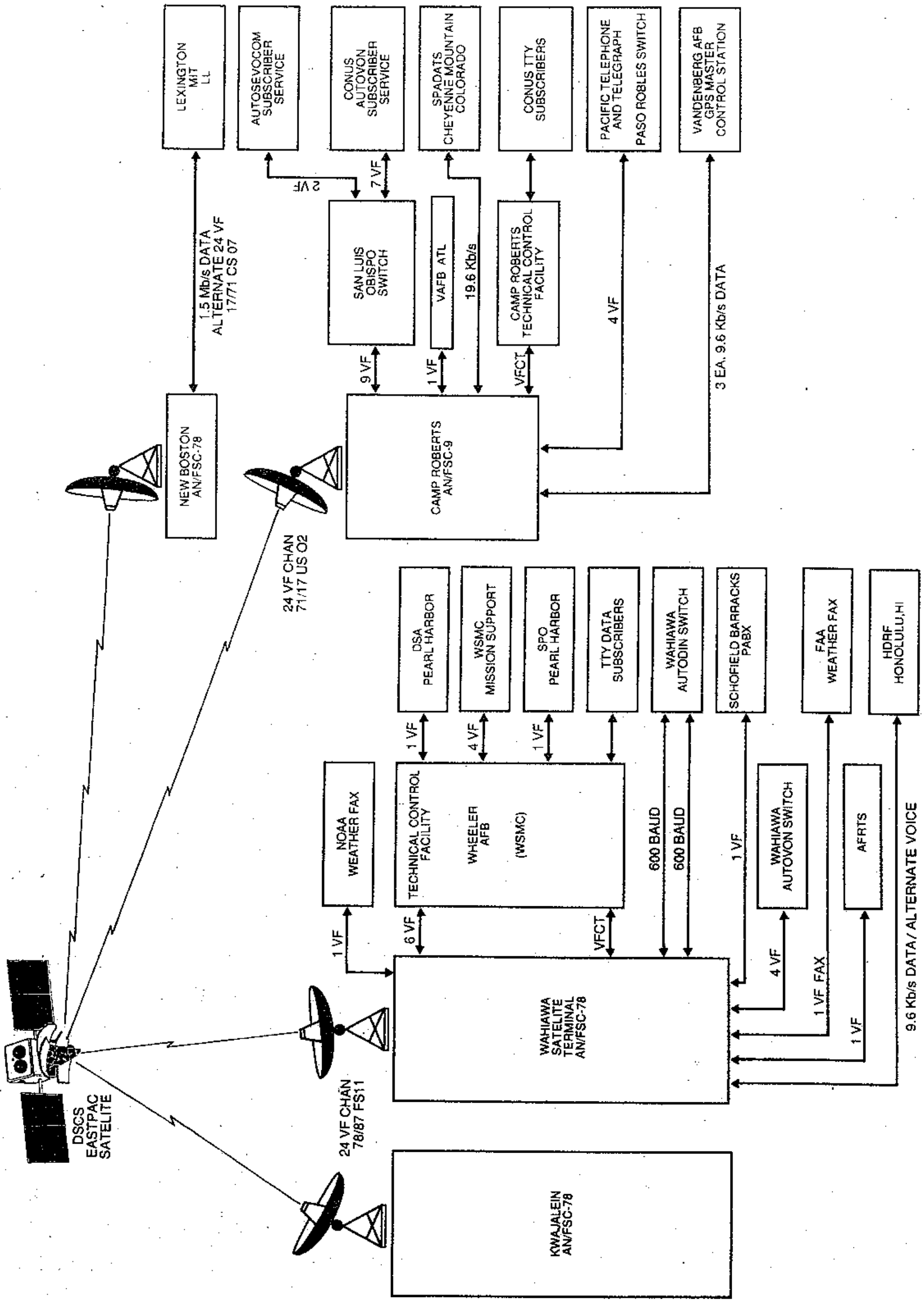
* Wahiawa in Hawaii, for near-instantaneous transmission of bulk data to the Honolulu Data Reduction Facility, where most of the flight test analysis is done. This link also provides a connection to Pacific-wide military and commercial communication networks.

* Camp Roberts in California, for near-instantaneous transmission of spacetracking data from KREMS to the USAF Space Command in its command post 400 metres under Cheyenne Mountain, Colorado, and for command control links with Vandenberg. This link also connects Kwajalein to the US Army Ballistic Missile Defense Systems Command in Huntsville, Alabama, and to continental US military and commercial communication systems.

* New Boston, in New Hampshire, whence a dedicated microwave link carries bulk re-entry phenomenology data from KREMS to Lexington, Massachusetts, where KREMS data is analyzed by Lincoln Laboratory. Data starts flowing into Lincoln Laboratory about two hours after the test is completed at Kwajalein (see Figure 1.5).

Bulk encryption is applied to all channels, and some channels are secure to Top Secret levels. At the Honolulu Data Reduction Facility, flight test data is digitized, processed and compiled

Figure 1.5: Data Flow from Kwajalein Facilities



as signature, trajectory, and impact reports for distribution within the ballistic missile research and development (R&D) community.

The collection of sensors and other support systems described above has no parallel. As a US Army Secretary expressed it 13 years ago:

> The Free World possesses no comparable capability to (1) collect exo-atmospheric signatures data, (2) record missile re-entry phenomena, (3) provide terminal trajectory and impact data, (4) recover re-entry vehicle structures, and (5) transmit near real time data via satellite to the mission sponsors in the United States.[13]

D. USAKA as Part of a Larger Complex

USAKA is administered as though it were an independent, self-contained entity confined to Kwajalein Atoll. By itself, however, USAKA would be almost useless. Neither ballistic missile testing, RV phenomenology studies, nor SDI testing could take place if there were no ballistic missiles being launched from other ranges toward Kwajalein. In practice, a number of other facilities contribute to the test activities centered on USAKA. Together, these are loosely referred to as the Western Test Range and are described below roughly in east-to-west order:

1. *Western Space and Missile Center (WSMC), Vandenberg AFB.*[14] WSMC supports developmental and operational testing of all US ICBMs and all re-entry technology launches. These tests terminate at USAKA and at BOAs. It also serves for all non-shuttle launches of

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13 E.Miller, Assistant Secretary of the Army for R&D, prepared statement, in US Congress, Senate Committee on Armed Services, *Hearings on Military Procurement for Fiscal Year 1977*, Part 6, pp. 3108-9.

14 *Land-based Instrumentation Systems Handbook*, Western Space and Missile Center, Vandenberg Air Force Base, prepared by ITT Federal Electric Corporation, 10 November 1987, released under FOIA.

satellites into high inclination ("polar") orbits. For these purposes, Vandenberg has a number of launch pads as well as ICBM silos for operational test launches. Associated with Vandenberg and distributed north and south along the Californian coast are a wide range of radar, optical, and meteorological sensors, together with telemetry reception, command, and communication facilities (see Figure 1.6). These systems are analogous to those at USAKA, but are used to monitor and control the boost phase, rather than the re-entry phase, of each missile flight or satellite launch.

2. *Pacific Missile Test Center (PMTC), Point Mugu, California.*[15] PMTC is the "lead range" for Trident SLBM test launches off the California Coat to Kwajalein. The SLBMs are actually fired from submarines offshore.

3. *Facilities located on Hawaii.* The Hawaiian Islands straddle the groundtrack of missiles launched from Vandenberg towards Kwajalein, and are located halfway along the groundtrack. They are thus ideal for various forms of mid-course monitoring. These facilities include:

- Kaena Point, Oahu, where an FPQ-14 on-axis tracking radar is located;
- Wheeler AFB, Oahu, a relay point for inter-range communication;
- Barking Sands Pacific Missile Range Facility, Kauai (PMRFK). Used for launching intermediate range (retired Polaris and Poseidon) missiles, at Kwajalein as targets for ABM systems undertest there (see Chapter 6);
- Maui Optical Station (AMOS), on the summit of Mount Haleakala. AMOS is a highly classified

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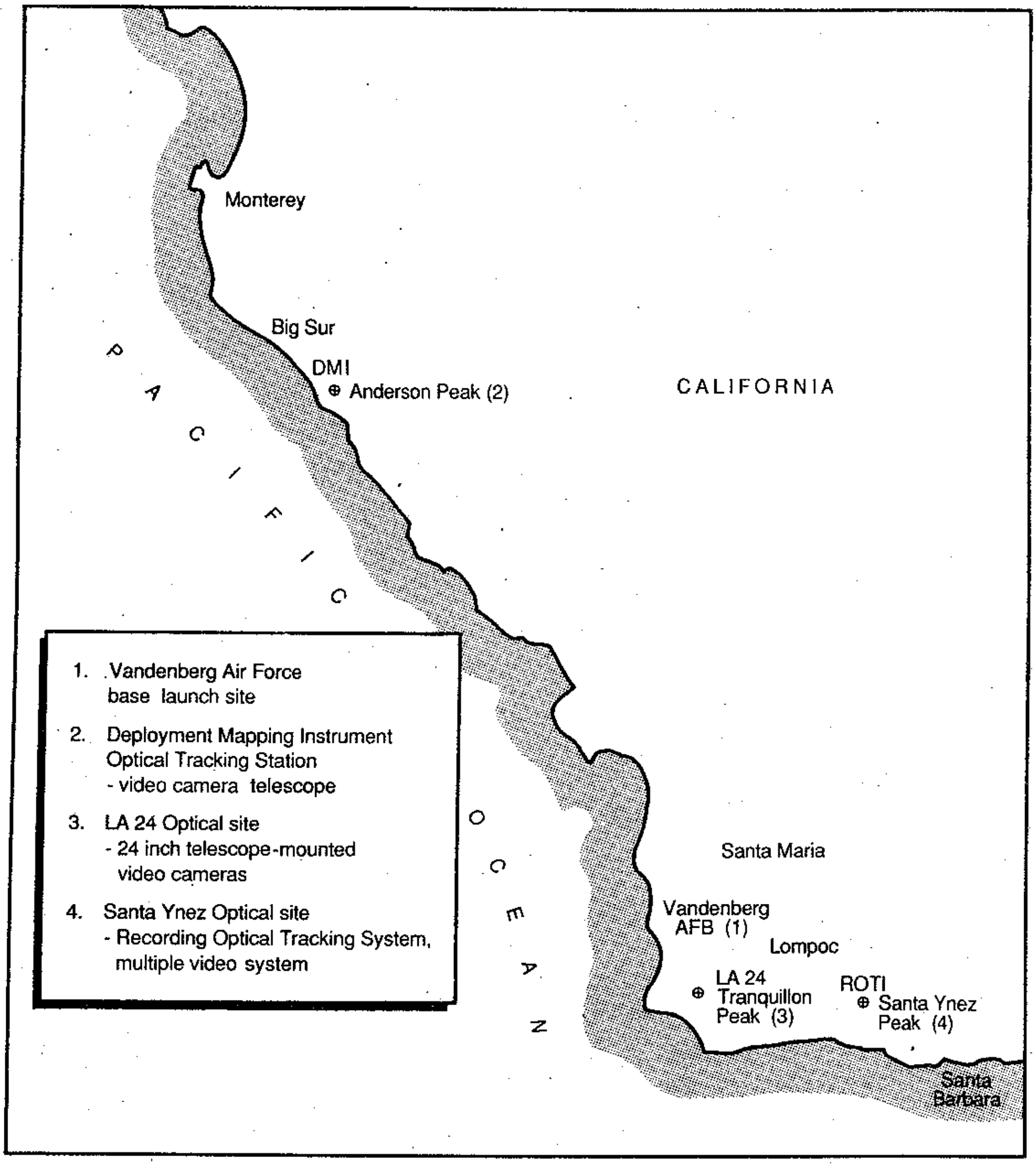
15 *Major Range and Test Facility Base: Summary of Capabilities,* DoD 3200.11D, Under-Secretary of Defense for Research and Engineering, June 1983, p.25; Pacific Missile Test Center (PMTC), *PMTC Organizational Manual,* COMPMTCINST 5451.1D, (PMTC, Point Mugu, California, 6 June 1988); see also PMTC, *Days of Challenge and Years of Change: A Technical History of the Pacific Missile Test Center,* (US Government Printing Office, Washington DC, 1989).

Figure 1.6: Vandenberg Air Force Base and Related Support Facilities



operation run by DARPA. Not actually part of the WTR, it takes advantage of missiles passing overhead for various optical, infrared and laser studies, now mostly linked to SDI.

4. *Midway Atoll.* Has served as site for ICBM impact location, especially in the early days, but has no known current role.

5. *Johnston Atoll.* This little-known atoll was used for launching Thor targets towards Kwajalein for use as Nike-Zeus targets in the sixties. It has no known current role in ballistic missile tests.[16]

6. *Wake Island.* Has on occasion been used to launch Athena target missiles mimicking SLBMs towards Kwajalein for BMD tests, at least until 1972. It was used in the past for ICBM impact acoustic location.

7. *Canton, Enderbury, and Hull Islands (Phoenix Group).* Detection, tracking, impact, and scoring sensors were operated on these three islands until 1975, for splashdowns in a BOA lying between them. This triangular area, about 150 km across, was known as the Western Terminal Complex of the Space and Missile Test Command (SAMTEC) that runs the tests in the Pacific. The TPQ-18 radar now on Kwajalein Island was previously on Canton.By agreement with Kiribati, the island state that now owns these islands, the United States retains access to Canton if needed.

8. *Enewetak Atoll.* To the northeast of Kwajalein, served as the original impact site for ICBM tests until 1962, when the tests were switched to Kwajalein.

9. *Other BOAs.* There are several other BOAs in the Pacific, described in Chapter 3.

10. *Indian Ocean BOA?* According to the US Air Force, "the Western Test Range extends from the California Coast to 90° Longitude in the

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16 Johnston is still designated as the launch site for a half-dozen or so rockets and nuclear warheads stored on the mainland to enable the United States to rapidly resume atmospheric nuclear testing, a program known as Safeguard C. D. Evans, "U.S. Spending Millions on Plan to Restart Pacific Nuclear Tests", *Chicago Tribune,* 26 August 1990.

Indian Ocean where it meets the Eastern Test Range".[17] Whether there are any instrumented BOAs in the Indian Ocean is not known, but at least one Star Wars intercept has taken place there.

E. Command Structure

There appears to be no overall management structure for US missile testing in the Pacific area. Three main chains of command relate to missile tests. These are: (1) an Air Force chain which handles ICBM launches and is in charge of the up-range activities centered on Vandenberg AFB; (2) a Naval chain which handles SLBM launches and operates PMTC and mid-range facilities; and (3) an Army chain which handles ABM/BMD/SDI activities and is in charge of USAKA.

Air Force Chain. Until 1989, the Western Test Range was subordinate to the USAF Space and Missile Test Organisation, which in turn is under the Air Force Systems Command (see Figure 1.7a). After October 1989, SAMTO was abolished.[18] Since then, the Western and Eastern Space and Missile Centers have reported directly to the US Air Force Space Command, thereby trimming costs (see Figure 1.7b).

At the WTR, the 6595th Missile test group is in charge of all missile launches. The actual launches may be made by contractors (developmental tests), by the WSMC itself (re-entry technology tests and target launches requested by Army BMD program) or by operational Strategic Air Command (SAC) units (operational tests, some BMD target launches).[19]

WSMC is lead range for all ICBM launchings, and appears to be in charge of the MX BOAs other than USAKA East and North, while the ETR is in charge of the ARIA aircraft used to service these BOAs.

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17 *Air Force Western Test Range, Backgrounder,* "current as of November 1986", supplied by Space and Missile Test Organization, July 1987.

18 US Air Force, *America's Western Spaceport: A Historical Perspective,* Fact Sheet 900-2, (1st Strategic Aerospace Division, Vandenberg AFB, January 1990), Attachment 1, p.4.

19 The three classes of tests are defined in Chapter 3.

WSMC is a support range for Pacific SLBM operations. Vandenberg AFB itself is a SAC base on which WSMC is a tenant.

Navy Chain. The Pacific Missile Test Center (PMTC), Point Mugu, California is subordinate to the Naval Air Systems Command, which in turn is under the Chief of Naval Material, who reports to the Chief of Naval Operations (see Figure 1.8).

Under PMTC's command are the Pacific Missile Range, off Point Mugu, from which Trident submarines fire operational test launches; the Pacific Missile Test Range Facility in Hawaii, which makes target launches to Kwajalein; and the Kaena Point mid-range radar. PMTC is the lead range for SLBM tests in the Pacific, but the actual launches are carried out by operational submarine crews under the Commander, Submarine Force, U.S. Pacific Fleet, who in turn is under the U S Commander-in-Chief, Pacific (CINCPAC) and his SSBN Operations Branch. PMTC may administer the BOAs established at Oeno and in the western Pacific for Trident.

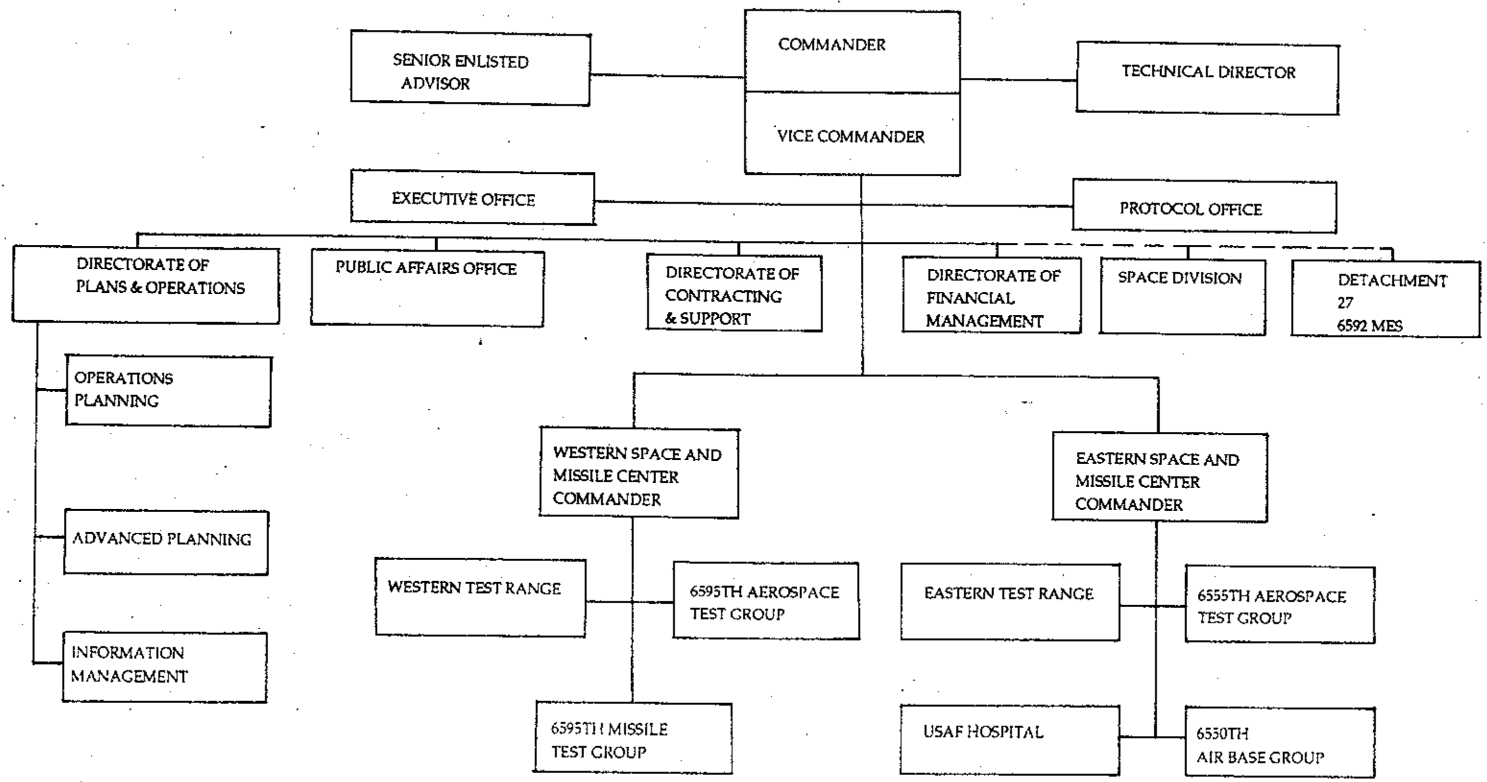
CINCPAC is responsible for delegating and co-ordinating "programs for specific missile and spacecraft impact, landing and/or recovery operations".[20] As part of his operational control over fleet ballistic missile (FBM) submarines, he states that he conducts "FBM weapon system operational tests (OTS) and follow-on operational tests (FOT) in the USPACOM ... The FBM weapon system test program validates FBM weapon system reliability and accuracy planning factors for use by the JCS in the SIOP".[21]

Commander, Third Fleet (under the Commander-in-Chief, US Pacific Fleet or CINCPACFLT) is responsible for the scheduling of the

20 CINCPAC, "Missile and Spacecraft/Space Shuttle Impact, Landing and/or Recovery Support in the PACOM Area", Instruction 3730.2B, dated 13 May 1980. Supplied under FOIA.

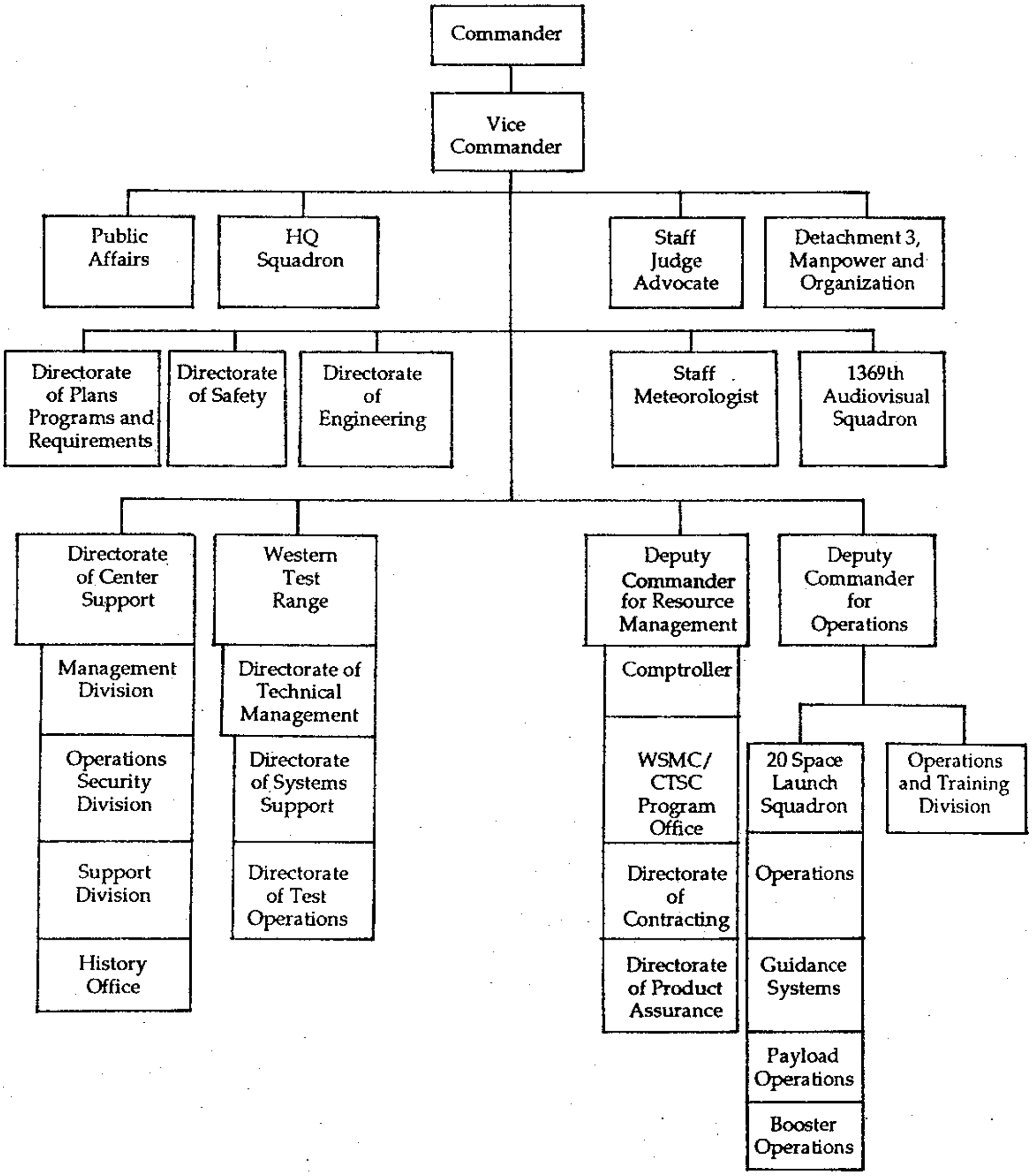
21 US CINCPAC, "USCINCPAC Fleet Ballistic Missile (FBM) Submarine Policy", USCINCPAC Instruction S3350.1A, 31 May 1984, p.5; partly declassified under US FOIA to Peter Wills.

Figure 1.7a: Air Force Command Structure, Space and Missile Test Organization



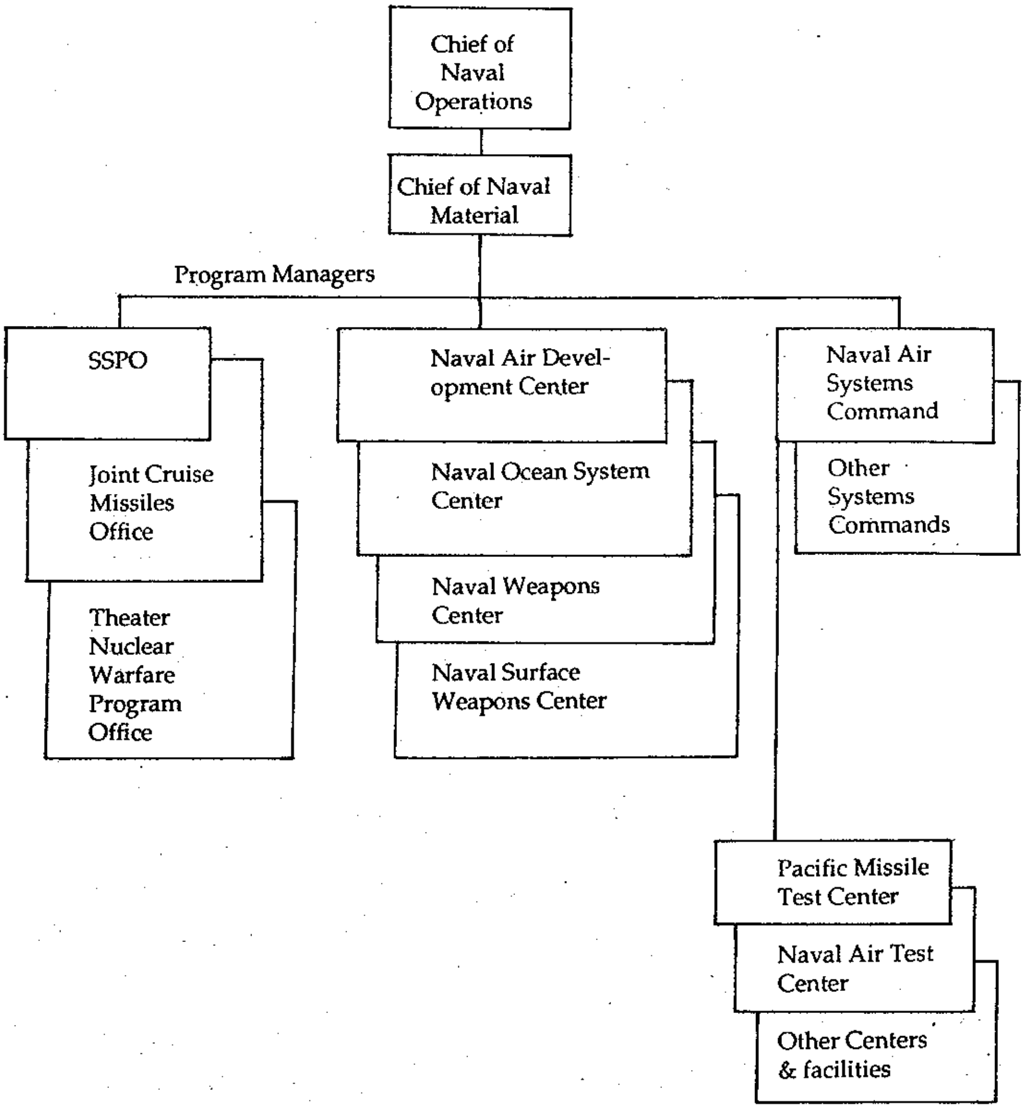
Source: Public Affairs Office, Vandenberg AFB, January 1991.

Figure 1.7b: Western Space and Missile Center, October 1990



Source: Public Affairs Office, Vandenberg AFB, January 1991.

Figure 1.8: Navy Command Structure



Pacific Missile Test Center facilities on Hawaii used in SLBM operational tests.[22]

CINCPAC's SSBN Branch states that it runs two types of tests. First is the *Operational Test,* which is:

> A test program for exercising the operational system in as near an operational environment as possible to determine weapon system reliability and accuracy factors under simulated tactical conditions.[23]

Second is the *Follow-on Operational Test,* which is:

> A test program conducted on a continuing basis to ensure the maintenance of established weapon system reliability and accuracy factors during the life of the weapon system.[24]

These tests are conducted under conditions of strict secrecy. "Communications while operating in the launch area", states CINCPAC, "will be minimized and the most secure means available will be used" to avoid divulging information "which will indicate the nature of the operation."[25]

Such tests require that a patrolling submarine be "stood down" or diverted from its SIOP target commitment for the duration of the test.[26]

Tests that mimic reality could also look like a Soviet attack on the United States to US early warning monitors (or like a US attack *on* the Soviets to the Soviets). Accordingly, CINCPAC has to approve the test schedule, and co-ordinates the tests with North American

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22 COMTHIRDFLT, "Scheduling and Coordination of Fleet Operations Using Pacific Missile Test Center and Pacific Missile Range Services", Instruction 3500.5B, dated 3 December 198x [illegible]. Supplied under FOIA.

23 CINCPAC, "CINCPAC Operational Test Plan for the Fleet Ballistic Missile Weapon System", Instruction 5341, 4 June 1982, partly released under FOIA.

24 *Ibid.*

25 *Ibid.*, p.3.

26 *Ibid.*, p.R-1.

Aerospace Defense Command (NORAD) in Colorado, the nerve center of the US early warning system.[27]

Army Chain. USAKA is a subordinate Command of the US Army Strategic Defense Command, located in Huntsville, Alabama, and is administered by a USAKA Directorate at Huntsville (see Figure 1.9). Under the Commander, USAKA, are USAKA field offices in Huntsville, Honolulu and Majuro (capital of the Marshall Islands), as well as the Range Command itself. Under the Range Command is a field office at Vandenberg and a liaison office at the Lincoln Laboratory (which operates KREMS).

The Strategic Defense Command is also in charge of all the SDI operations at Kwajalein, which it carries out on behalf of the SDI Organisation (SDIO, an agency of the US Department of Defense in charge of Star Wars). This arrangement has been of some concern to other users of Kwajalein, who thought that the Army might give preference to its own SDI programs at the expense of those of other organizations.

The KREMS radars are operated by contractors on behalf of the Lincoln Laboratory, which itself is funded and controlled by the Army Strategic Defense Command.

The USAKA commander also functions as CINCPAC representative to the Republic of the Marshall Islands.[28]

Cross-links between the Chains. It is not clear how all these organisational chains intermesh. It seems that all activities requiring only USAKA facilities are co-ordinated by USAKA and the sponsoring organisation. For activities involving the WTR, achieving the requisite co-ordination for conducting tests is more complicated:

> Prospective users of the WSMC range facilities document their requirements through the National Range Universal Documentation System (UDS). Supplemental land and mobile instrumentation

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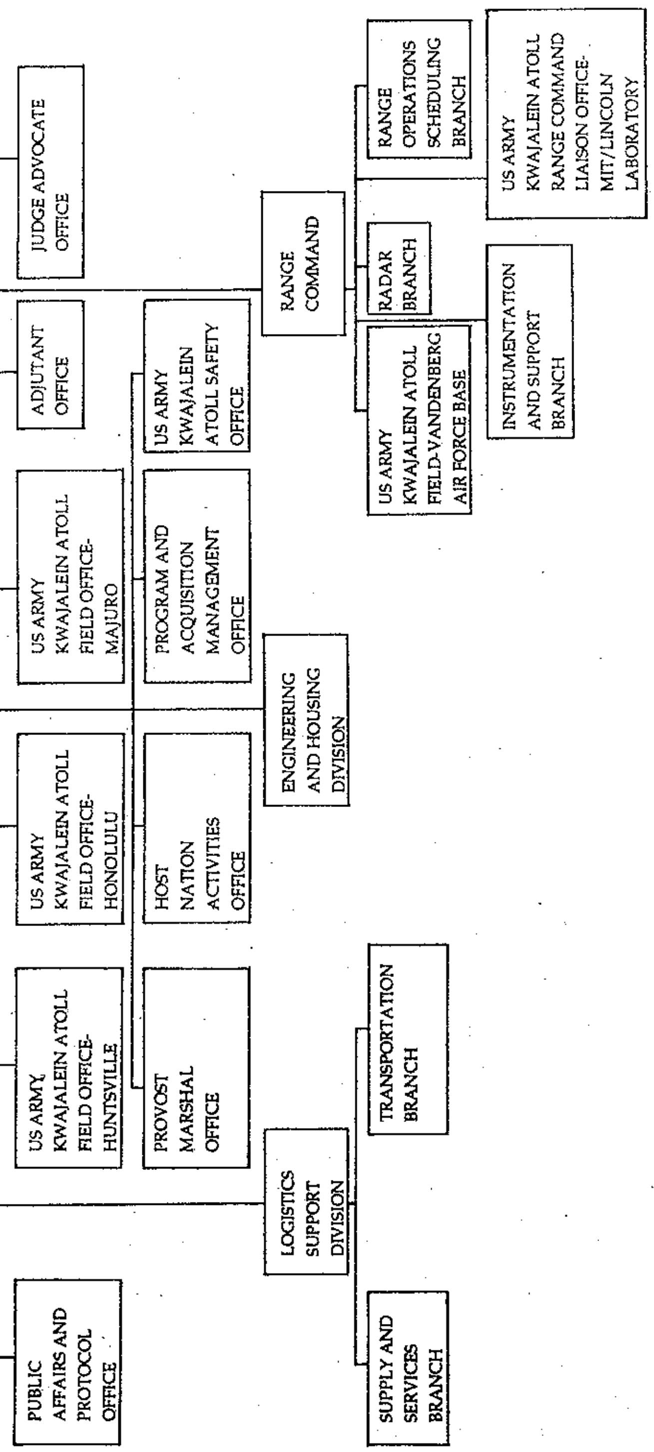
27 *Ibid.*, p.J-1.

28 *USAKA Mission and Function Statement*, USASDCR 10-1, December 1987, part 1, p. 19.1.

Figure 1.9: Army Command Structure, US Army Strategic Defense Command, US Army Kwajalein Atoll



> support is provided by other facilities (Kwajalein Missile Range (KMR), [that is, USAKA], Pacific Missile Test Center (PMTC) ... and agencies (NASA ... Defense Advanced Research Projects Agency, other AFSC, Pacific Missile Range Facilities Hawaii ...) in support of ballistic ... operations under the DoD [US Department of Defense] lead range concept. This policy allows WSMC to serve as the focal point for submission of all test requirements and to co-ordinate with other ranges and agencies in providing the required test capability for the respective programs ... A Joint Pacific Area Scheduling Office (JPASO), established by OUSDRE [Office of the Under-Secretary of Defense for Research and Engineering] and located at WSMC, is a centralized scheduling and co-ordination facility for Pacific Area strategic test operations. The JPASO consists of representatives from the Air Force, Army, Navy, DARPA, NASA and their technical support contractors. The JPASO is the single information source for sensor status and availability and has the authority to issue a consolidated forecast schedule.[29]

The WSMC's Scheduling Control Branch issues pre-launch safety notifications of impending missile launches to Air Route Traffic Controllers in Oakland, Honolulu and Los Angeles; and to Defense Mapping Agency in Washington, DC and a variety of US Coast Guard offices.[30]

There are a variety of other horizontal links which remain to be investigated. Some of the information-flow links are shown in Figure 1.4. Other presumed links which have not been documented are:

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29 "T&E Support Resource Plan Part III: Western Space and Missile Test Center FY 82-89, Vandenberg AFB", p. III-1-2. Material omitted from quote concerns space launches.

30 Western Space and Missile Center, "Prelaunch Hazard Notice", WSMC Regulation 127-7, 3 December 1985, p.4.

* those between the WSMC and the Space Command, for joint use of the PACBAR radars (PACBAR is explained in the next section. The Saipan radar, northwest of Kwajalein, is primarily for PACBAR, and secondarily for the nearby MX BOA, while Altair is primarily for USAKA, and secondarily for PACBAR);
* those for conveying intelligence information collected by KREMS about Soviet missiles to the relevant US intelligence agencies - including the Army Missile Intelligence Agency at Huntsville, Alabama;[31]
* those between between WTR and the US State Department. These presumably pass through the Defense Department's Office for International Security Affairs to the State Department's Bureau of Politico-Military Affairs. Such links are involved in the negotiations for use of foreign facilities during missile testing,[32] and for forwarding advance information about planned tests to the Soviet Union;
* those between USAKA and the US Department of Interior and the US Department of State that pertain to relations with the Marshalls Islands Government and the Kwajalein landowners.

F. Other Activities

The flight testing activities at Kwajalein are described in Chapter 3, and SDI-related activities are described in Chapter 4. The remainder of this chapter describes some of the other activities carried out at Kwajalein.

Some of these activities are located at Kwajalein to take advantage of the missile re-entries as targets of opportunity. Other activities are located at Kwajalein to make use of the radars already

31 J.Richelson, *The US Intelligence Community*, (Ballinger, Cambridge, Massachusetts, 1986), p.69.

32 For example, staging bases for missile range aircraft. See *SSTSS* vol.1, p.68.

there for the flight testing. Still others are at Kwajalein to take advantage of its geographic location.

Space Tracking

USAKA hosts a variety of space tracking activies. These include "special Space track missions for the US Intelligence Community".[33]

These and other more dominant missions are located at Kwajalein to take advantage of the superlative qualities of the KREMS radars. Moreover, Kwajalein's location is ideal for monitoring Soviet and Chinese satellites early on in their first orbits after launch. The near-equatorial location is also ideal for monitoring equatorial orbit geosynchronous satellites.

Most Soviet space launches are made in a northeasterly direction from the Baikonour cosmodrome in the Soviet Union. Such launches have a ground track which heads towards the Arctic, then curves and passes southeast across the western Pacific, before swinging northeast again so as to pass over North America. Kwajalein lies under the southeast leg of this ground track. To cover it, the USAF Space Command uses the big Altair radar on Roi-Namur; a GPS-10 radar, formerly at San Miguel, but recently moved to Clark Air Base in the Philippines; and a specially constructed radar on Saipan known as a "Pacific Radar barrier" (PACBAR) to monitor all Soviet space launches.[34] (The Saipan radar in turn has a secondary role of providing metric data for missile launches into the nearby BOA.)

Altair needs only 15 minutes' warning of the launch of a new satellite to get a first-orbit fix, and it does so for 93 per cent of Soviet and Chinese launches.[35]

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33 US Congress, Senate Appropriations, *Hearings on Defense Appropriations, Fiscal Year 1977*, part 4, p. 1135.

34 "Altair to Enhance Space Surveillance", *AWST*, 14 July 1980.

35 K.Roth, M.Austin, D.Frediani, G.Knittel and A.Mrstik, "The Kiernan Reentry Measurements System on Kwajalein Atoll", *The Lincoln Laboratory Journal*, Summer 1989, p. 259.

Altair also tracks over 1,000 deep space satellites per week, two-thirds of all such tracks obtained by the US Space Command. The Tradex radar has better resolution than Altair, and is used to track satellites at up to 45,000 km range, far beyond that of most other satellite tracking radars.

Alcor specializes in imaging[36] foreign satellites as part of the Space Object Identification (SOI) program of the USAF Space Command. The images of satellites at 200 km or more altitude, prepared by inverse synthetic aperture radar,[37] are of near-photographic quality and can be used to assess the size, shape and configuration of "non-co-operating"[38] satellites. The MMW radar generates even better images of satellites for SOI purposes.[39]

USAKA is one of 27 installations around the globe carrying out cataloguing of space objects for the SPADATS program of the USAF's Space Command.

Apart from tracking foreign satellites for intelligence purposes, USAKA, because of its location, is "critical for tracking the space shuttle and other United States ... space objects".[40]

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36 The verb "to image" has come into favour to describe the making of photograph-like images by processes other than photography. Thus Alcor and MMW are imaging radars, while the others are metric radars.

37 Inverse SAR is described in E.Brookner, "Radar Imaging for Arms Control", Chapter 11 in K.Tsipis, D.Hafemeister, and P.Janeway, *Arms Control Verification: The Technologies That Make It Possible*, (Pergamon-Brassey's, Washington, 1986), pp. 151-154.

38 That is, satellites which do not broadcast their own identification. The term primarily refers to foreign (that is, Soviet) satellites, but also to dead satellites, old boosters and the like, which all need to be identified to ensure that they pose no threat.

39 Roth *et al.*, "The Kiernan Reentry Measurements System on Kwajalein Atoll", p.268.

40 *DEIS*, p. ES-2.

Intelligence

USAKA, "through the use of sensing and tracking capabilities", monitors "missile launch activities of foreign nations".[41] In 1961, *Aviation Week and Space Technology* observed that: "The opportunity to develop methods of identifying Russian warheads by studying actual Russian warheads is obviously too good to miss".[42] Kwajalein is officially described as a "prime station for early detection of foreign launches and ... precise trajectory determination and signature measurements of suborbital launches".[43]

Again, it is the KREMS radars which primarily serve in this role, for many Soviet missile testing re-entries are made into the northern Pacific, often well within tracking and signature determination range of the KREMS radars.

Nuclear-Effects Research

Important research on the effects of nuclear explosions on early warning radars and on satellite communications has been carried out at Kwajalein by the Defense Nuclear Agency (DNA) as part of its so-called Wideband project. Since the 1962 Test Ban Treaty bans atmospheric tests, the DNA had to simulate the nuclear-induced ionization by disseminating billions of tiny metal particles in the ionosphere, creating "the prettiest sunsets you'd ever see" at Kwajalein.[44] Effects on Altair radar signals were measured.

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41 *DEIS*, p. 1-2.

42 "Missile Defense Dominates PMR Efforts", *AWST*, 17 April 1961, p.16.

43 *Major Range and Test Facility Base: Summary of Capabilities*, Under-Secretary of Defense for Research and Engineering, June 1983, p.5.

44 G. Zorpette, "Kwajalein's New Role: Radars for SDI", *IEEE Spectrum*, vol. 26, no. 64, March 1989.

Nuclear Warfighting Exercises

Some ICBM launches are rehearsals for nuclear war. On 10 July 1979, SAC crews launched two Minuteman missiles within 12 seconds of each other as part of the global SAC exercise called Global Shield 79, which simulated a full nuclear war.[45] These missiles re-entered at Kwajalein.

Anti-satellite Weapons System (ASAT)

The USAF's most recent and non-nuclear anti-satellite interceptor has been successfully launched from a fighter aircraft against an orbiting satellite over Kwajalein. Kwajalein radars observed the intercept. Kwajalein has been suggested as a suitable location for an operational ASAT.[46] The program, however, has reportedly been cancelled.

Radiological Surveys of Bikini and Enewetak

Kwajalein provides support for annual surveys by the Defense Nuclear Agency of the former nuclear test sites at Bikini and Enewetak Atolls.

Defense Meteorological Satellite Program

About two meteorological rockets per week were launched for several years in the early 1980s to provide "ground truth" calibration data for the Defense Meteorological satellites. These satellites are used to map cloud cover for spy satellite scheduling. They would also report on weather within the Soviet Union if the United States should launch a strategic nuclear attack against the Soviet Union.

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45 "Kwajalein Targeted for Missile Test", *Honolulu Advertiser*, 10 July 1982, p. A-12.

46 Stockholm International Peace Research Institute, *SIPRI Yearbook 1990*, (Oxford University Press, London, 1990), p. 70.

Emergency Rocket Communications System (ERCS)

This system is one of the United States' last-ditch communication systems in the event that all other communication systems are destroyed in a nuclear war. It consists of radio transmitters in the nose cones of selected Minuteman missiles which can broadcast launch orders to all other US strategic weapon systems. ERCS is tested once a year, and monitored from Kwajalein.

Navstar Global Positioning System (GPS)

GPS is the main navigation aid and precise positioning system for the US military. It consists of 18 satellites and several ground monitoring stations. Since 1984, one of these ground stations has been at Kwajalein.

Short-Range Attack Missile (SRAM)

This is a "stand-off" strategic nuclear missile intended for B-52s and FB-111s. It was tested from B-52s at Kwajalein in 1980.[47]

Stratsec Experiment

This was an experiment in very low frequency (VLF) communications in a "post-nuclear environment". Balloons were launched from Kwajalein carrying a 6,000-metre antenna and transmitter in 1983 and 1984. Receivers were deployed at Guam and Wake.[48]

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47 *Annual Historical Review, Kwajalein Missile Range,* US Army Ballistic Missile Systems Defense Command (henceforth referred to as *Annual Historical Review*), 1979-1980, p. 14, and 1980-1981, p. 24. Released under FOIA.

48 *Annual Historical Review*, 1982-1983, p. 24.

All this activity did not spring up overnight. The next chapter describes the historical origins of the current activity at Kwajalein.

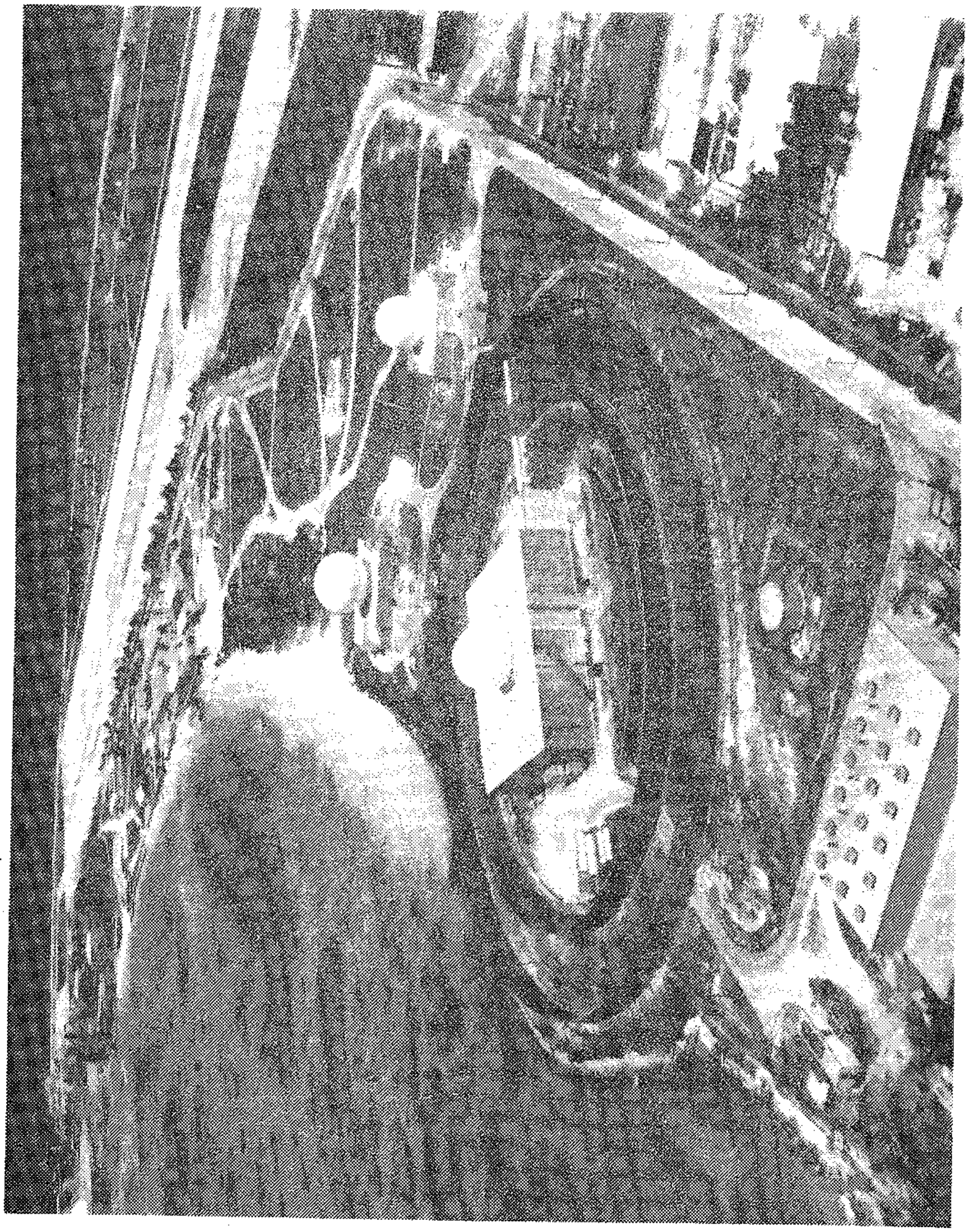

Plate 2: Radar Sites at Kwajalein Atoll (USAF Photo)

CHAPTER 2

PACIFIC BALLISTIC MISSILE TEST ARENA[1]

The history of Kwajalein is inseparable from the history of missile and anti-missile testing in the Pacific. This chapter looks at the history of US missile flight testing only. The Soviet Union has tested fewer ballistic missiles in the Pacific, but has been active almost as long as the United States. China, too, has tested its ballistic missiles into the Pacific. Cruise missiles have also been tested in the Pacific, but are not covered in this report. Figure 2.1 and Tables 2.1 and 2.2 summarise the numbers and types of US ballistic missile tests in the Pacific.

A. Origins of Kwajalein Range, 1940s-1959

The military history of Kwajalein Atoll began in 1935 when Japan, then the occupying power, began fortifying the islands of the Marshalls group as part of its push southwards. Kwajalein was seized from Japan in 1944 by US forces after a particularly intense and sustained bombardment. It was used in the forties and fifties as a support base for the nuclear tests at Bikini and Enewetak. Flights also transited Kwajalein for the Korean War airlift. By 1958, no more nuclear tests were planned for Micronesia, and the Navy placed Kwajalein on the military base surplus list. For five months it looked as though the Marshallese would be allowed to opt out of the nuclear arms race. This was not to be, however. The Army was looking for a safe place to test anti-ballistic missiles against ICBM targets, and in February 1959 it selected Kwajalein Atoll. This decision was the result of intense inter-service rivalry to lead in deployment of ballistic missiles as the Cold War intensified.

The first Soviet ballistic missile test in August 1957 and the Sputnik scare of October 1957 led to fears in the United States of a surprise Soviet missile attack. The US Army in 1956 was already planning to build an ABM system against the contingency of a Soviet

1 The title is a quote from the *SSTSS* study, which drafted "plans for using the Pacific as a ballistic missile test arena". See footnote 11, Chapter 1: *SSTSS*, vol. 1, p. 68.

Figure 2.1: ICBM and IRBM Launches from Vandenberg, 1959-1989

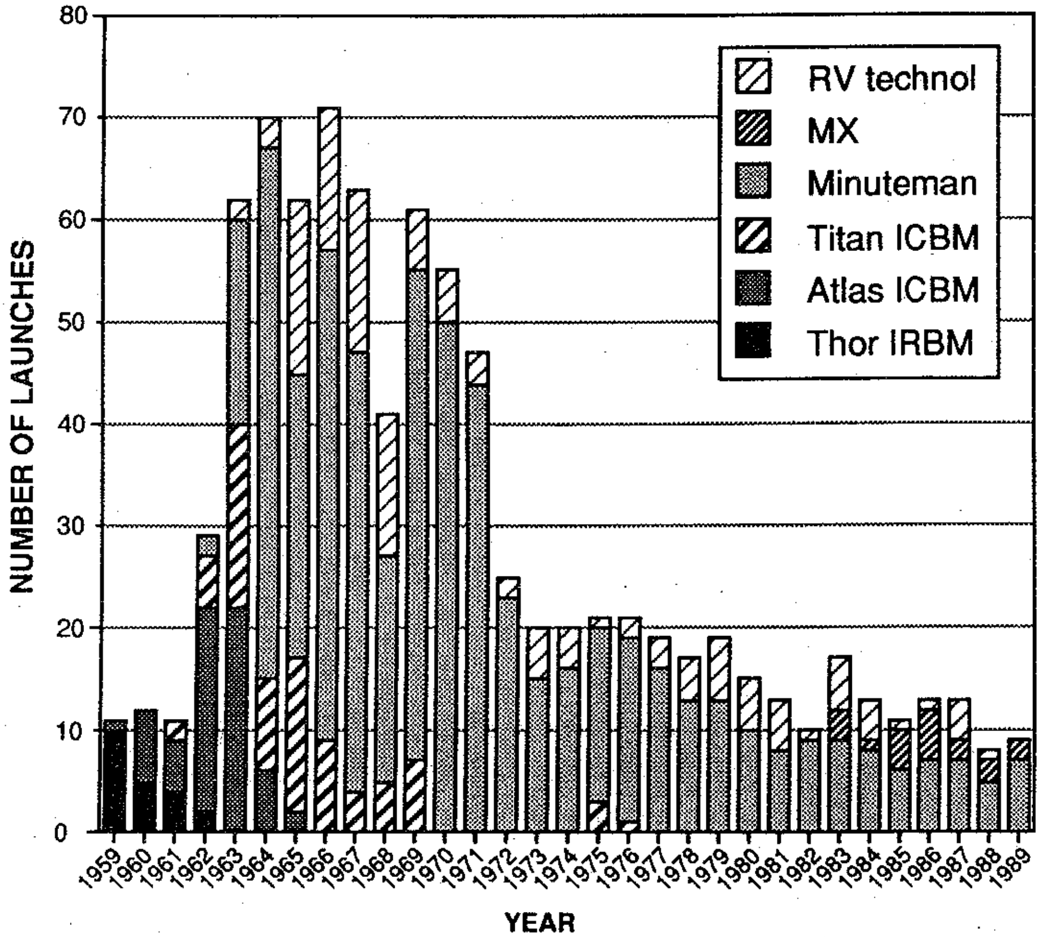

Table 2.1: Ballistic Missile Flights on Western Test Range, 1959-1989

	Missile Type											
Year	1	2	3	4	5	6	7	8	9	10	11	12*
59	10	1										11
60	5	7										12
61	4	5	2									11
62	2	20	5	2			3					32
63		22	18	20			7	2				69
64		6	9	52			3	3				73
65		2	15	24	4			17				62
66			9	39	9			14				71
67			4	34	9			16				63
68			5	10	12			14				41
69			1	18	25	5	1	6				56
70				15	25	10	3	5				58
71				11	16	17	7	3				54
72					9	14	6	2				31
73					5	10	9	5				29
74					5	11	6	4	3			29
75			3		3	11		1	7			25
76			1		6	11		2	1			21
77					3	13		3				19
78					3	10		4				17
79					3	10		6				19
80					1	9		5				15
81						8		5				13
82					3	6		1				10
83					2	7		5		3		17
84					1	7		4		1		13
85						6		1		4		11
86						7		1		5		13
87					3	4		4		2		13
88						5		1		2		8
89						7				2	1	10

Note: This table does not include launches of ABM/BMD targets from Hawaii, Johnston Atoll, and Wake Island, nor does it include SLBM launchings from submarines. SLBM launchings, so far as they are known, are shown in Table 2.2.

* Explanation of columns -

1	Thor IRBM	7	ICBM targets for ABM tests
2	Atlas ICBM	8	ABRES and other RV technology tests
3	Titan ICBM	9	Trident technology tests
4	Minuteman 1	10	MX
5	Minuteman 2	11	Midgetman (SICBM)
6	Minuteman 3	12	Total (minimum)

Source: 1st Strategic Aerospace Division, "Vandenberg AFB Launch Summary", 31 December 1984; Vandenberg AFB Fact Sheet 90-2, January 1990.

Table 2.2: Known US SLBM Test Flights in the Pacific

Date	Missile	Test Type	Number of Missiles in Test	Launch Mode
January 1958	prototype SLBM		1	from Point Mugu
March	prototype SLBM		1	from "Popup" underwater launcher
April 1960	Polaris		1	first underwater launch, San Clemente Island, 6 sec. flight
December 1966	Poseidon		1	launch only from landbased tube launcher, San Francisco
April 1967	Poseidon		1	launch only, from tube launcher
[1964-1970, no data available for Polaris flights]				
...... 1971	Polaris		-	several launches into Kwajalein
...... 1972	Polaris		-	3 launches into Kwajalein
February 1974	Polaris	FOT	5	
March	Trident-1	SFT	1	
May	Polaris	DASO	1	
May	Trident-1	SFT	1	
June	Polaris	FOT	5	
June	Trident-1	SFT	1	
July	Polaris	DASO	1	
August	Polaris	DASO	1	
	Polaris	DASO	1	
October	Polaris	FOT	5	
	Polaris	DASO	1	
January 1975	Trident-1	SFT	1	
March	Trident-1	SFT		
April	Polaris	DASO	1	no Polaris into Kwajalein in 1975
April	Polaris	DASO	1	
May	Trident-1	SFT	1	Mark-500 MaRV test
June	Polaris	FOT	5	
August	Trident-1	SFT	1	Mark-500 MaRV test
September	Trident-1	SFT	1	
September	Trident-1	SFT	1	
November	Trident-1	SFT	1	Mark-4 RV test
January 1976	Polaris	FOT	?	
January	Polaris	FOT	?	no Polaris into Kwajalein in 1976
January	Trident-1	SFT	1	
March	Polaris	DASO	1	
July	Polaris	DASO	1	
September	Polaris	FOT	2	
September	Polaris	FOT	2	
September	Polaris	DASO	1	
December	Polaris	DASO	1	
June 1977	Polaris	FOT	5	none into Kwajalein in 1977
June 1978	Polaris	DASO	1	none into Kwajalein in 1978
July	Polaris	FOT	2	
July	Polaris	FOT	3	
September	Polaris	DASO	1	
November	Polaris	DASO	1	final Polaris DASO
April 1979	Polaris	FOT	2	none into Kwajalein in 1979
April	Polaris	FOT	3	
September 1983	Trident-1	FOT	4	Wake Island BOA
June 1984	Trident-1	FOT	4	Wake Island BOA
July	Trident-1	FOT	4	Wake Island BOA
September	Trident-1	OT	4	
April 1985	Trident-1	FOT	4	first Trident SLBM into Kwajalein
May	Trident-1	FOT	4	
September 1985	Trident-1	FOT	2	splashdown at Kwajalein
April 1986	Trident-1	FOT	2	

Source: *FBM Facts/Chronology: Polaris, Poseidon, Trident*, (Strategic Systems Program Office, US Navy, 1986), miscellaneous references.

missile attack, and in 1958 it began to develop a Nike-Zeus missile. Along with its powerful missile detection radars, the Army deployed the Nike-Zeus all over the United States.

The US Army originally intended to test its Nike-Zeus ABMs against missiles being tested on the Atlantic Missile Range (later renamed Eastern Test Range, see Chapter 3), and looked at potential sites on Barbuda (in the Leeward Islands), Ascension, and Antigua. However, these islands were all administered by Great Britain, which was hostile to the idea of hosting a Nike-Zeus installation.[2] Having run out of sites in the Atlantic, the Army began to look westward to the Pacific, ostensibly to take advantage of the ICBM launches planned from California. In 1959 they chose Kwajalein, even though it was somewhat off the axis of the ICBM flights, which were planned to splash down near Enewetak.

Their real reason was that Kwajalein was about 1,900 km away from Johnston Atoll, an ideal distance for launching Jupiter target missiles. Of course, the Jupiters were Army missiles. This fact gave the Army an excuse to maintain their Jupiter production line. Herbert York, then Director of Defense Research and Engineering, intervened and insisted that good technical reasons existed to use ICBMs. Consequently, the Army was forced to abandon the Jupiter project.[3]

B. Early Ballistic Missile Tests, 1958-1962

Meanwhile, the US Navy had established a Pacific Missile Range (PMR) off Point Mugu, northwest of Los Angeles.[4] Originally intended for testing short-range tactical missiles, PMR was later extended to include a space launching site. Polar orbiting satellites could not be launched from Canaveral, because their initial launch trajectory took them over South American countries. The PMR offered

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2 M.S.Holtcamp, *KREMS: The History of the Kiernan Reentry Measurements Site,* (Kwajalein Missile Range Directorate, BMD Systems Command, Huntsville, Alabama, 1 October 1980), p. 29.

3 H.York, *Making Weapons, Talking Peace: A Physicist's Odyssey from Hiroshima to Geneva,* (Basic, New York, 1987), p.177.

4 E.E. Mouton, "Pacific Missile Range", *U.S. Naval Institute Proceedings,* June 1959, pp. 80-85.

safe trajectories oveer empty ocean all the way to Antarctica. It was also felt in those days that nuclear-powered satellites were too dangerous to be launched from Canaveral.[5] The wisdom of not launching nuclear satellites from Canaveral was demonstrated in April 1964 when a Transit satellite powered by a thermo-isotope generator launched from Vandenberg burnt up over Madagascar, releasing a kilogram of Plutonium 238 into the southern hemisphere stratosphere. Another thermo-isotope generator, aboard a Nimbus spacecraft, only got to 30 km altitude before plunging back into the Santa Barbara Channel in 1968. Soon the combined workload of satellite launchings and ICBM tests began to exceed the capacity of the Cape Canaveral-based Atlantic Test Range. There was also concern that a missile which would fly accurately down the Atlantic Missile Range would not necessarily be as accurate on any other azimuth. The Pacific Missile Range would give the engineers a new direction in which to point a missile.

The first tests to shift to the PMR were those of intermediate range ballistic missiles (IRBMs). The first IRBM, a USAF Thor, was tested in December 1958, and was monitored by a PMR down-range facility at Kaneohe, Hawaii. Most of Thor's developmental testing was done at Point Mugu, and 21 training launches were carried out there by British Royal Air Force crews in 1959-62 prior to Thor deployment in Britain in 1963.

In 1959, the range was extended to Enewetak, Midway and Wake Islands in preparation for ICBM testing by the Air Force.[6] Missile Impact Locator System (MILS) splash-nets were set up on the sea bottom off these islands.[7]. SOFAR (sound-fixing and ranging) arrays were also established for monitoring the more distant re-entries, including those of Soviet RVs.

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5 US Congress, House Committee on Science and Astronautics, *Hearings on Missile Development and Space Sciences,* February, March 1959, p.274.

6 US Congress, House Committee on Government Operations, *Missile and Space Ground Support Operations,* Twenty-third Report, 21 March 1966, p.20.

7 "DoD Considers Asking Reds to Pacific Missile Match", *Missiles and Rockets,* 18 January 1960.

The first ICBM test into the Pacific, an Atlas, splashed down 120 km northeast of Wake in September 1959. By November 1960, the US Navy was talking about extending the PMR all the way into the Indian Ocean, so that Titan missiles could be tested to their full range.[8] The journal *Missiles and Rockets* reported that there were plans to establish down-range instrumentation on Manus Island, New Guinea, and Christmas Island, northwest of Australia.[9] Twelve radar tracking ships were planned.

Initially, the Pacific Range lacked the complex instrumentation found on the Atlantic Test Range. Only the latter stages of testing of missiles were conducted in the Pacific after the initial R&D tests had taken place in the Atlantic.

Henceforth, one missile type after another was fired across the Pacific. The first Titan missile test in the Pacific took place in 1961 and Minuteman tests began in 1962. An Atlas was tested over a distance of 12,000 km, to a point 320 km east of Mindanao in the Philippines in July 1962.[10] This may be the only occasion a US ICBM has ever been tested to full range.

Most other early ICBM tests were to Enewetak, about 8,400 km from Vandenberg. In late 1962, test flights to Enewetak ceased, and in late 1969 the Enewetak facilities were reduced to caretaker status. This left the United States with only Kwajalein as an instrumented terminal area in the Pacific. Kwajalein is only 7,900 km from Vandenberg, considerably less than the 10,000-km range typical of ICBMs.

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8 Statement of Captain E.O. Wagner, Co-ordinator of Missile Ranges, Office of the Deputy Chief of Naval Operations (Air), to US Congress,House Committee on Science and Astronautics, *Hearings on Missile Development and Space Sciences*, February, March 1959, p. 274.

9 "PMR May Stretch to Indian Ocean", *Missiles and Rockets*, 21 November 1960. Earlier, there were plans to establish a PMR satellite launch facility on Manus, "[u]nbeknownst to its 15,000 woolly haired inhabitants, whose major preoccupations are growing coconuts and practicing mana (magic) - and sometimes when things are very dull - cannibalism [sic] ..."; "US seeks Manus Launch Site", *Missiles and Rockets*, 18 May 1959.

10 *AWST*, 16 July 1962, p. 37.

C. Nuclear Explosions, 1962

From April to November 1962, the United States went on a nuclear-testing spree, following the Soviet Union's abrupt ending of the 1958 nuclear testing moratorium. Both sides wanted to carry out as many atmospheric nuclear tests as possible before an atmospheric test ban was concluded.

US tests included Operation Frigate Bird, the only live test of a strategic nuclear missile ever carried out by either the United States or, as far as is known, the Soviet Union. In May 1962, a real, live Polaris missile with nuclear warhead was launched from a submerged submarine off the Californian coast. It flew 2,000 km to the vicinity of Kiritimati (Christmas) Island, and exploded with an energy release equal to 40 Hiroshimas "right in the pickle barrel".[11]

Four days later (the United States was exploding one nuke per day at the time), an ASROC short-range anti-submarine nuclear rocket was detonated in the near-shore tactical part of the PMR off the coast of California.

The Air Force also had plans to test one of their Atlas missiles with a live nuclear warhead. They knew that no-one would let them actually explode it, but they wanted to test it with a live warhead on nevertheless, just to be sure it really would fly. According to *Aviation Week and Space Technology*, they felt that "the need to proof-fire the warhead outweighs the risk of the Atlas exploding". The nuclear warhead was "arranged so it would not explode in such an event".[12] Permission was refused, but the Air Force persisted until at least 1965.[13]

The Air Force did get to test nuclear warheads aboard missiles, however. But these tests occurred at Johnston Atoll, with vertical

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11 "Live Polaris Launch", *AWST*, 14 May 1962, p. 35.

12 According to *AWST*, 14 May 1962, p. 25.

13 D. MacKenzie, "Towards an Historical Sociology of Nuclear Weapons Technologies", in N. Gleditsch and O. Njølstad (eds), *Arms Races: Technological and Political Dynamics*, (Sage, Beverly Hills, California, 1990).

ascents rather than ballistic trajectories. In August 1958, a rocket carried a hydrogen bomb to an altitude of 30 km over Johnston Atoll, where it exploded with an energy yield in the megaton range - the first nuclear explosion ever in the stratosphere. A few days later, another missile was exploded at 80 km altitude. These tests were quite risky, as no-one then knew what effects nuclear explosions in the stratosphere or in space might have on the ionosphere, or how far the radioactivity might travel.

Further tests took place in 1962, after two launch pads for Thor missiles had been built on Johnston Atoll. A series of tests in space culminated with the explosion called "Starfish" on the night of 9 July 1962 - a 1.4 megaton explosion at 400 km altitude. This explosion created an electromagnetic pulse (EMP) which triggered burglar alarms in Honolulu, 1,150 km away.

During the test series, one missile with a nuclear warhead went off course. It was never recovered, but fell into the ocean with the loss of its plutonium warhead.[14] Another exploded on the launch pad, scattering finely divided plutonium all over the island and the surrounding sea. It took weeks to decontaminate the launch pad so that tests could continue.[15]

D. Developing the Safeguard ABM, 1959-1974

While ICBMs and IRBMs rained down elsewhere in the Pacific, construction of ABM facilities at Kwajalein had been proceeding apace since June 1959. The Army found that the high water-table on Kwajalein ruled out excavating for Zeus silos. Instead, an artificial mound was built (later named Mount Olympus, for obvious reasons) for the silos. They also built an enormous prototype ABM radar.

The targeting of Army ABMs against Air Force ICBMs was supposed to be a "serious and purposeful rivalry" in which the Air Force would not warn the Army when precisely missiles were

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14 "Nuclear Test Fails", *AWST*, 11 June 1962.

15 G. Seaborg, *Kennedy, Khrushchev, and the Arms Race*, (University of California Press, Berkeley, California, 1981), p. 158.

expected to arrive.[16] However, the ABM schedule needed more targets than the ICBM tests could provide, and the Army had to purchase 18 Atlas missiles to launch at Kwajalein as ABM targets. Thus it happened that ICBMs were targeted on Kwajalein rather than Enewetak after 1962.[17]

In May 1963, the first "successful" Zeus intercept, of an Atlas warhead, took place over Kwajalein - the world's first ABM intercept. Sixty-one further tests took place, but it soon became apparent that Nike-Zeus, based on existing technology, was too slow to be an effective ABM. In February 1964, the Nike-Zeus program was abandoned and Nike-X, a program to develop entirely new ABM technology, was initiated. This missile required construction of further facilities at Kwajalein, mostly on Meck Island. Thereafter, re-entries took place into Kwajalein lagoon. The mid-atoll corridor was established, and all Marshallese inhabitants were relocated to Ebeye Island, at the south end of Kwajalein Atoll. Zeus launchings continued until June 1966, developing the technology base for Nike-X.

Nike-X, in its turn, was abandoned in 1967. It was replaced by the Sentinel concept, which involved trying to provide a nuclear air defense over most of the United States, using Spartan and Sprint interceptors. Each Spartan would destroy several missiles well above the atmosphere with X-rays from a big nuclear explosion. Sprint, a much faster and smaller missile, would destroy incoming missiles that got past Spartan and into the lower atmosphere, utilizing the blast from a big nuclear warhead. (There is no blast in the vacuum of outer space, which is why Spartan utilized X-rays. Conversely, X-rays get absorbed in the lower atmosphere, which is why Sprint used an alarmingly big warhead.) The Sentinel concept was later abandoned due to the existing Thor capability in Project 437 (see Section F). Moreover, testing the full system, including the warhead explosion, had been banned under the 1963 limited test ban treaty. Tests for this system's missile, however, began at Kwajalein in March 1969 and ceased by December.

The next ABM concept to keep the acronym alive was Safeguard, which involved the same Spartan and Sprint missiles

16 "Kwajalein Range Plays Unique Role", *AWST*, 16 June 1980, p.223.
17 *AWST*, 17 April 1961.

together with smaller radars to protect US ICBM silos only. New facilities were built at Kwajalein for Safeguard. A successful Spartan simulated intercept took place in June 1970, while a real intercept took place in August 1970. Sprint launches from Meck, and later Illeginni, began in 1971. The final ABM launch took place in 1974. That was the last missile launch from Kwajalein until 1983.

E. Project Defender, Project PRESS, 1961-1968

Another US Defense Department response to the apparent Soviet lead in ballistic missiles was to set up, early in 1958, the Advanced Research Projects Agency (ARPA, now DARPA). ARPA was charged with R&D into space projects and anti-missile missiles. Amongst its first programs was Project Defender, for R&D on advanced defense technologies against space weapons and ballistic missiles, beyond those already being developed by the Air Force for BMEWS and by the Army for Nike-Zeus. One of the first Defender projects was a program to detect RVs and identify decoys. Kwajalein was the logical place to run such a project, which was later called Pacific Range Electronic Signature Studies, or Project PRESS. The Tradex radar was the first manifestation of PRESS, constructed on Roi-Namur in 1961. Tradex was ready to monitor the first missile fired at Kwajalein in June 1962.

As the test pace accelerated, more radars were built. The scientists tested a succession of new optical and infrared sensors.The radars at Roi-Namur were consistently expanding the frontiers of radar technology. PRESS made important advances in the detection and tracking of RVs, and in discriminating between nuclear RVs and decoy RVs. Special instrumentation was installed on a PRESS C-135 aircraft.

Soviet missile testing into the Pacific produced several bonuses for the United States. MILS turned out to be unexpectedly efficient at monitoring the Soviet splashdowns, and data on the firings was funnelled back to the United States, both as intelligence and as system development data. The Tradex radar was used to develop methods of identifying warheads through direct observation of Soviet

RV signatures.[18] Sometimes Soviet ICBMs were used as targets for US Nike-Zeus firings. To avoid the possibility of a direct hit, the Zeus missile aim-points were offset from the positions of the Soviet missiles.[19] Once, a US submarine reportedly almost managed to retrieve a Soviet RV before the Soviet recovery vessel could reach it.[20]

In 1968 PRESS was transferred from ARPA to the Army and became part of the Kwajalein Missile Range.

F. Nuclear Anti-Satellite Role, 1963-1966

Project Mudflap, later known as Project 505, was concerned with adapting Nike-Zeus to shoot down hostile satellites, and later the maintenance of a nuclear anti-satellite weapon system on Kwajalein. The Army had wanted to launch a nuclear-tipped Zeus at a satellite from Kwajalein in the 1962 nuclear test series, but failed to get approval from the Defense Department. In May 1962, however, the Army got permission to develop Nike-Zeus as an anti-satellite weapon. In May 1963, a Zeus missile got close enough to a US satellite to have been able to destroy it had been carrying a nuclear warhead; and in May 1964, Program 505 became officially and secretly operational on Kwajalein. The missiles maintained in readiness probably carried one megaton warheads. The system was phased out in 1967, three years after a more capable nuclear ASAT system, "Project 437", became operational at Johnston Atoll. Project 437 used longer range Thor missiles.[21] Ten launches, seven of them "successful", took place during the life of the Thor system.[22]

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18 "Missile Defense Dominates PMR Efforts", *AWST*, 17 April 1961, p. 69.

19 *AWST*, 27 December 1965.

20 *AWST*, 9 December 1963.

21 P. Stares, *The Militarization of Space: US Policy, 1945-84*, (Cornell University Press, Ithaca, New York, 1985), pp. 117-120.

22 *Ibid.*, Appendix 2.

G. Administrative Changes, 1962-1964

By mid-1962, the Army was complaining about the quality of support it was getting from the Navy at Kwajalein, and recommended that the Navy relinquish Kwajalein to the Army. No action was taken on this proposal at the time. In 1963, however, US Secretary of Defense Robert McNamara recommended a rationalisation of all test range activities, and in particular that each range should be operated by the service which made most use of it.[23]

In July 1964, Pacific Missile Range Facility Kwajalein was therefore transferred from the Navy to the Army and renamed Kwajalein Missile Range. In 1965, the Air Force took over the ballistic missile test activities at PMR from the Navy. The Navy had reportedly become increasingly disillusioned with the secondary role then assigned to PMR in the Pentagon's missile testing program.[24] After the transfer of administrative control of PMR ballistic missile testing, the Navy retained control of its tactical missile test facilities and of its offshore SLBM testing, both of which continued under the name of Pacific Missile Range. The ICBM facilities became the Western Test Range. At the same time, the Atlantic Missile Range was renamed Eastern Test Range (ETR).

H. Ballistic Missile Tests, 1962-1980

During the sixties, about 50 to 70 ICBMs were launched at Kwajalein each year. From 1971 onwards, the number gradually declined to about 20 a year but continued inexorably.

Atlas tests continued until 1965; Titan tests began in 1961 and continued until 1976. Minuteman-1 tests continued until 1971. Minuteman-2 tests began in 1965, and Minuteman-3 tests began in 1969. A new BOA for Minuteman testing was established in the midst

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23 Holtcamp, *KREMS: The History of the Kiernan Reentry Measurements Site*, p.37.

24 "Navy May Unload PMR", *Missiles and Rockets*, 5 February 1962, p.9.

of the British-administered Phoenix Islands (now part of Kiribati) in 1972, replacing Enewetak, which was shut down entirely in 1969.[25]

The first Polaris submarine was deployed in the Pacific in 1964. Polaris SLBMs were tested from submerged submarines near Hawaii to Johnston Atoll from the mid-sixties. Some of the early Polaris tests were made from the vicinity of Hawaii towards the United States, splashing down in the PMR. Later, the Navy took advantage of Kwajalein facilities and began testing Polaris from near Johnston Island to Kwajalein. In the seventies, between 10 and 20 Polaris a year were test-launched in the Pacific, often in "ripple-firings" of up to 5 missiles in quick succession from the one submarine.[26] Most of these firings were probably from submarines just off the coast of California to ocean target areas in the vicinity of Hawaii, with down-range tracking by the Kaena Point radar.

As far as is known, prior to Trident deployment, there were only Polaris missiles deployed in the Pacific. Maintenance support for Poseidon was not available in the Pacific. There are, however, occasional incidental references in congressional testimony to Poseidon missiles being tested in the Pacific.[27] Polaris submarines were withdrawn from the Pacific in 1981.

Data on Navy SLBM tests is less readily available than that on Air Force ICBM tests. All known SLBM tests in the Pacific are listed in Table 2.2.

Trident technology tests took place from 1974 to 1976 using old Minuteman boosters to test-fly the advanced MIRVed Trident payloads from Vandenberg to Kwajalein.[28] An "upside-down GPS"

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25 US Congress, Senate Committee on Aeronautical and Space Sciences, *Hearings on NASA Authorization, Fiscal Year 1972*, p.722.

26 *FBM Facts/Chronology: Polaris, Poseidon, Trident*, (Strategic Systems Program Office, US Navy, Washington DC, 1986).

27 For example, written testimony supplied to the Senate Appropriations Committee in 1970 said that Poseidon missiles were fired by the Navy "into the KMR area". *Hearings on Defense Appropriations, Fiscal Year 1972*, part 2, p. 1386.

28 *SSTSS* vol. 2, p. 8.

system called SATRACK[29] was installed on several islands to allow more accurate determination of trajectory than provided for by midcourse radars. These tests developed amongst other things the Mark 500 "Evader" MaRV, a big step towards making SLBMs accurate enough to hit military targets and not just cities.

Not all flights were for testing specific missiles. A large number of flights were intended to develop various aspects of RV technology using retired strategic missiles. From 1963 to 1981, these tests mostly went under the name ABRES (Advanced ballistic re-entry system) studies. PRESS was found to be more important for this kind of research than it was for the ABM development. PRESS had "a dramatic impact upon the design of re-entry vehicles for both Air Force and Navy strategic missiles, to reduce their detectability by enemy radars ... Current models [of ICBM warheads] reflect knowledge gained by project Press."[30]

During the seventies, some secret missile tests were fired into the southeastern Pacific. The missiles splashed down in the vicinity of Oeno, a British-administered island 23° south of the equator west of Pitcairn Island. These tests were intended to prove that the missile guidance systems did not lose accuracy when the missiles were fired on a north-south trajectory instead of the east-west trajectories they were usually tested on. No azimuth-dependent "bias" was found.[31]

In 1980, a Minuteman-3 made its longest flight ever, from Vandenberg past Kwajalein and into a BOA near Guam.

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29 GPS is the Air Force Navstar satellite global positioning system. Prior to deployment of the Navstar satellites, GPS transmitters were installed on Pacific islands so that missiles overhead could receive the signals and in effect determine their own positions.

30 "ARPA Stresses Advanced ABM Research", *AWST*, 23 October 1967.

31 US Congress, Senate Armed Services Committee, *Hearings on Defense Authorisation, Fiscal Year 1978*, part 10, p.6539.

I. Ballistic Missile Defense Experiments, 1974-1984

Neither the signing of the ABM treaty in 1972, nor deactivation of the US ABM system in 1976, meant the end of ABM research. In fact, the US military only agreed to the ABM treaty on the condition that it could continue a strong program of ABM research and testing. Only the name - and the acronym - changed. ABM became BMD, or ballistic missile defense. Supposedly this program, by maintaining a US technological lead, would provide a safeguard against the possibility of a Soviet "breakout" from the ABM treaty.

BMD also sent a message to the Soviets, according to the Pentagon:

> The construction of the site defense radar [a BMD project] at Kwajalein provides visible evidence to the Soviet Union of our continued resolve to maintain a BMD competence. The US demonstrates its resolve to maintain a credible BMD option through this visible testing activity at KMR.[32]

For Kwajalein, it all meant more of the same. The phased array ABM radar on Meck Island stayed in operation, and was replaced in 1976 by a much more advanced missile site radar. An in-space infrared tracker, the Designating Optical Tracker (DOT), was tested in 1979. In 1983, a new missile launch system was built on Illeginni for testing a new Low Altitude Defense (LoAD) system - basically a follow-on to Sprint, but employing a non-nuclear kill mechanism. A non-nuclear higher-altitude system, successor to Spartan, but called HOE (homing overlay interceptor), was successfully tested from Meck in 1984 and billed as the first success of the new SDI.

The BMD tests continued to use incoming missiles as targets of opportunity. In addition, Thor missiles were occasionally launched from Johnston Atoll specifically for BMD tests at Kwajalein.[33]

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32 Major Robert C. Marshall, BMD program manager, testimony, in US Congress, Senate Armed Services Committee, *Hearings on S.920, Fiscal Year 1976*, part 6, p.3239.

33 *Annual Historical Review*, 1975-1976, pp. 11, 22.

J. Shift From Kwajalein? 1977-1985

In the 1970s, relations between the Marshallese inhabitants of Kwajalein and the US military authorities began to deteriorate seriously.[34] From 1964, all inhabitants of Kwajalein Atoll had been confined to Ebeye Island for most of each year. Ebeye had become progressively more overcrowded as Marshallese moved in from other atolls, hoping to get work on the range at US-controlled islands. Displaced landowners re-occupied missile range islands in 1969, 1977, 1978, and 1979. In 1982, over a thousand islanders took part in "Operation Homecoming", a large-scale and protracted occupation of most of the range islands. The unrest led the United States to carry out contingency studies of other islands and BOAs that could be used if Kwajalein became unusable.

The imminence of MX missile testing was another factor which spurred a search for new impact areas. MX was to be longer range, and more accurate. The longer range created a need for impact zones further away from Vandenberg. The potentially greater accuracy meant that hitherto ignored possible sources of error became worth testing for. Some of these were measurable only at full range or at different launch azimuths. In particular, there was concern about "bias" - that a CEP (circular error probable) measured for a missile tested in an east-west direction might not indicate the true accuracy achievable when a missile was launched in wartime over the North Pole. The oblate shape of the earth, the varying magnetic and gravitational field, and *Coriolis deflection* forces from the earth's rotation might conceivably exert different influences during a polar trajectory. In fact, this issue was probably not a real problem, as an enormous data base accumulated on equatorial and polar orbiting satellites was probably adequate for discovering whether such effects existed. MX RVs were also bigger and re-entered more rapidly. The MX was viewed as a "hotter" missile by the military and posed safety

34 See G. Johnson, *Collision Course Kwajalein: Marshall Islanders in the Shadow of the Bomb*, (Pacific Concerns Resource Center, Honolulu, 1984), and *Marshall Islands: A Chronology, 1944-1983*, (Micronesia Support Committee, Honolulu, 3rd edition 1983), and various issues of *Pacific News Bulletin* since then. Also S. Firth, *Nuclear Playground*, (University of Hawaii Press, Hawaii, 1987).

problems. Kwajalein lagoon was not big enough to accommodate the expanded safety requirements. All these factors led to several studies of alternative locations for missile testing in the Pacific.

A preliminary study in 1979, known as the ARK (Alternatives to Kwajalein) study, apparently concluded that the best location for testing MX to nearly full range would be the uninhabited Kermadec Islands, to the north of and administered by New Zealand.[35]

A much more detailed study, the *Strategic Systems Test Support Study* (*SSTSS*) was undertaken by a tri-service committee in 1979-1981. This study dropped the Kermadecs possibility, but considered three other alternative instrumented terminal areas (ITAs). Ascension Island in the South Atlantic, and already part of ETR, was one possibility, but was too small to provide the angular separation needed between various tracking sensors (see Figure 4.4), especially for BMD testing, which requires at least 30 km.[36] The Northern Mariana Islands were another possibility, with the PACBAR radar planned for installation in 1989 being usable as a tracking radar. The uninhabited Farallon de

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35 The ARK study was first mentioned by General Grayson Tate, the Army's BMD program manager. According to him:

> It turns out that what appears to be the best site is [deleted] and a couple of large rocks sticking up out of the ocean there. One is a very rocky island, volcanic, that is north of [deleted]. This does give the separation distance in order to get the right base legs to get your angular measurements, but it would be extremely difficult and very expensive to construct because some of these islands come up out of the ocean almost vertically and there are not many flat places on the islands.

(Testimony in US Congress, House Armed Services Committee, *Hearings on Military Posture, Fiscal Year 1981*, part 4, vol.1, p.954.)

The Kermadecs site was illustrated in a commentary on ARK by Andrew Hamilton, "Does Kwajalein Missile Range have a Future?", memo for James Moorman, a lawyer acting on behalf of Kwajalein landowners. Original source of the illustration is unknown.

36 *SSTSS* vol. 2, p. 56.

Mendinilla, near Guam and long used by the Navy as a bombing range, would serve for land impacts. The third alternative was to again use the Phoenix Islands, now part of Kiribati.

With the introduction, in November 1981, of the first Trident submarine to the Pacific, the Navy required operational SLBM testing on a variety of azimuths. Due to the fact that in war the submarines could be anywhere in the ocean and hence have to fire on a wide variety of ranges and azimuths, the Navy needed a number of BOAs and chose three. An old BOA was to be re-established at Wake, and new ones were to be established near Oeno Island (close to Pitcairn) and on the Chatham Rise east of New Zealand. To cut costs, the *SSTSS* panel persuaded the Navy to abandon the Chatham proposal and use a proposed Air Force BOA near the Northern Marianas. In November 1984, when the Chatham proposal was revealed, the then New Zealand Prime Minister, David Lange, declared that his government would not have permitted such activity.

The *SSTSS* report, partially declassified in 1984, also revealed that the USAF had plans to use three BOAs, providing different ranges as well as avoiding the hazards implicit in testing to Kwajalein. Two of the BOAs were near the Northern Marianas Islands and west of Guam respectively. The third location was deleted from the released report, but its sonobuoy missile impact locating system (SMILS) was to be serviced from Sydney. There was uproar in Australia when it was revealed that BOA-3 was in the South Tasman Sea near Tasmania. Moreover, it was revealed that the Australian Prime Minister, Bob Hawke, had secretly given permission for the use of Australian facilities, and that the deep ocean transponders for the SMILS had already been laid by the USS *Egebrag-3*, which had used Tasmanian ports while on the job.[37] Hawke had to withdraw permission for further use of Australian facilities. The planned test into BOA-3 never took place, and no substitute full-range location was used.

At one stage, there were also plans to send MX missiles into the Trident BOA near New Zealand instead of into BOA-1,[38] but nothing came of this. Strangely, the USAF has announced it has no

37 "Ship with Sensitive Mission", Melbourne *Sun*, 6 February 1985.

38 *SSTSS*, vol. 2, p. 23.

need for azimuth diversity in MX testing.[39] This attitude seems to indicate that the earlier fuss about "bias" was not based on any real concern.

Thus, the missileers have begun to convert the whole Pacific Ocean into a test site. They fire far fewer tests today than in preceding decades, but they have vastly enlarged their reach. Anti-ballistic missile tests have accompanied missile testing throughout the history of the test range, but are now increasing rapidly again at Kwajalein. The missile tests have sometimes become embroiled in alliance and regional politics. But they are mostly run out-of-sight, out-of-mind, above the heads of islanders. For them, the pre-dawn, fiery arcs of re-entry vehicles plunging from the sky into the sea are commonplace reminders of who controls the Pacific in the nuclear era.

39 *SSTSS*, vol. 2, p. 39.

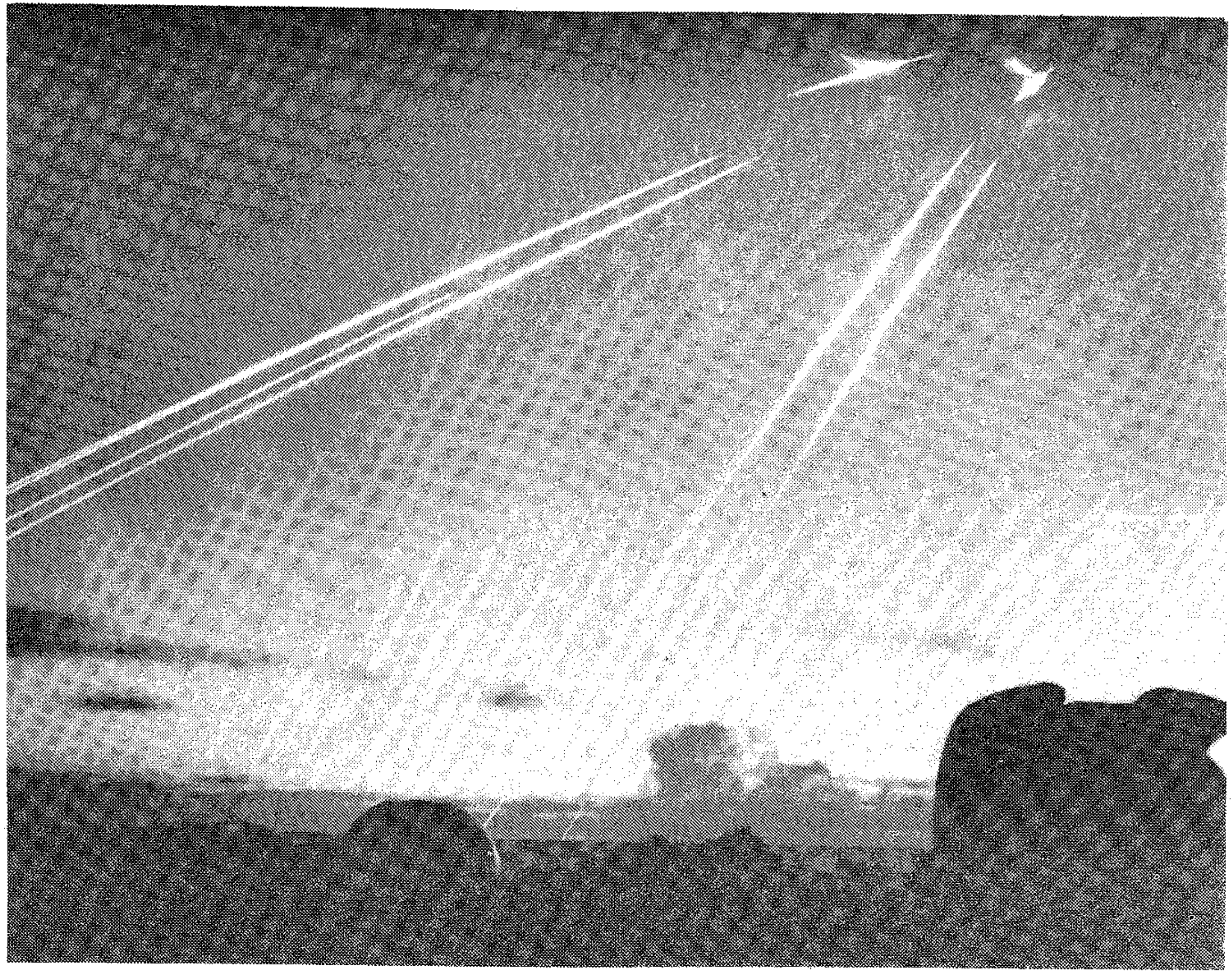

Plate 3: Six Unarmed Minuteman II Mark 12 Re-Entry Vehicles Approach Targets near Kwajalein Atoll during an Operational Test of Two ICBMs Launched from Vandenberg on 10 July 1979 as part of SAC's Global Shield Exercise for World-Wide Nuclear War (USAF Photo)

CHAPTER 3

BALLISTIC MISSILE TESTING

This chapter looks at the various kinds of missile flight tests and summarizes the flight testing conducted at Kwajalein. It compares the Kwajalein facilities with those available elsewhere, and draws some conclusions on the extent to which flight testing at Kwajalein contributes to the arms race. Finally, it evaluates the extent to which the arms race might decelerate if Kwajalein were closed.

A. Categories of Flight Tests

Six categories of flight tests are involved in the development and deployment of ballistic missiles. The nomenclature and the nature of the categories varies slightly between ICBMs and SLBMs.[1] The tests are dress rehearsals for nuclear war, but not full dress rehearsals. No test flights ever carry "real" nuclear warheads (with one single historical exception, see Chapter 2). The categories are as follows.

1. Technology/Components Tests (Supplementary Flight Tests, SFTs)

In the case of some missiles, it is thought necessary to test particular advanced components or sub-assemblies, incorporating high-risk unproven technology, before the missile as a whole is ready for testing. This is done by testing the new components aboard retired or obsolete boosters. The Trident-1, for example, was developed in this way. Mark-4 RVs and Mark-500 manoeuvring RVs (MaRV, or "Evader") were tested aboard modified Minuteman boosters. SFTs are generally very heavily instrumented.

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1 A. Lowell and M. Brodsky, "Flight-testing the US Navy's Sea-based Ballistic Missile System", *Lockheed Horizons*, Spring 1981, pp. 13-23.

2. Research and Development (R&D) Tests

While a missile is still under development, a number of prototypes are custom built and flight tested. The tests validate successive stages in the design process. The tests are performed in an artificial environment - on a test launch pad (a "flat pad"), in ideal weather, and by engineers and technical contractor employees. The later R&D tests, known as performance evaluation tests, approximate more closely operational conditions and are used to validate successively various production-line components as the designs are tentatively finalized. Other tests attempt to exercise the system over a variety of trajectory possibilities. Typically, 20 to 30 flight tests are needed before the design of a new missile is frozen.

3. Initial Operational Tests (IOTs or Phase 1 Operational Tests)

When a missile is ready for deployment, a number of the early production-line models undergo tests under launch conditions approximating those expected in war-time. The tests are designed to uncover any significant problems early in the deployment phase, and the results are used to estimate reliability and accuracy data for the SIOP (the single integrated operational plan for assignment of all strategic weapons to their various possible targets). ICBMs are launched by SAC crews from silos similar to operational silos. SLBMs are launched from submarines submerged to antenna depth, with launch area support ships in attendance to provide telemetry reception and range safety. Often, the submarine launches several missiles as fast as possible. The Joint Chiefs of Staff stipulate that the number of missiles tested must be sufficient to give 90% confidence that the reliability is not more than ten percentage points lower than the test series success rate. Phase 1 tests generally need 30 to 40 flights to achieve this level of confidence.

4. Demonstration and Shakedown Operational (DASO) Tests

These are more significant in the case of submarines, where there is a need to test the submarine and its crew as much as to test the missile. When a new submarine is commissioned, or after an existing submarine has been overhauled, three missiles with instrumented and non-nuclear RVs are loaded. The other tubes are fitted with "active inert missiles" (AIMs), which are concrete-filled missiles carrying only the electronics of a normal missile.The submarine then goes to sea for several weeks, during which time the crew members practise aligning guidance systems and executing fire control procedures. At the end of the cruise, one of the real missiles is launched from a location sufficiently close to Canaveral for land-based facilities to monitor the launch.[2] SLBM DASOs cannot be done in the Pacific because the water off Vandenberg is not deep enough.[3]

Air Force DASOs are done between the R&D tests and the IOTs. In the case of the MX, they were overlaid on the later R&D tests.

5. Follow-On Tests (FOTs or Phase 2 Operational Tests)

These are operational tests carried on at reduced rates over the service life of the missile. They are intended to detect any deterioration over time, and to validate any modifications being made to a missile. There may be more subtle benefits too. "Ancillary benefits of a system's test program", says the US Congressional Budget Office, "include crew training and however much deterrent effect might result from public demonstrations of confidence in the system's effectiveness."[4]

Follow-on testing is carried out under conditions that approximate as closely as possible expected war-time conditions. Thus, for ICBMs, a missile is selected at random from an operational SAC silo field, and the missile crew are put through a simulated countdown which is stopped just short of launch. The missile is then removed from its silo, transported to Vandenberg and put into a silo

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2 "Trident Missile Program", Staff Working Paper, Congressional Budget Office, February 1986, p. 18, note 18.

3 US Congress, House Armed Services Committee, *Hearings on Defense Authorization, Fiscal Year 1984*, Testimony of Admiral Kelso, part 5, p.439.

4 "The MX Missile Test Program", Staff Working Paper, US Congressional Budget Office, January 1986.

that resembles an operational silo. The nuclear RVs are removed and replaced by instrumented RVs of identical weight and balance. The same crew members then complete their countdown and launch the missile.[5] It is debatable whether these tests are realistically "operational". Four months elapse, for example, from when each missile is selected to the time it is fired from Vandenberg.[6]

For SLBM FOTs, a submarine on patrol is randomly selected and ordered into port. Nuclear RVs are removed from two to five missiles and instrumented RVs are substituted. The submarine returns to sea and is ordered through tactical communication links to launch the test missiles in rapid succession at operational speed and depth.[7]

The number of FOTs depends on the numbers of that variety of missile, but works out at about six per year for ICBMs and somewhat more for SLBMs (because of the additional uncertainties and stresses associated with underwater launches).

6. Aging and Surveillance (A&S) Tests

These are similar to FOTs and generally are not listed separately from them. Missiles are subjected to sequential static firing of the various stages, tests of various sub-systems, X-ray and other inspections.

This kind of testing is said to provide a better monitoring of the aging process than flight testing because it results in more parametric data, allowing trend analysis. Thus the military can predict failures caused by aging, rather than waiting for them to happen in the

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5 The most detailed description of the process is in K. Tsipis, "The Operational Characteristics of Ballistic Missiles", Chapter 11 of *World Armament and Disarmament: SIPRI Yearbook 1984*, (Taylor and Francis, London, 1984) pp. 405-406.

6 Des Ball notes that missile firing competitions are staged to test missile crew proficiency and operational performance. It is unknown if these competitions involve separate firings from those referred to in this passage.

7 E. Kolcum, "Navy Improving Test Facilities for Trident-2 Missile Program", *AWST*, 20 September 1985, p. 79.

Table 3.1: Flight Tests and Other Events Requiring Warning Notices to Shipping, Covering Period 1 January 1989-11 April 1990

Date	Missile	Mission Name	Impact (coordinates)	Source
25 January 1989	Minuteman-3	Glory Trip	USAKA-E (11N 171E)	V,N
22 February	Minuteman-3	Glory Trip	?	V
7 March	Minuteman-3	Glory Trip	USAKA-N (13N 171E)	V,N
7 March	?	?	MAC, USAKA-E	N
13 March	?	?	MAC, USAKA-W	N
17 March	?	?		N
19 March	MX	MFT-18[1]	?	V
11 May	Midgetman	MFT-1	USAKA-N (failed)	V,A
17 May	?	?	USAKA-N, USAKA-E	N
17 May	Trident?	?[2]	USAKA-N	N
8 June	?	?	MAC, USAKA-N	N
6 July	Minuteman-3	Glory Trip		V
11 July	Minuteman-3	Glory Trip	MAC, USAKA-N, USAKA-W	V,N
11 July	(sounding rocket?)		USAKA-E	N
18 August	Trident?		Wake Island BOA	N
12 September	?	?	USAKA-N (12N 171E)	N
12 September	?[2]	?	USAKA-N (11N 171E)	N
14 September	MX	Glory Trip	USAKA-N (13N 171E)	V,N
26 September	Minuteman-3	Glory Trip	MAC, USAKA-W	V,N
6 November	Minuteman-3	Glory Trip		V
6 February 1990	Minuteman-3	Glory Trip		V
14 February	Minuteman-1	MAST/RSLP		V
8 March	MX	Glory Trip		V
21 March	Minuteman-3	Glory Trip		V
24 March	Minuteman-3	Glory Trip		V

Abbreviations
MAC = Mid-atoll corridor (presumably including Illeginni)
MAST = Manoeuvring systems technology
MFT = Missile flight test
RSLP = Re-entry systems launch program
Sources
V = Vandenberg launch lists, supplied by WSMC
N = Notices to Mariners (compiled by Martini Gotje, New Zealand Greenpeace Office)
A = *Aviation Week and Space Technology*

1 Launched by an airborne crew aboard a SAC flying command post EC-135 aircraft.
2 This would appear to have been a Trident test, since a Notice to Mariners was simultaneously issued for an area off the California coast that may have been the launch point.

FOT tests and then trying to identify the cause. "These aging surveillance programs are moderately expensive to conduct", according to a declassified Martin Marietta study, "but their results justify their implementation even if there is no reduction in flight testing."[8]

Hereafter, SFTs and R&D tests will be referred to as *developmental* tests, while IOTs, DASO tests and FOTs will be referred to as *operational* tests.

B. Current Flight Testing in the Pacific

Currently, between 12 and 20 ICBM tests a year and one or two Trident tests are undertaken each year in the Pacific. Information about missile tests is not readily available and must be assembled from a number of sources. Known flights in the Pacific from January 1989 to the present are shown in Table 3.1.

MX Tests

As described in Chapter 2, the increased range, accuracy, and risk associated with MX testing led to a stocktaking of WTR resources and the establishment of new BOAs at longer ranges in the Pacific.

Five impact locations were eventually selected for MX testing. These were:

BOA-1	Near the Northern Mariana Islands, supported by range aircraft from Guam, and with down-range tracking to be provided by the PACBAR radar there.
USAKA-N	About 130 km north of Kwajalein. It had already been used for two launches, and SMILS was already installed.

8 *Analysis of the effects of flight test limitations*, TR-E-80-008, Phase B final report, Martin Marietta Corporation, Denver, Colorado, December 1980, p. 45. (Report of a project sponsored by DARPA, monitored by Defense Nuclear Agency.) Released under FOIA.

USAKA-E	About 450 km to the east. SMILS installed about 1984.
USAKA-W	The location of this BOA is not known. SMILS was supposed to be installed in 1984. Possibly it corresponds to what was originally called BOA-2 in the 1981 *SSTSS* report. Volume 2 of that report said that BOA-2 had been re-named BOA-4, and shifted 800 nautical miles up-range.[9] It is probably to the east of Guam, adding 2,500 km to the 7,800 km flight distance to Kwajalein.
BOA-3	BOA-3, off Tasmania, was to provide for "mandatory testing at an extended range of over 6,500 miles [12,000 km] for two DT&E [development test & evaluation] missions".[10]

As described in Chapter 2, BOA-3 was the cause of political controversy in Australia, and had to be dropped. The MX test program as planned and as carried out is shown in Table 3.2.

Because of the successful nature of the developmental tests, the MX test series was shortened, so that flight 18 became the first operational test. Ironically, that flight went out of control, and the missile was destroyed 160 km down-range from Vandenberg. The first successful operational test was not until March 1990, with flight 20.

It was originally intended that up to 200 MX would be deployed in some sort of mobile basing arrangement. But after a tortuous legislative history, it was eventually decided that only 50 MX missiles would be deployed, and initially they would be deployed in relatively vulnerable former Minuteman silos, since agreement could not be reached on a workable and affordable mobile basing mode.

There was no corresponding reduction in the number of missiles allocated for testing. Apart from the 20 missiles in the development program already described, another 24 missiles were allocated to initial operational testing, and about seven per year to

9 See Footnote 11, Chapter 1, *SSTSS*, vol.2, p.211.

10 S. Woodbury and R. Gorman, "Program Overview of Peacekeeper Flight Test Planning", AIAA Second Flight Testing Conference, 1983.

Table 3.2: MX Developmental Test Program

Purpose of Test	No.	Planned Impact (Actual Impact)	Planned Date	Launch Mode	Actual Date
Missile Functional Performance	1	USAKA-N	mid 1983	flat pad	June 1983
	2	USAKA-N		flat pad	October 1983
	3	BOA-1		flat pad	December 1983
	4	USAKA-N		flat pad	March 1984
	5	USAKA-N		flat pad	June 1984
RV Capabilities & Systems Integration	6	USAKA-N	late 1984	flat pad	October 1984
	7	USAKA-N		flat pad	February 1985
	8	BOA-1		flat pad	June 1985
	9	BOA-3 (USAKA-N)		silo	August 1985
	10	BOA-3(?)		silo	November 1985
	11	USAKA-E		silo	March 1986
	12	USAKA-N&E		silo	May 1986
	13	USAKA-N		silo	August 1986
Weapon System Performance	14	USAKA-N	late 1986	silo	September 1986
	15	BOA-1		silo	December 1986
	16	USAKA-N&W		silo	February 1987
Operational System Verification	17	USAKA-N	early 1987	silo	March 1987
	18	BOA-1 (failed)		silo	March 1989
	19	USAKA-N&W		silo	September 1989
	20	USAKA-N&W		silo	March 1990

Source: Data on purpose and proposed impact points from S. Woodbury and R. Gorman, "Program Overview of Peacekeeping Flight Test Planning", AIAA Second Flight Testing Conference, 1983. Actual Impacts from *AWST* and Notices to Mariners.

follow-on testing, plus one for aging and surveillance testing per year over the expected 12-15 year life of the missile.[11] In other words, about 120 missiles in total will be launched over the next 15 years just to maintain confidence in the other 100 missiles that the US government plans to deploy (currently there are only 50 in silos)!

All MX test flights are made from Vandenberg. Aside from the superiority of the down-range facilities, MX testing is constrained to the Pacific by what a report to the Pentagon called the "extreme cost of launch-head relocation".[12]

From 1990 onwards, approximately eight operational tests per year, each carrying up to ten RVs per missile, will be heading towards Kwajalein. These will be targeted on the lagoon, the two BOAs and, for land impacts, on Illeginni Island.

Another four or five test launches from Vandenberg are scheduled for 1991-2 to test the "Rail Garrison" method of launching MX missiles from trains.

Minuteman Operational Tests

Currently, Minuteman is still the most frequently tested missile at USAKA. Minuteman-2 and -3 constitute the backbone of the current US ICBM arsenal and all test launches are carried out at Vandenberg. It is intended to test about nine Minuteman per year for the next seven to ten years. Minuteman-2 and most Minuteman-3s are aimed at Kwajalein Lagoon.

Minuteman-2 missiles all carry Mark-11 RVs which are test-flown into shallow water to allow RV recovery. This procedure is necessary because the Mark-11 has severe problems with plasma sheath telemetry blackout during re-entry, and hence flight recorders instead of telemetry packages are provided in the test instrumentation.

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11 "The MX Missile Test Program", Staff Working Paper, US Congressional Budget Office, January 1986. See also "MX Missiles", Defense Marketing Survey (DMS) Report, 28 September 1989.

12 *SSTSS*, vol. 3, p. 8.

The flight recorders are subsequently retrieved from the bottom of the lagoon.[13]

At least one Minuteman-3 test was to a BOA well to the west of Kwajalein. An operational test in September 1980 was described by KMR as a "fly-by mission" and, according to Vandenberg Public Affairs Office, at 10,400 km it was the longest flight ever by a Minuteman.[14]

Land Impacts on Illeginni Island

Several Minuteman-3s per year are targeted for land impact on Illeginni Island. Minuteman-3 flights began in 1969, but RVs were targeted on Illeginni for the first time in fiscal year 1979.[15] An environmental impact assessment (EIA) on the land impacts was not prepared until fiscal year 1977.[16] The EIA was classified, but it reportedly concluded there would be no significant environmental impact on the island[17] from having RVs hurtling down onto it. Communications cables crossing Illeginni were replaced with microwave links to reduce the possibility of a re-entry cutting vital intra-range communications.[18] At one stage, consideration was given to carrying out the land impacts in the Northern Marianas,[19] presumably at Farallon de Medinilla.

The only known explanation for the land impacts is that they are "required to test fusing techniques."[20] Presumably this is due to some idiosyncrasy in either the Mark-12 or the Mark 12A RVs they

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13 *SSTSS*, vol.2, pp.13, 56; G. Zorpette, "Kwajalein's New Role: Radars for SDI", *IEEE Spectrum*, vol. 26, no. 64, March 1989.

14 "Vandenberg Air Force Base and 1-STRAD History", Fact Sheet #90-2, attachment 1.

15 *Annual Historical Review*, 1978-1979, p. 58.

16 *Annual Historical Review*, 1976-1977, p.24.

17 "US Army Kwajalein Atoll", (USAKA Final Environmental Impact Statement), US Army Strategic Defense Command, (henceforth referred to as *FEIS*), undated [late 1989], p.3-14.

18 *Annual Historical Review*, 1978-1979, p.68.

19 *Annual Historical Review*, 1980-1981, p.23.

20 *SSTSS*, vol. 2, p. 13. See also vol. 3, p. 17.

carry.[21] The *SSTSS* specified that "still-photographic documentary of land impact was required."[22]

Illeginni is quite a small island, less than a kilometre long and 200 metres wide.According to a US Army map,[23] it is largely covered with buildings, antennae and a helicopter pad (see Figure 3.1). Most of the land not built on is shown as sea-bird rookeries. Presumably the RVs come down on the lagoon-edge reef rather than on the island itself (see Appendix 1). Even so, it says something for USAF confidence in the accuracy of Minuteman that such a small island can serve as a target. Minuteman-3 accuracy is usually given as about 200-300 metres CEP.

There have been proposals for developing earth-penetration warheads for ICBMs, similar to those developed for the Pershing-2 IRBM. Such warheads would be used in war to destroy deeply buried Soviet command bunkers.[24] Lockheed is reported to have been awarded a developmental contract.[25] According to the commercial Defense Marketing Service, land impacts are also planned for MX missiles.[26]

Midgetman (Small ICBM)

Midgetman will carry only one or two warheads per missile and will be deployed in a land-mobile mode intended to be relatively invulnerable to pre-emptive attack by Soviet missiles. Some arms

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21 "The radar altimeter fuse of the current MK 12A warhead was said to be inaccurate enough to noticeably reduce its kill probability against hardened targets, implying an inaccuracy of several tens of meters." Tsipis, "The Operational Characteristics of Ballistic Missiles", p.398.

22 *SSTSS*, vol. 3, p. 16.

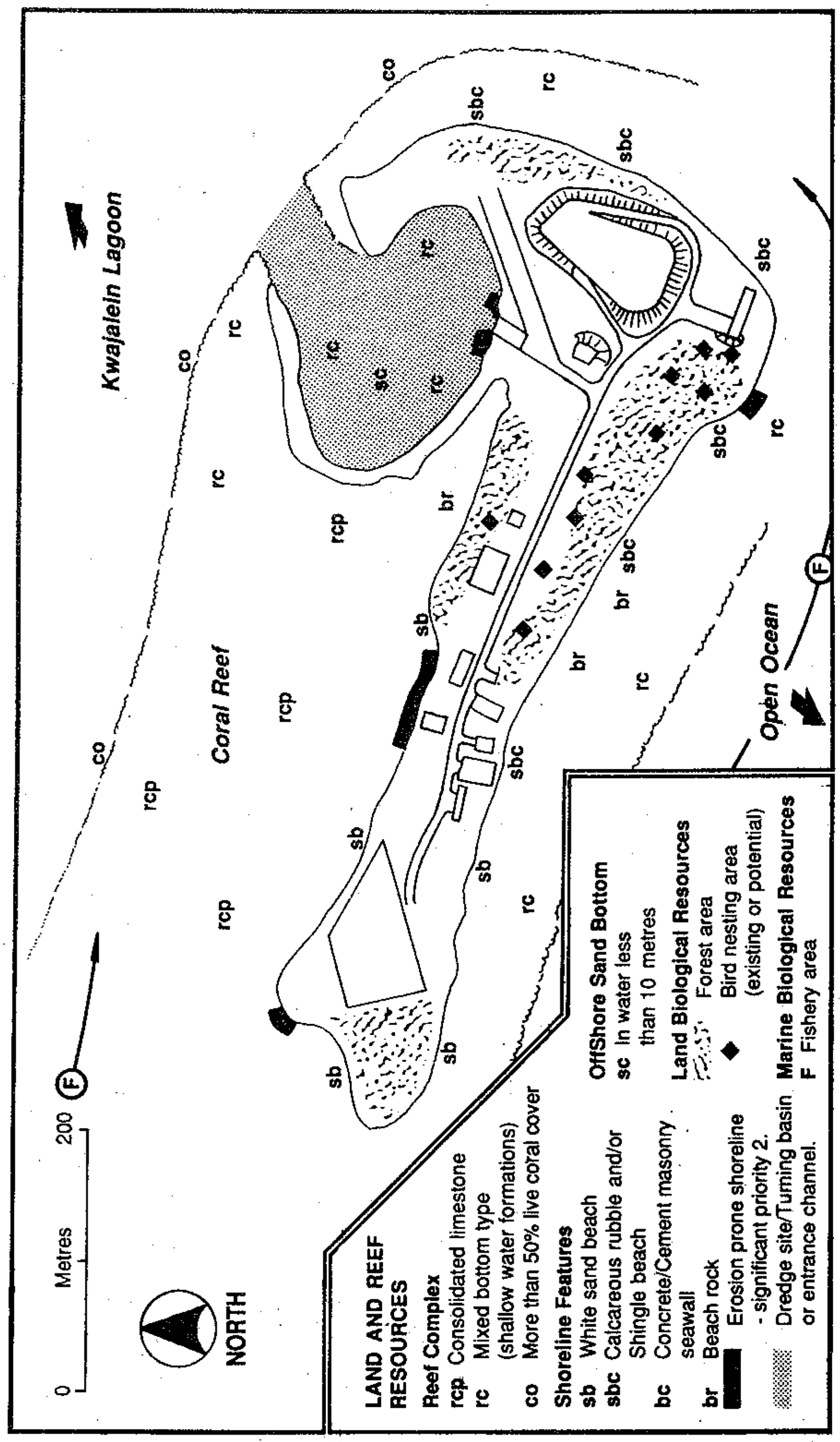
23 *Kwajalein Atoll Coastal Resource Atlas*, US Army Corps of Engineers, Pacific Ocean Division, August 1989.

24 J. Morrocco, "Defense Dept Plans to Study Earth-penetrating Nuclear Weapons", *AWST*, 8 June 1989, pp. 28-29.

25 "Newsdigest", *AWST*, 10 August 1987, p. 32.

26 But according to the *SSTSS*, land impact will be required only if new fusing is developed.

Figure 3.1: Illeginni Island



control proponents see this combination of few warheads plus secure basing as enhancing deterrent capability without contributing particularly to first-strike capability. In general, the US military opposes Midgetman, which is seen as taking funds from MX, and providing many less warheads on target than if the same amount of money were spent on more MXs.

Supplementary flight tests, testing Midgetman components aboard Minuteman-3, began in early 1987. So far only two launches of prototype Midgetman missiles have been scheduled. Two test missiles were scheduled for launch in 1989. The first, in May 1989, went out of control shortly after liftoff, and was destroyed.The second launch was delayed as a consequence and was scheduled for September or October 1990.[27]

Assuming that development of Midgetman proceeds, all test launches will be from Vandenberg, and most will come down at Kwajalein.

Trident

Some Trident technology was developed in the seventies at USAKA, with SFTs using old Minuteman missiles, but all subsequent developmental testing of Trident has been carried out at the Eastern Test Range, which has launch pads specifically for SLBM tests, including one which simulates the motions of a submarine. New land facilities were built at Canaveral specifically for the Trident program.

Trident-1 was first deployed in the Pacific, and operational tests have been carried out in the Pacific since late 1983 (see Figure 2.1). Little is known about the tests, but it seems they are held only once or twice a year and that most of them come down into the BOA near Wake Island. One or two operational tests of Pacific-deployed Trident-1 SLBMs are planned each year for the foreseeable future.

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27 *Aerospace Daily*, 8 March 1990.

When Trident-2 is deployed in the Pacific in the early 1990s,[28] operational testing of it can be expected at about the same rate as for Trident-1. In 1981, it was described as "probable" that Trident-2 operational tests would also be carried out in the Pacific.[29] It has also been suggested that further Trident Mark 500 "Evader" penaid developmental flights might be carried out in the Pacific, using Kwajalein for re-entries.[30]

In the Pacific, there are three BOAs for Trident re-entries, at Wake, Guam, and Oeno. (Oeno was used to support Trident-1 tests in the 1976-77 period.)[31] The two BOAs at Kwajalein are also available to Trident, but, like MX, Trident is regarded as too "hot" to target into the lagoon.There are two launch point BOAs for Trident. The various combinations of launch point and target provide an ample variety of ranges and azimuths.

C. Re-Entry Technology

Many missile launches targeted on USAKA are devoted to developing new technology for RVs and warheads in general rather than to testing a particular model of missile. Technical objectives include improving accuracy, improving ability to penetrate enemy ABM defenses, reduction of RV electro-optical signatures, the development of terminal manoeuvring capability, and so on. Generally, obsolete missiles retired from the arsenal are used to carry the items being tested. Many of the tests have been launched aboard IRBMs or non-missile rockets from the PMR facility at Kauai.

From the early sixties until 1981, most of this activity was within the Advanced Ballistic Re-entry Systems (ABRES) program. ABRES was crucial in the development of the high accuracy needed for

28 *Navy Strategic Forces: Trident II Proceeding Towards Deployment*, GAO/NSIAD-89-40, (US Government Accounting Office, Washington DC, November 1988), p.23, note 1.

29 *SSTSS*, vol.2, p.25.

30 *SSTSS*, vol.2, p.27.

31 US Congress, Senate Committee on Armed Services, *Fiscal Year 1978 Authorization for Military Procurement* (Hearings), (US GPO, Washington DC, 1977), part 10, p.6539.

counterforce targeting. Such accuracy - or the promise of it - encourages some US strategists - including some in very high official positions - to espouse first-strike doctrines in the 1980s. Minuteman-3, MX, and Trident all incorporated technology developed on the ABRES launches. Amongst ABRES projects flight-tested at Kwajalein were:

Pave Pepper - Minuteman with 7RVs	1975
Advanced MaRV	1976
ABRV (Advanced ballistic RV) Mark-21 for the MX	1977-82
Mark-500 Evader RV tests for Trident-1	1978
Penetration aid flight tests	1986-87

ABRES is now called ASMS (Advanced Strategic Missile Systems). Current projects include MAST (Manoeuvring Systems Technology), and ERPA (Evader Replica Penetration Aid) RVs. Currently, these programs require one or two flights from Vandenberg per year. In fiscal year 1989, ASMS was granted $US142 million.

The KREMS facility is central to re-entry studies. The KREMS radars were originally intended to study re-entry phenomenology solely in connection with developing better ways for US ABM systems to detect and attack Soviet RVs. It soon became evident, however, that they were just as useful for improving the ability of US RVs to penetrate Soviet ABM systems. In 1963, Tradex was adapted to operate at 60 Megahertz (that is, a shift from UHF to VHF), because the Soviet Union was building ABM radars (Henhouse and Doghouse) at this frequency. Pentagon scientists believed that the Soviet Union knew more than the United States about the effects of nuclear explosions on radar propagation and had chosen this frequency band because it was more resistant to nuclear blackout. The 60 MHz modification allowed Tradex to "see" US missiles the way it was presumed the Soviet radars saw them.[32] The big Altair radar was originally built in the late 1960s to provide a further data base on how US RVs and penetration aids (penaids) appeared to Henhouse and Doghouse. In 1970, Tradex underwent extensive modifications to allow it to view US RVs, and penaids, decoys, chaff, etc. the way they appeared to a new Soviet radar of concern to the US military.

32 M. Holtcamp, *KREMS: The History of the Kiernan Re-entry Measurement Site,* ((Kwajalein Missile Range Directorate, BMD Systems Command, October 1980), p. 74.

According to Lincoln Laboratory, "missile system development and operational testing" is today the prime mission of the KREMS radars, ahead of space surveillance and BMD. KREMS collects data on RVs, decoys, chaff and post-boost vehicles. The data go to the Air Force Ballistics Systems Division, the Strategic Air Command, and the Navy, as inputs into future missile design.[33] Tradex today is still the main radar for seeing US RVs as a Soviet radar sees them - with a wide repertoire of wave forms, pulse rates, frequencies and scan modes for this purpose.

KREMS, according to the *SSTSS* report, is "... a cluster of the best signature measurement radars in the free world ... This one-of-a-kind capability could not be replaced ..."[34]

D. Comparison of US Ballistic Missile Test Ranges

All US ballistic missile testing is carried out over only two ranges, the Western Test Range (WTR) and the Eastern Test Range (ETR), administered respectively by the Western Space and Missile Center (WSMC) at Vandenberg and the Eastern Space and Missile Center (ESMC) at Patrick AFB, Cape Canaveral.

The ETR consists of shuttle and satellite launch facilities, IRBM and SLBM launch pads, tracking and telemetry stations in Florida and on various Caribbean islands, a down-range instrumented terminal area at Ascension Island, a telemetry station in South Africa (currently inactive), and about eight BOAs.

The relative capabilities and functions of the two ranges are summarized in Appendix 3. In general, the capabilities of the WTR and ETR relevant to ballistic missile testing can be compared as follows:

* Both ranges have extensive and sophisticated tracking and telemetry equipment for the boost phase.

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33 K. Roth, M. Austin, D. Frediani, G. Knitel and A. Mrystik, "The Kiernan Re-entry Measurements System on Kwajalein Atoll", *The Lincoln Laboratory Journal*, Summer 1989.

34 *SSTSS*, vol. 2, p. 232.

* The ETR has ample midcourse equipment, while WTR has minimal midcourse equipment (on Hawaii).

* Only WTR has sophisticated terminal area tracking and telemetry support. Only WTR is equipped for re-entry studies. Only WTR can provide RV recovery and land impact. Only WTR has mid-range and down-range facilities for launching target missiles.

* Both ranges can and do support operational tests of SLBMs.

* Only ETR is equipped to support IRBM tests (now banned under the INF treaty) and SLBM R&D tests.

* WTR has the only facilities for testing ICBMs (and for technology/component tests on ICBM boosters).

The possibility of moving out of Kwajalein has been considered. But official and insider statements uniformly stress that there would be very high costs and severe disadvantages in shifting from Kwajalein.

As General Grayson Tate told Congress in 1980:

> What if we have to leave Kwajalein? Well that is an alternative that we really would prefer to not even think about, but we have to think about it. So, we have looked at some other places and we can say that they would be very expensive and would be very disruptive to our ongoing programs, including M-X, Trident and our BMD programs, should we ever have to do that. We hope we don't have to, because we have a [deleted] dollar investment here which to replace obviously would cost us at least a [deleted] dollars and several years and would be very disruptive to all our ongoing problems.[35]

Or as the *SSTSS* report stated in 1981:

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35 Major General Grayson Tate, BMD Program Manager, in US Congress, House Armed Services Committee, *Hearings on Military Posture, Fiscal Year 1981*, part 4, vol.1, p.954.

> Ascension Island does not have sufficient geography [sic] or instrumentation to support complex instrumentation geometry required by programs such as the Air Force ABRES program or the Army BMD programs. Even if the instrumentation for these programs could be installed at Ascension Island, the Air Force Minuteman programs, which provide many of the TOOs [targets of opportunity] required by the BMD programs, would need to relocate the launch facilities from VAFB to the East Coast to use the Ascension Island terminal area.[36]

And as Defense Marketing Service stated in 1986:

> It is the only range in the free world where Intercontinental Ballistic Missiles (ICBM) can be fired in a tactical configuration with sophisticated technical data collection during the terminal portion of the trajectory. Locating experiments at USAKA has a synergistic effect since both the strategic offensive and defensive programs benefit. USAKA's unique capabilities are collection of signature data on objects outside the earth's atmosphere, collection of terminal trajectory and impact data, recovery of re-entry vehicles and nearly immediate transmission of data to respective mission sponsors.[37]

The US military will not give up Kwajalein or the WTR easily. Indeed, the United States is more likely to shut down the ETR and concentrate all its missile launches in the Pacific. Space launches need to be launched in an easterly direction to take advantage of the earth's rotation, and this provides the only compelling reason for retaining the ETR. Tracking such launches was apparently the main justification for keeping the ETR operating. The possibility of shutting down the ETR was seriously considered back in 1977, when it was thought that the shuttle would replace all use of ordinary rockets (now called

36 *SSTSS*, vol. 2, p. 47.

37 "Kwajalein Missile Range: Program Element Descriptive Summary", Defense Marketing Service (DMS), 22 September 1988.

"expendable boosters") for space launches.[38]. The notion was abandoned after the Challenger shuttle exploded in 1986.

Presumably, if the ETR had been shut down, the Navy would still have kept performing operational tests in the Atlantic, but without the support of land-based monitoring facilities. Alternatively, the Navy may have been considering doing all its operational testing in the Pacific, and rotating its missile submarines between the two oceans for this purpose. The only cost in doing so would be the construction of SLBM launch pads at the WTR for developmental tests. The only loss would have been the azimuth diversity provided by shots into the South Atlantic.

E. Managing Without Kwajalein and the WTR

Technically, it would be feasible for the United States to stop using Kwajalein and other WTR land-based down-range facilities and still test missiles.

There are at least six possibile responses to the loss of Kwajalein, including:

1. The United States could build ICBM launch facilities at Cape Canaveral and carry out all testing in the Atlantic. It would lose the ability to test on a wide range of azimuths.
2. The United States could set up BOAs anywhere in the ocean without the need to lay deep ocean transponders for SMILS once GPS-SMILS becomes available. This is a form of SMILS in which the sonobuoys which register the re-entry also register their own positions by receiving and re-transmitting Navstar GPS signals. At present GPS SMILS are apparently used only for monitoring Soviet

38 "Military Studies Closing of Eastern Test Range", *AWST*, 12 September 1977, pp.16-17.

splashdowns, and allegedly have allowed the United States to locate and retrieve Soviet RVs.[39]

3. Highly accurate tracking of a missile over its entire trajectory is possible using the Missile Tracking Instrumentation System (MTIS) developed from SATRACK. MTIS is already used by the Navy for simultaneously tracking up to 40 RVs from Trident ripple launches. The system relies on translators on board each missile which receive and retransmit signals from Navstar GPS satellites. The retransmitted signals must be picked up by a telemetry receiver for post-flight determination of trajectory. Currently, ground-based receivers are used, but nearby aircraft are equally suitable. Accuracy obtainable is about 12 metres in position and 0.2 metres/second in velocity.[40] The system has been proposed for MX tests and tested with Minuteman.[41] The Commander of WSMC has been quoted as saying that SAMTEC hopes to move towards a "GPS range" to get more flexibility and less dependence on land-based tracking facilities.

4. Telemetry could be received, though not in the vast quantities it is recorded at Kwajalein, by the use of advanced range instrumentation aircraft (ARIA), which have telemetry reception antenna dishes in bulbous nose radomes. The United States has seven ARIA, mostly used in the ETR to make up for the lack of land-based telemetry antennae. Similar aircraft operate out of Shemya AFB in the Aleutians to

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39 *Defense Week*, 17 January 1989, as cited by G. Zorpette, "Kwajalein's New Role: Radars for SDI", *IEEE Spectrum*, vol.26, no. 64, March 1989.

40 T. Thompson, "Performance of the Satrack/Global Positioning System Trident-1 missile tracking system", IEEE Position, Location and Navigation Symposium, 1980. Thompson makes the encouraging observation that "... it is anticipated that the SATRACK system will perform better than expected".

41 "GPS Translator Atop Minuteman Tracked across Pacific", *Aerospace Daily*, 1 December 1989.

intercept telemetry from Soviet missile tests.[42] At present, the capacity of these aircraft is quite limited, since each one can only collect telemetry from one RV. However, if phased array antennae were fitted, each aircraft could monitor up to four RVs.[43]

5. Additional telemetry and tracking could be obtained by the use of range instrumentation ships. The United States presently has one such ship in the ETR, and formerly had the USNS *Hap Arnold* in the Pacific, dividing its time between WTR and monitoring Soviet tests.

All these possibilities would increase the per-test costs enormously. The principal disadvantage for the United States would be its loss of all the special features of Kwajalein already described. It would be difficult, even impossible, to do all the re-entry phenomenology studies. ABM/SDI research also would be seriously handicapped.

F. Interaction Between Ballistic Missile Testing and Arms Control

A recent controversy over flight testing of the Trident-2 illustrates the impact that ballistic missile testing can have on the domestic politics of arms control. The controversy arose from the counting procedures which have become formalized in the two SALT and first START treaties, and which will be used in START-type agreements negotiated in the future.

It is difficult, if not impossible, for "national technical means of verification" to determine the number of RVs under the shroud of each ballistic missile of the other side. The following procedure has been accepted to allow numerical limits on RVs to be set in arms control treaties. Each missile type is credited with carrying the maximum number of RVs which have been *tested* on that type. Trident-1 and -2 were originally designed to carry eight RVs. But in 1987, the Navy

42 J. Richelson, *The US Intelligence Community*, (2nd edition, Ballinger, Cambridge, Massachusetts, 1989), pp.178-179.

43 *SSTSS*, vol.2, p.85.

tested Trident-2 with 10 warheads, and leaks to the press revealed there were plans to test with 12. Secretary of Defense Caspar Weinberger apparently pushed for the tests, despite misgivings among the Joint Chiefs of Staff and in the State Department as to how the Soviets would respond under the SALT counting rule. The Joint Chiefs wanted only eight RVs per missile, because this rule would allow the United States to have 50 per cent more submarines under whatever limits were negotiated.[44]

If the test had proceeded, then the Soviet Union could have insisted on counting all Trident missiles as having 12 missiles. The United States would have been penalized in any agreement, with 400-900 "phantom" RVs counted in the agreement which did not actually exist for warfighting purposes. The controversial test was postponed, and the issue was resolved in December 1987 at the Washington superpower summit, where the United States announced that only the 8-RV version would be deployed.

Something similar happened 12 years earlier with Minuteman tests in the Pacific. The USAF carried out two tests in 1975 of Minuteman-3 missiles carrying seven warheads instead of the usual three. The tests, called "Pave Pepper", were carried out with considerable publicity.[45] Part-way through the SALT-2 negotiations, it looked like this test might have given an advantage to the United States. Under a draft provision freezing each missile type with the maximum number of RVs ever tested, the United States would have been able to add four RVs to each of its Minuteman-3s whenever it wanted.[46] But Pave Pepper became a problem in the final stages of the negotiations when, if the Soviet Union had chosen to push the issue of "fractionation", all Minuteman-3 missiles would have been counted as having seven RVs. The issue was finally resolved when the United States undertook not to put more than three RVs on Minuteman, just

44 M. Gordon, "US Plans to Test Submarine Warhead with 12 Warheads", *New York Times*, 7 October 1987, p.1; "The Trident II Missile Test Program: Implications for Arms Control", Staff Working Paper, US Congressional Budget Office, November 1987.

45 For example, "DoD Announces Pave Pepper Schedule", *Air Force Magazine*, April 1975, p. 29.

46 S. Talbot, *Endgame: The Inside Story of SALT II*, (Harper Torchbooks, New York, 1980), pp. 178-179.

three days before the six and a half years of negotiation for SALT-2 concluded with an agreement.[47]

47 *Ibid.*, pp.275-279.

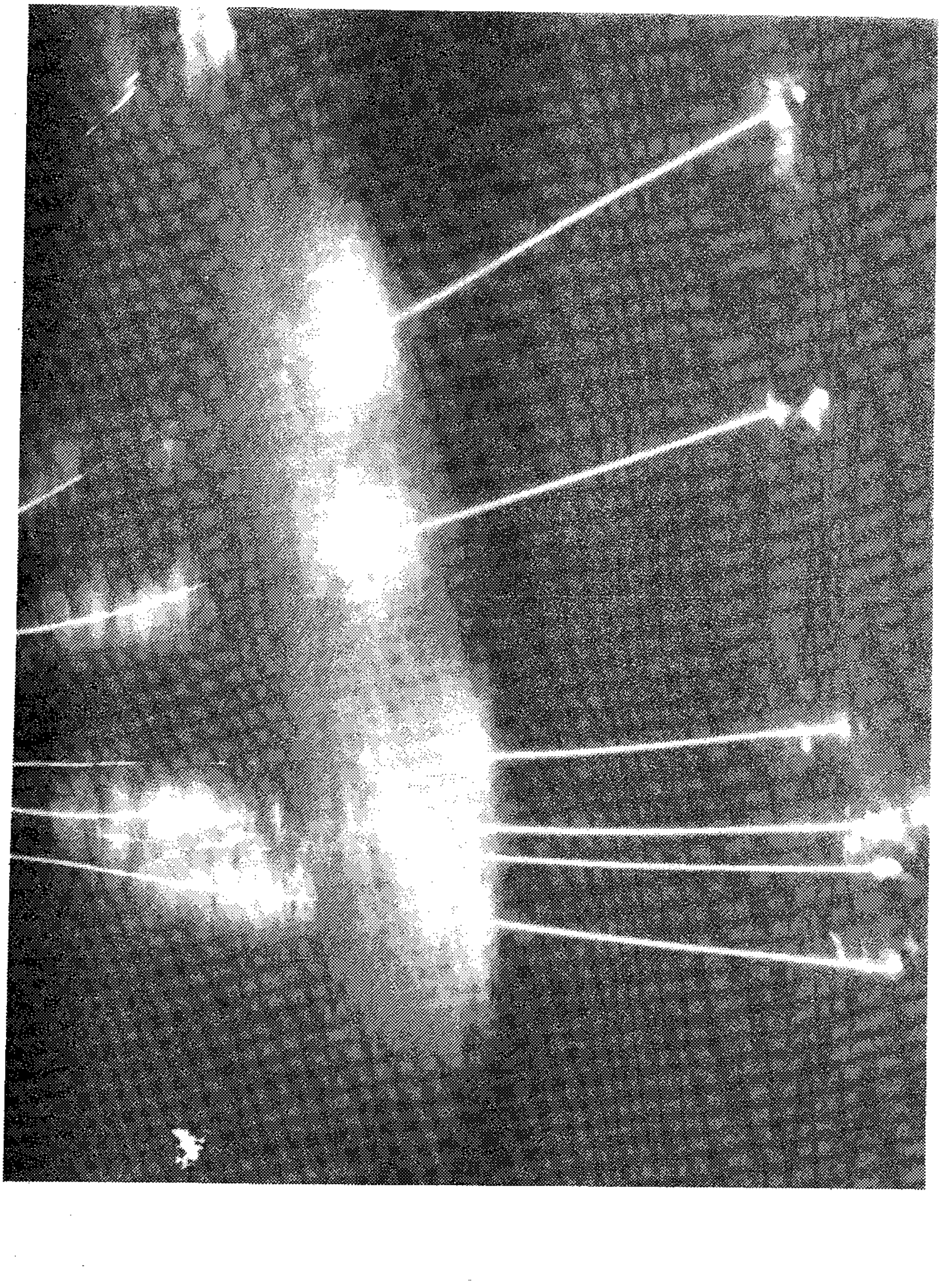

Plate 4: Re-Entry Vehicles Approaching Ocean Targets during Early MX Night-Time Test (USAF Photo)

CHAPTER 4

SDI "BATTLESPACE"

Most publicity about Kwajalein today concerns the Star Wars projects being undertaken there. This activity, however, differs little from that at Kwajalein since the sixties. This chapter looks at the Strategic Defense Initiative (SDI), and the SDI projects being undertaken at Kwajalein and their potential impact on the ABM treaty. The SDI facilities on Kwajalein are described and compared with those available elsewhere.

A. The Strategic Defense Initiative

SDI was launched dramatically and precipitately by President Reagan in March 1983. Since then, it has threatened the grim stability of mutual deterrence and cast an ominous shadow over arms control possibilities in general and the ABM treaty in particular.[1] As SDI proponents in the Reagan era portrayed it, SDI was to involve all sorts of exotic surveillance and weapons technologies - in particular, "directed energy" beam weapons, nuclear-pumped space-based X-ray lasers, and electromagnetic railguns.

After the first efflorescence of these "astrodome" fantasies passed away, the SDI budget began to shrink. The more outlandish proposals are now getting less press and funds. The Defense Department has abandoned the dream of a total defense of the United States, adopting a very limited scheme which will at best defend against 30 per cent of Soviet missiles - and let 3,300 warheads reach their targets! SDI is now divided into a "phase 1", of near-term technologies which might be deployed by the turn of the century (although this is being seen now as more a dream than a schedule), and longer term technologies that need much more experimentation.

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1 Current SDI issues are well covered in B. MacDonald, "Lost in Space: SDI Struggles through its Sixth Year", (*Arms Control Today*, September 1989, pp. 21-26), which was the basis for this introduction.

Canaveral was put into orbit, where the two upper stages separated. One stage simulated a thrusting missile, while the other carried sensors which observed the rocket plume of the first. After orbiting the earth the second stage was commanded to home in on the simulated "missile". Impact occurred over Kwajalein at a closing speed of 12,000 km an hour. KREMS and the Kwajalein-based HALO aircraft collected vast quantities of data on the intercept.

Space-based Interceptor (SBI). The SDIO are planning to put orbiting "garages" into orbit round the earth, from which interceptor missiles can be launched at Soviet missiles during their boost phase and before they have released RVs. The concept is called Space-based Interceptor (SBI). In the USAKA tests, there will be no "garage" because this action would violate the ABM treaty. Instead, experimental interceptor missiles will be launched from Meck at target missiles launched from Roi-Namur. Debris from the intercept will fall into the northern BOA.

Boost phase interceptors are generally seen as the least workable of all SDI concepts. If they work then it can be argued that they would be highly destabilizing. This conclusion follows from the fact that they could be used to neutralize a retaliatory second strike against a U.S. first strike.

Ground-based Surveillance and Tracking System (GSTS). GSTS is confusingly named. It will consist of a rocket which, when launched into space, will track incoming missiles in their mid-course and relay the data back to ERIS and other SDI weapons. It will be launched from the ground, hence the name. At USAKA, old Polaris or Poseidon missiles will be used to launch GSTS payloads from Omelek. Two missiles will be launched simultaneously, to provide "stereo" views.

As a component of a mid-course weapons capability, the destabilizing potential of GSTS might be seen as intermediate between that of SBI and ERIS.

Exo-atmospheric Re-entry-vehicle Interceptor Subsystem (ERIS). ERIS will consist of a ground-launched missile carrying a non-nuclear kill vehicle (KV) which will basically destroy an incoming RV by simply smashing into it. Obviously, the KV will require very fast-acting and sublimely accurate homing mechanisms. For the tests at Kwajalein Atoll, missiles consisting of the first and second stages of a

Minuteman-1 will be launched from a silo on Meck to intercept RVs from Vandenberg. The intercepts will take place over USAKA-North, well outside the atmosphere, and debris will come down over an area much wider than the normal BOA (see Figure 4.3). ERIS is a follow-on from HOE, and is a non-nuclear equivalent of the Spartan missile of the old Safeguard system.

ERIS is one of the more workable SDI weapon concepts. If it works, it may be deployed at the old Grand Forks, North Dakota, Safeguard site[5] (which would not violate the ABM treaty).

Because of its high-altitude capability (1,200 km), ERIS must be regarded as an area-defense weapon, rather than a point-defense weapon. Area-defense ABMs are seen as more destabilizing weapons than point-defense weapons, since they can be used (at least in theory) to protect large areas of the United States from the consequences of a Soviet second strike, thus weakening deterrence by making the United States more confident of surviving Soviet retaliation after a US first strike.

ERIS is also a candidate weapon for the next-generation US ASAT system.[6]

High Endo-atmospheric Defense Interceptor (HEDI). HEDI will be similar to ERIS, but will employ a smaller, faster accelerating missile. Intercepts will take place within the upper reaches of the atmosphere, where air-drag will help to distinguish decoys from real RVs.[7] Two tests at USAKA are planned, using old Sprint missiles left over from the 1970s.

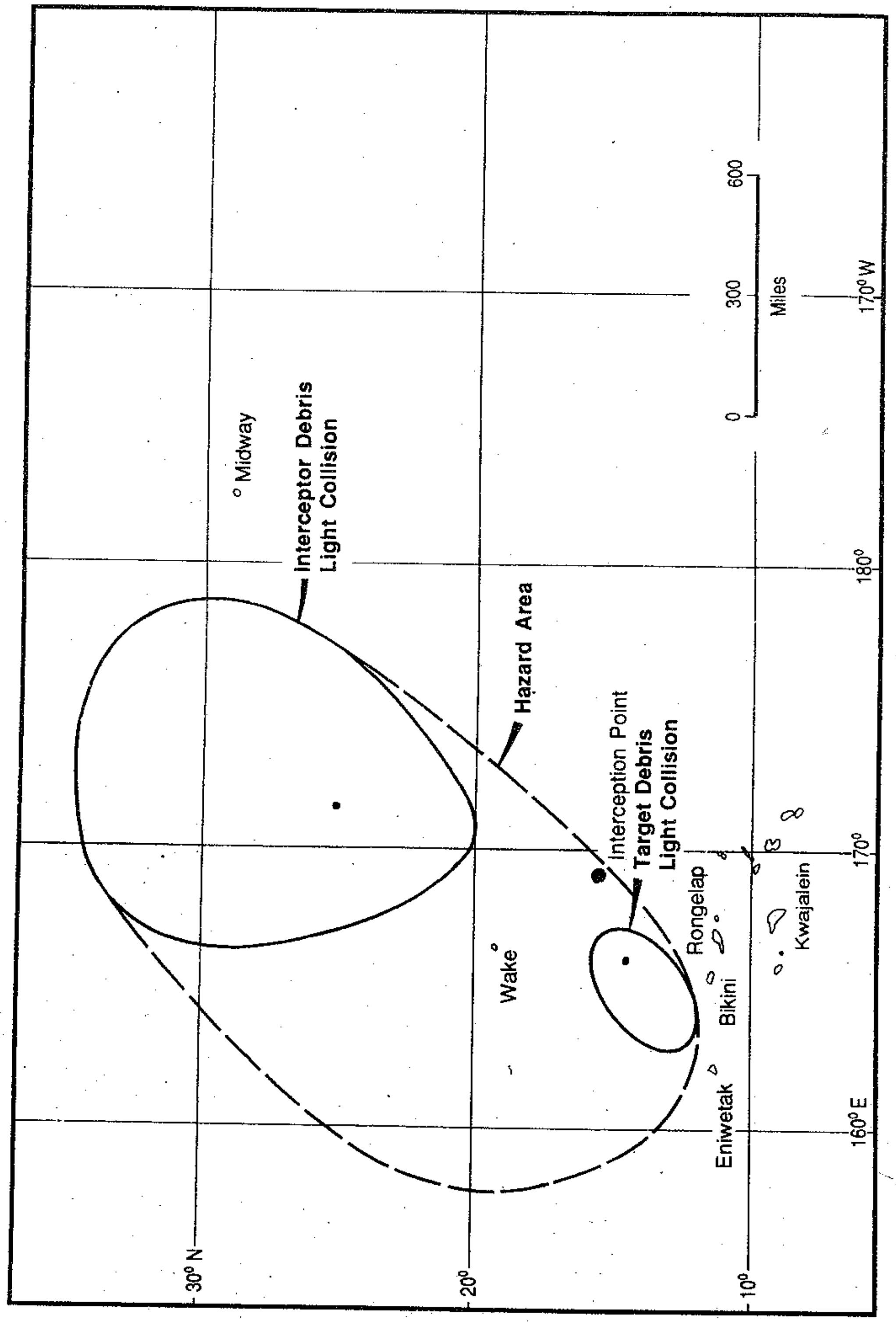
Airborne Optical Adjunct (AOA). AOA is a specially modified Boeing 767 intended for experiments in long-wave infrared (LWIR) detection of missiles. It will fly to Kwajalein and observe incoming RVs. AOA will carry an advanced infrared detector with 38,400 discrete elements, capable of detecting the heat of a human body at

5 P. Klass, "SDIO to Emphasize Space Surveillance Systems in Shift of Phase 1 Priorities", *AWST*, 23 May 1988, p.23.

6 "Pentagon Preparing to Restart Anti-satellite Program in January", *AWST*, 14 November 1988, p.33..

7 Air-drag will slow the lightweight decoys more than it will the warhead RVs

Figure 4.3: ERIS Danger Zone



1,800 km. The technology is intended to eventually be put aboard drone aircraft which would fly at 15-20 km altitude for days at a time.

Other SDI Tests. A number of other SDI tests will be undertaken at USAKA.[8] These include:

* Aerothermal re-entry experiment (ARE), a program of temperature and pressure measurements on RVs, which will provide data for ERIS.
* Exo-atmospheric discrimination experiment (EDX), a series of 10 launches into Kwajalein Lagoon. Sounding rockets will be launched from Kauai to collect mid-course discrimination data.
* Ground-based radar experimental (GBR-X), a large phased array radar to be built on Kwajalein Island for tracking several RVs simultaneously from mid-course to re-entry. As an experimental radar, it is seen as a prototype for future ABM radars. On Kwajalein, it will be used to manage the duels between incoming RVs and the various ABM systems being tested from the atoll, starting with ERIS. GBR-X software is already being tested on data from the KREMS MMW radar.
* High Altitude Learjet Observatory and Infra-red Instrumentation System (HALO/IRIS), an aircraft equipped to collect visible-wavelength and infrared signature data about re-entries and launches over Kwajalein.
* Mid-course sensors experiment (MSX), involving a satellite launched from Vandenberg which will observe target missiles launched from Kauai. USAKA will provide tracking data.
* Optical aircraft measurement program (OAMP), an aircraft based in Hawaii that will fly to Kwajalein and circle around to observe re-entries. This aircraft is normally employed observing Soviet tests, and the trips to Kwajalein will provide calibration data to

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8 *DEIS*, p.2-26.

facilitate interpretation of the data obtained from Soviet tests.

* Project Cardinal was a single test in 1989 into BOA North. All other information about it seems to be classified.[9]

C. ABM Treaty Compliance[10]

The SDI projects at Kwajalein involve numerous near violations and perhaps actual violations of the ABM treaty, and some of them have been designed in rather convoluted ways to violate the intent of the treaty while abiding by its letter. More particularly:

HOE. The ABM treaty bans testing ordinary missiles "in an ABM mode". HOE was launched on old Minuteman boosters, leading the Soviet Union to charge the United States with breaching the treaty. However, this ban was included in the treaty to prevent either side making a rapid "breakout" from the ABM treaty by converting ICBMs into ABMs. Obviously, the United States had no intention of converting its dwindling supply of retired Minuteman-1 into ABMs. Thus, the minor violation of the letter of the treaty was not a violation of the intent of the treaty.

Delta 180. The ABM treaty bans all developing and testing, let alone deployment, of any ABM system except fixed, land-based ones. Space-based ABMs are banned. Delta was intended to simulate a space-based interceptor. The experiment was designed to do a full orbit of the earth so that, technically, the target was a satellite, even while it was simulating a ballistic missile; therefore, according to the SDIO, the treaty was not violated. Yet SDIO director, Lieutenant General James Abrahamson, claimed that the test was a major step towards the development of a space-based ABM. If what he said was true, then this test was a definite violation.

SBI. To avoid violating the treaty, the experiments for SBI will use ground launches rather than out-of-orbit launches. But the

9 It is mentioned in the *DEIS*, p. 2-49.

10 This section is largely based on M. Bunn, "Star Wars Testing and the ABM Treaty", *Arms Control Today*, April 1988, pp. 11-19.

experiments are directed toward the development of a space-based system - as the name implies - and therefore may violate the ABM treaty.

GSTS. This system will use old SLBM boosters, and is open to the same objection as was made to HOE.

ERIS. This experiment uses old Minuteman boosters, and is open to the same objection that was made to HOE.

AOA. This apparently innocuous experiment actually constitutes the most serious violation of the treaty. It is designed to demonstrate the feasibility of tracking and discriminating missiles from an airborne platform. Airborne ABM systems are banned by the treaty. If AOA were to be "capable of substituting for" an ABM radar, then it violates the treaty. If it is only an "adjunct" to radar, then it does not. The experiment has such an awkward name precisely to maintain this ambiguity. A March 1987 study by John Pike for the Federation of American Scientists described AOA as the "most immediate challenge to the ABM treaty".

A commentary on the Army's Kwajalein SDI *DEIS* by the Massachusetts chapter of the Lawyers Alliance for Nuclear Arms Control complained that these possible treaty violations were not discussed in the *DEIS*. The Army responded that possible ABM treaty violations "were not the proper subject of an EIS". Moreover, they argued that: "The effects of a nuclear war are remote and speculative and are not within the scope of the Proposed Action."[11]

D. SDI Facilities at Kwajalein

Numerous facilities on Kwajalein are undergoing refurbishment and expansion for SDI.

In particular, the range control center on the atoll has been upgraded to handle the increased launch activity, and the added complications of intercepts with the resultant clouds of collision and explosion debris. A Cray X-MP/14 supercomputer is being installed, together with super-minicomputers, for this workload.

11 *Final Environmental Impact Statement (FEIS)*, p.3-26.

SDI will use most existing facilities at USAKA, but will require several new facilities, especially for launching rockets and missiles. Most construction is now complete. New facilities were built on Meck Island for the HOE experiment in the early 1980s, and these facilities have now been extended. The currently planned SDI activity at Kwajalein will peak in 1992, when about 400 extra US personnel are expected on the atoll.[12] Extra accommodation is under construction to house these forces. Earlier, more ambitious SDI plans called for about 2,000 extra personnel on Kwajalein.

ERIS has required refurbishment of the HOE launch facilities on Meck. GSTS requires new launch facilities on Omelek, SBI requires Minuteman launch facilities on Meck and Polaris launch facilities on Roi-Namur. According to the Defense Marketing Service, a large percentage of future activities at Kwajalein will probably be funded from the SDI military construction account or from specific project budgets such as those of SBI, GSTS or ERIS.[13]

E. Role of KREMS and Telemetry in BMD and SDI

The PRESS complex described in Chapter 2 was gradually transferred from ARPA to KMR management between 1968 and 1970, about the same time as overall ABM research was transferred from ARPA to the Army's Ballistic Missile Defense Research Office. Project Defender lapsed and its role was taken over by what was eventually called the Ballistic Missile Defense Systems Command. The PRESS radars, later re-named KREMS, performed most of the BMD research done between 1976 and 1983, when interceptors were not being launched at Kwajalein. Whether the enormous data base on re-entry phenomenology accumulated then has actually been used by SDI, or whether it has been any use to SDI, is not evident from the technical literature.

The Wideband experiments utilizing Altair and carried out by DNA are also seen as an important lead-up to SDI, since they helped to

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12 *FEIS*, p.2-16.

13 "Strategic Defense Initiative ... Test and Evaluation - Kwajalein Range Instrumentation and Support", DMS report, 26 March 1988.

characterize the sort of nuclear environment in which the SDI radars would have to function in wartime.

KREMS is currently undergoing upgrades in readiness for SDI.[14] The Tradex radar is being upgraded for the eighteenth time since it was installed in the early 1960s, this time to allow it to track as many as 64 SDI targets simultaneously, even if they are obscured by a cloud of intercept debris.[15]

Monitoring ABM intercepts poses maximum demands on both radars and telemetry receivers. The data is more important in the case of failed intercepts, where it is important to work out what went wrong. During a re-entry, which takes no more than 30 seconds, something like 4 billion bits of radar data alone may be collected, with Altair, Tradex, MMW and Alcor recording at 60, 30, 40 and 3 megabits per second respectively. The telemetry installation at Ennylabegan may be collecting at 800 kilobits a second, with up to 14 downlinks from as many RVs and interceptors.[16]

F. Comparison between Kwajalein and White Sands

The one other test range supporting SDI tests is White Sands Missile Range, New Mexico. USAKA and the White Sands Missile Range are specified in the 1972 ABM treaty as the only two places where the United States is allowed to carry out testing of ABM radars and weapons. The White Sands insignia proclaims the range to be the "Birthplace of America's missile and space activity". It is, of course, Native American land by treaty with the US Congress.

As a target zone, White Sands is, in many ways, a mid-continent equivalent to USAKA. It has a main test area of about 160 by 65 km, dimensions considerably greater than those of the Kwajalein mid-atoll corridor (59 by 18 km) (see Figure 4.4). This area has been

14 *Ibid.*, 26 March 1988, p.5.

15 K. Roth, M. Austin, D. Frediani, G.. Knittel and A. Mrstik, "The Kiernan Re-entry Measurements System on Kwajalein Atoll", *The Lincoln Laboratory*, Summer 1989, p.259.

16 G. Zorpette, "Kwajalein's New Role: Radars for SDI", *IEEE Spectrum*, vol. 26, no. 64, March 1969.

Figure 4.4: Comparison of Ascension Island, Kwajalein Atoll, and White Sands Missile Range

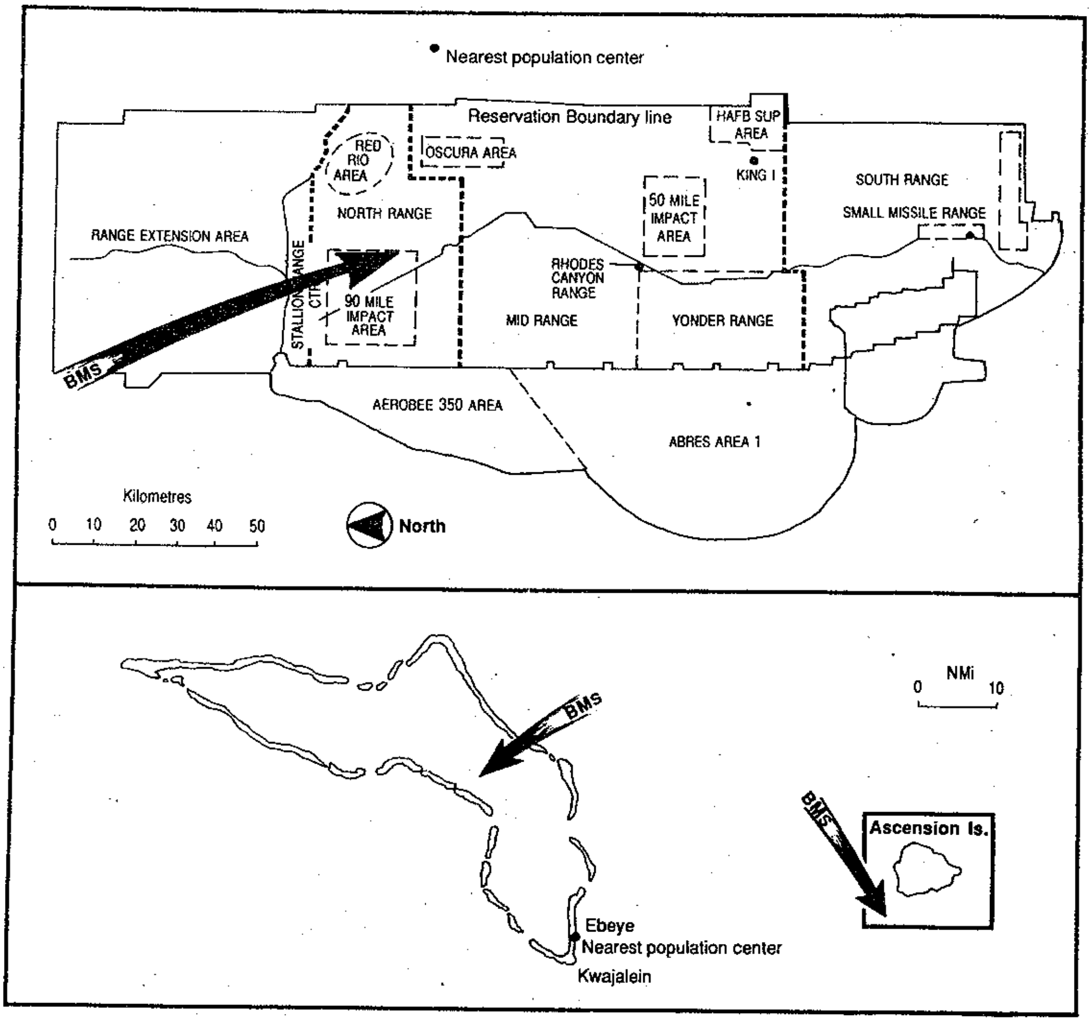
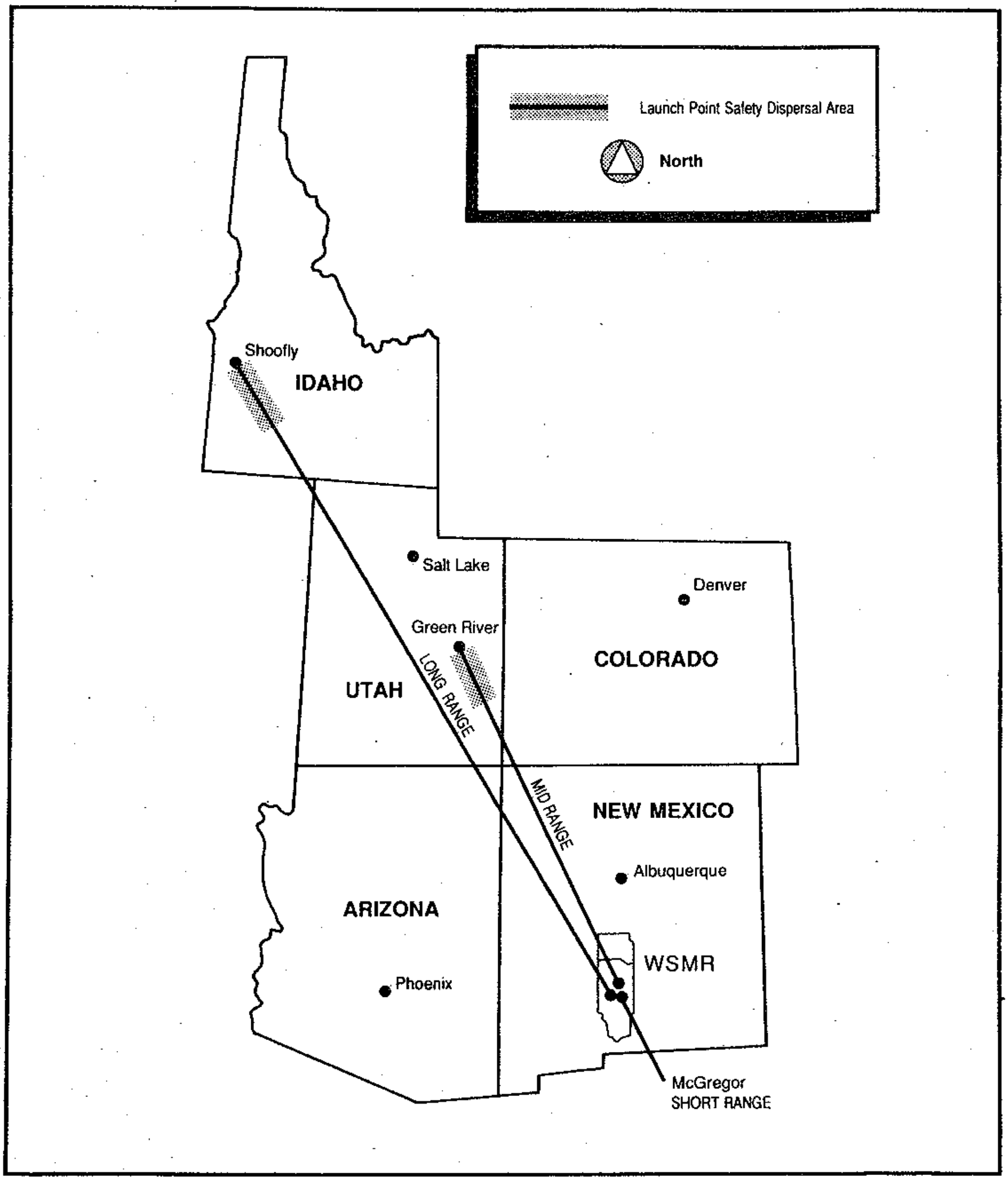


Figure 4.5: White Sands and Missile Range Corridors



surveyed to a very high degree of accuracy and is heavily instrumented, especially with high-speed, high-accuracy optical equipment, highly suited to the thin, clear, high-altitude desert air. However, the range for shooting missiles into White Sands is much shorter than for USAKA. Missiles can be launched from Green River, Utah, about 750 km away, or from Home AFB, Idaho, about 1,200 km away[17] (Figure 4.5).

White Sands is used primarily for testing tactical surface-to-surface, air-to-air, and cruise missile systems. The developmental tests of Pershing-2 IRBMs took place here. Army Hawk surface-to-air, Navy Standard surface-to-air, and Air Force strategic nuclear short-range attack missiles (SRAMs) are tested at White Sands. Some ABRES tests were also done at White Sands.

White Sands deals with the more exotic SDI concepts, such as directed energy weapons, which are far from ready for intercept testing. In May 1989, White Sands hosted the first test of a neutral particle beam generator, one of the favourite weapon concepts of the "High Frontiers" publicists. Called Bear ("Beam aboard rocket"), the prototype beam weapon was boosted to about 200 km altitude.[18]

Laser beam weapon research is also undertaken at White Sands, using a high-energy laser test facility.[19] Ground-based free-electron lasers with space-based pointing mirrors for boost phase intercept are amongst the concepts under test.[20]

White Sands also tends to handle the shorter range and lower altitude SDI concepts. Much of the preliminary developmental testing of systems is done at White Sands prior to more strenuous and realistic testing at Kwajalein. Most of the LoADS tests, for example, were done

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17 *Major Range and Test Facility Base: Summary of Capabilities*, Under-Secretary of Defense for Research and Engineering, June 1983, p.1-4; *US Army White Sands Missile Range, New Mexico: Technical Capabilities Summary*, White Sands Missile Range, May 1983.

18 T. Foley, "US Prepares for First Test of Neutral Beam in Space", *AWST*, 15 May 1989, pp.56-58.

19 "Defense Dept. Asks $9 Million to Expand Laser Test Facility", *AWST*, 9 April 1984, p.19.

20 B. Greeley, "SDIO stresses gains in ICBM intercept", *AWST*, 19 May 1986, pp. 24-25.

at White Sands, and only the final "realistic" tests were done at Kwajalein. This continues the pattern established during the ABM programs of the 1960s. The low-altitude interceptor Sprint was developed at White Sands and tested against Athena rockets from Green River. Only later was it tested more rigorously at Kwajalein.

White Sands' one big advantage over Kwajalein is that it is a much more convenient place to test. It is centrally located within the United States and close to numerous other high-tech military research facilities.

It also has big disadvantages. These include:

1. No regular succession of incoming test ICBMS as targets of opportunity.

2. Lack of facilities for RV phenomenology and discrimination studies. White Sands has nothing comparable to the KREMS radars.

3. Size and safety limitations. Although much bigger than Kwajalein and surrounded by rural areas with low population density, White Sands is seen by the military as providing a very different test environment from that available in the Pacific, where there are even lower population densities of non-US citizens. It is doubtful whether today's communities under the Home AFB-Green River-White Sands flightpaths would tolerate the numbers of rockets flying overhead that were routine back in the sixties during ABM tests. Moreover, there are no expanses of "empty" ocean around White Sands to accommodate the debris from SDI intercepts.

John Pike, space expert of the Federation of American Scientists, estimates that moving the Kwajalein SDI tests is technically feasible but would cost up to five times as much as at Kwajalein. Moreover, if the SDI tests were done anywhere other than at Kwajalein or White Sands, then the United States would have to modify or abrogate the ABM treaty. Even if the United States was prepared to undertake this drastic step, the only other possibility for intercept tests with any realism would be on another island (such as Johnston Atoll) or, alternatively, on the Eastern Test Range. In neither case is there a potential instrumented terminal area offering the advantages of Kwajalein.

There seems little doubt that as SDI continues, and the tests become bigger, more dangerous and more realistic, the importance of Kwajalein for SDI will increase. New concepts such as "Brilliant Pebbles" (if they ever advance to the test stage) will have to be tested at Kwajalein. White Sands is suitable for tests to show that interceptors can fly. But Kwajalein is required for tests to show they can kill ballistic missiles.

According to the Defense Marketing Service:

> Kwajalein Missile Range is vital to the success of the SDI demonstration/validation programs for the Space Based interceptor (SBI), the Ground Surveillance and Tracking System (GSTS) and Exo-atmospheric Re-entry Vehicle Interception System (ERIS). KMR provides unique capabilities for the collection of exo-atmospheric signature data, recording missile re-entry phenomena, providing terminal trajectory and impact data, recovering re-entry vehicles and transmitting near-real time data on tests.[21]

The chief engineer for the Strategic Defense Command's Testing Operations office put it more bluntly: "Kwajalein is the Army's primary SDI test site."[22]

Or, as the Army's DEIS on the SDI programs at Kwajalein concluded:

> There are safety considerations and range size limitations at the White Sands Missile range (the other range recognised in the [ABM] treaty); therefore, USAKA provides an opportunity for more realism and flexibility in the ABM [that is, SDI] program. This makes USAKA an important asset in the support of ABM testing. Without this capability, the United States

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21 DMS, "Strategic Defence Initiative ...", 26 March 1989.

22 As quoted in the Kwajalein base newspaper, *Hourglass*, 12 August 1988, p. 3.

> would be hampered in its ability to test and evaluate ABM technologies ... USAKA is the only reasonable site for field testing of the Strategic Defense System.[23]

G. Pacific "SDI Battlespace"

In mid-1984, the Army Ballistic Missile Defense Organisation initiated a "Kwajalein Advanced Range Study" (KARS) to determine if "reconfiguration and contract efficiencies might produce cost savings sufficient to support future requirements such as SDI". In February 1985, the KARS committee reported on a concept for Kwajalein support of SDI, which involved:

> ... a flexible instrumentation array utilizing Wake, Johnston, Midway, and the Hawaiian Islands in a network to obtain independent measurements throughout the "SDI battlespace". It recognised that this "virtually land-free area" would make an ideal place for SDI tests. The study concluded by preparing an ASDI work package to support range development efforts.[24]

On 22 March 1985, Lieutenant General Gen. James Abrahamson, Director of the SDIO, concluded that funding for the SDI battlespace was essential. SDI has suffered many rebuffs and setbacks since then. But it still needs its "battlespace" in the Pacific to simulate operational conditions in a nuclear war.

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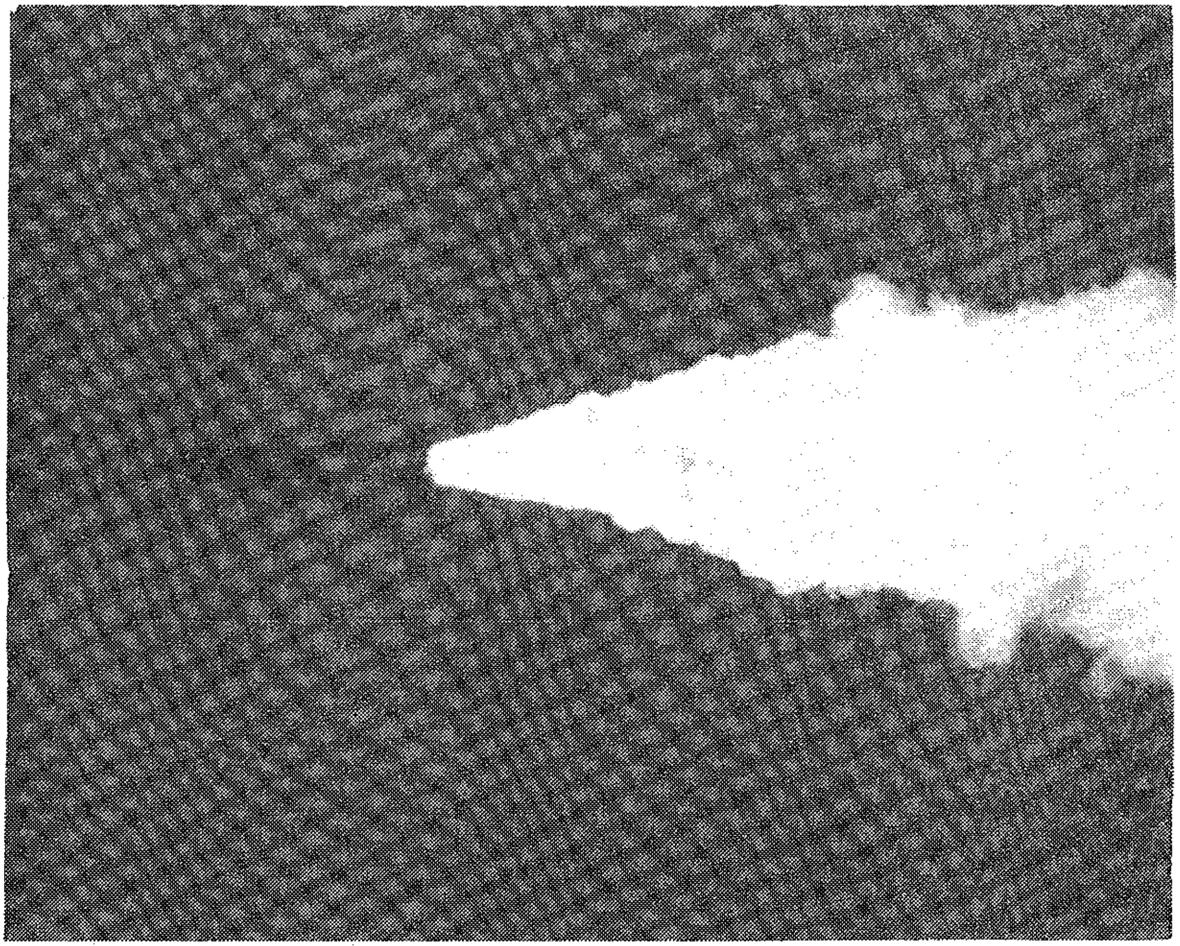
23 *DEIS*, pp. 1-9, 2-55.

24 *Annual Historical Review*, 1985, pp. II-161-64.

Plate 5: Test Launch of Minuteman III from Vandenberg AFB



(USAF Photo)

CHAPTER 5

BANNING MISSILE TESTS

It is evident that the US military race harder to prepare for nuclear war at Kwajalein than at any other spot on the earth. Only the Soviets match or exceed the US effort. This chapter reviews briefly the impact of missile testing on the people who live at Kwajalein. It also examines the emergence of opposition to missile testing in the region, and the first attempt to create a ballistic missile test-free zone (BMTFZ) in the South Pacific. The last section considers the prospects for a Pacific-wide BMFTZ and reviews the pros and cons of partial and comprehensive forms of ballistic missile test bans.

A. Atomic Apartheid

For many years, the United States has clung to Kwajalein and ignored the needs, rights and aspirations of Marshallese people. During the UN "strategic" trusteeship, the United States had virtual sovereignty and total *de facto* control over the Marshall Islands. The US military forcibly relocated whole island populations at will, banned them from carrying on traditional fishing, hunting and horticultural activities at particular places, and imposed "atomic apartheid" on the atoll.

Seized from the Japanese in 1944, Kwajalein - with its ideal central Pacific location and huge lagoon - was designated as part of the Pacific Missile Range in 1960. The people of Kwajalein signed a lease giving up their atoll to the US military for 99 years. In exchange, they received $US750,000, or less than $US23 per hectare. When the central two-thirds of the atoll's lagoon - the "mid-atoll corridor" - was set aside for incoming missiles, the residents of the main island of Kwajalein and other smaller islands were uprooted, provided with $US25 a month as "compensation", and relocated to the tiny island of Ebeye.

The population of Ebeye swelled from 500 in 1951 to 4,500 by the mid-sixties. By 1984, the population had more than doubled again, as people from all over the Marshalls flocked to the island to fill KMR's demand for logistic and service personnel. Today, Ebeye has a population density higher than that of Washington, DC.

While life for the 3,000 American military and civilian personnel on Kwajalein's 364 hectares resembles that of a comfortable Southern California suburb - with tennis, basketball, and handball courts, swimming pools, bowling alleys and a golf course - living conditions on Ebeye were so bad by the end of the seventies that the island was nicknamed the "slum of the Pacific".[1] The island's sewage system broke down in 1979 so that when people flushed toilets, human waste reportedly gushed into their sinks. There was only one ill-equipped hospital on Ebeye, with three doctors and no dentists. Educational facilities consisted of one dilapidated public elementary school for 1,200 children. With no high school, fewer than half of Ebeye's students who completed elementary schooling went on to some form of secondary education.[2]

Economic hardships have been matched by social indignities. To visit Kwajalein - their own island - the people of Ebeye had to have passes, which were issued in limited numbers. Passes were required not only for those running errands but also for the hundreds of Marshallese working on Kwajalein as house-servants, gardeners and mechanics. They had to be off the island by nightfall or risk arrest. To transact business at the Kwajalein branch of the Bank of Hawaii, they first had to wait in a hot bus (since no more than 10 Marshallese were allowed to enter the bank at a time) and then be escorted and watched by Army security personnel.

These conditions were targets of criticism and a source of US international embarrassment. Knowing this, the people of Kwajalein have won marginal improvements through direct action. In defiance of Army regulations, landowners occupied some mid-corridor islands in 1969. As a result, the Pentagon changed the conditions of the original

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1 G. Johnson, *Collision Course at Kwajalein: Marshall Islanders in the Shadow of the Bomb*, (Pacific Concerns Resource Center, Honolulu, 1984), p. 23.

2 See Kwajalein Atoll Corporation, "Complaint for Declaratory and Injunctive Relief" (mimeo), US District Court, District of Columbia, 5 December 1984.

lease: from $US750,000 for 99 years, the military agreed to pay $US420,000 per annum over five years to 1,470 people.

A larger protest took place in July 1979, when 500 landowners staged a "sail-in" to several restricted islands. This action forced the United States to agree to provide $US9 million annually as rent for KMR; $US5 million would go directly to the landowners while $US4 million would be channelled to the Marshall Islands central government for capital improvements and other projects.

The biggest protest, "Operation Homecoming," took place from June to November 1982. About 1,000 people occupied parts of Kwajalein and some mid-corridor islands in response to terms set forth in the Compact of Free Association, newly signed by the Marshall Islands government and the United States. The draft Compact would have given the US military the right to use Kwajalein for missile testing for 50 years. It also would have reduced the annual rent from $US9 million to $US1.9 million.

Despite harsh reprisals, the Islanders persisted and succeeded in renegotiating parts of the Compact, including: 1) reduction of the maximum term of the KMR lease from 50 to 30 years; 2) an agreement to give the Kwajalein landowners a greater portion of the $US1.9 million annual rent; and 3) establishment of a $US10 million fund to improve living conditions on Ebeye over a three-year period.

These concessions, however, have not corrected the fundamental injustice faced by the landowners. Their deep dissatisfaction surfaced dramatically in September 1983, when 70 per cent of the people of Kwajalein voted against the Compact of Free Association between the Marshalls and the United States. According to Ataji Balos, Chairperson of the Board of Directors of the landowners' Kwajalein Atoll Corporation, the vote was a protest against "the imposition of thirty more years of the same treatment on the Kwajalein people".[3]

Today, the Marshall Islands have partial independence from the United States within the relationship known as the "Compact of Free Association". The Compact has a contradictory and legally

3 Testimony to US House of Representatives, Subcommittee on Public Lands and National Parks, 9 August 1984.

dubious political status, in which the nation is held to be "sovereign" in its domestic and foreign policy-making while entrusting its defense to the United States. It has two faces: for the United States, it ends the embarrassment of being saddled with the last trusteeship, while maintaining effective control of the islands. Most importantly, the United States retains the right of "strategic denial" - the ability to keep out any other foreign power from Micronesian land and waters. For Micronesians, the Compact is a cosmetic arrangement which commits them to continuing economic and political dependence on the United States. They are no longer able to appeal to the United Nations to mediate between themselves and the United States. It is but a new form of strategic colonialism.

Thus, Kwajalein is locked into the current terms for thirty years. Theoretically, the Marshallese could then evict the USAKA. In reality, they would face massive and punitive pressure from Washington if they tried to shut down USAKA. Apart from sticks, Washington also wields carrots. Through wages, taxes, rentals, and compensation payments, USAKA injects about $US23 million annually into the Marshallese economy - about one third of the Marshalls' public budget. The Republic of the Marshall Islands is a poor nation that cannot afford to reject USAKA's largesse. In the late 1970s and early 1980s, the Kwajalein landowners took direct action against USAKA. These protests forced the United States to respect some of their rights and to pay better compensation.[4]

B. Push for a South Pacific Missile Test-Free Zone

The first attempt to construct a ballistic missile test-free zone occurred in the South Pacific. This effort grew out of earlier popular opposition to missile testing in the Pacific that was first expressed at the Conference for a Nuclear-Free Pacific in Suva in 1975. This meeting launched a campaign for a nuclear-free and independent Pacific known as NFIP. A draft "People's Treaty for a Nuclear-Free Pacific" included a clause banning missile testing. At the fourth NFIP

4 See G. Johnson, "Ebeye: From Pacific Slum to Isle Showcase", *Pacific*, January/February 1990, pp. 30-39.

conference in Vanuatu in 1983, a People's NFIP Charter renewed the demand for a missile testing ban.

There were also moves to include a ban on missile testing in the 1986 South Pacific Nuclear-Free Zone Treaty (SPNFZ, sometimes called "Spin-fizz"). These moves were initiated in mid-1985 by the Melanesian Spearhead group; that is, by Vanuatu, the Solomon Islands and Papua New Guinea; and by Nauru, one of the Marshalls' closest island neighbours. According to David Sadleir, an Australian diplomat who chaired the nuclear-free zone working group that prepared the treaty: "Various approaches were considered, including inviting nuclear weapon states not to conduct missile tests into the zone area".[5]

According to Sadleir, these moves did not succeed:

> It was recognised that [South Pacific] Forum members did not have the legal power to ban missile tests in the region since these were usually conducted over and into international waters. There also would be problems of verification. The inclusion of delivery systems in the definition of nuclear explosive devices [in Article 1(c)] would have presented serious difficulties since delivery systems capable of being used for nuclear weapons are also capable of being used with conventional warheads, and some such systems are used by at least some Forum members in their conventional defense forces. The Working Group also discussed the likely reactions of the nuclear weapons states if the treaty were to cover missile tests. It was noted that such a provision could jeopardise acceptance of the Protocols to the treaty by the nuclear weapon states which were likely to regard it as an attempt to restrict their rights in international law. Vanuatu, Solomon Islands, Nauru and PNG [Papua New Guinea] asked that their concern about missile testing in the South Pacific be recorded.[6]

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5 Report by the chairman of the working group on a South Pacific nuclear-free zone to the South Pacific Forum, Rarotonga, 4-6 August 1985.

6 *Ibid.*

In fact, Australia was working actively to promote US interests within this working group and in the South Pacific Forum to negate efforts by other South Pacific states for a much more comprehensive nuclear-free zone than was created in SPNFZ. As Ambassador Paul Warnke, former director of the US Arms Control and Disarmament Agency, told a US House Foreign Affairs Committee in 1987: "Australia has seen to it that the treaty is carefully crafted to protect our genuine security interests".[7]

The Australian chairman drafted the rationale cited earlier for rejecting a stronger stance on missile tests. Yet the reasons given were spurious, shoddy, and false on at least five grounds. It is instructive to examine these arguments closely (in the order in which they were listed by Sadleir), as they provide much insight into the arms control issues that are raised by a ballistic missile test-free zone.

First, in contrast to the argument that the South Pacific Forum members lack legal powers, they can in fact claim whatever legal powers they wish under international law. The whole idea of such a treaty is to make a bargain with other nations whereby they forgo certain "rights" on the high seas in return for other advantages. No-one finds it problematic to ban piracy in international waters. Indeed, the final treaty attempts to ban nuclear warhead testing on the high seas. Presumably, Australia allowed this constraint because the United States had no desire to conduct such tests, unlike missile tests.

Second, missile tests are not, as Sadleir stated, "usually conducted over and into international waters". Most US tests in the Pacific are into the territorial waters of what is now the Republic of the Marshall Islands, and most Soviet tests descend within the Soviet Union. Presumably, Australia was not seeking to protect the ability of the Chinese or the Soviets to test into the South Pacific. At best, this stance reflected woolly and ill-informed thinking. At worst, it revealed a desire to accommodate US testing that was particularly scandalous in light of the MX imbroglio that had erupted seven months earlier (see below).

7 US Congress, House Committee on Foreign Affairs, *The South Pacific Nuclear-Free Zone: Hearings and Markup*, 15 July 1987, p. 22. See also *Wellington Pacific Report*, No. 23-24, pp. 1-3.

Third, what Sadleir called "problems with verification" on a missile test ban are negligible. The United States has never expressed any doubts about its own ability to detect all Soviet missile tests into the Pacific. Clandestine US missile tests into the Southeast Pacific might present problems of verification for the Soviet Union, but it is doubtful that this consideration was uppermost in the Australian's mind. Moreover, both superpowers are also committed to promulgating warning notices to mariners and airmen before launching missile tests. This procedure eases the verification problem for a regional ballistic missile test ban, as it permits the tracking of "routine" tests that would highlight anomalous launches and splashdown zones.

Fourth, "inclusion of delivery systems in the definition of nuclear explosive devices" was not necessary. In fact, it would probably have been counter-productive. What was needed was a separate article in the treaty banning long-range missile tests as distinct from nuclear tests. As Sadleir said, "delivery systems capable of being used for nuclear weapons are also capable of being used with conventional warheads". (He could have added chemical and biological warheads.) But is this concern realistic enough to block a ballistic missile test ban? Is it really likely that the Soviets might sometime want to put a wad of plastic explosive on an SS-18? Or that the Americans might want to put a can of napalm on a Minuteman? If they did, would it change the balance of terror significantly? If used against the other, would firing a conventionally armed ballistic missile not risk igniting general nuclear war? If used against a non-nuclear adversary such as North Korea, would a $US50 million missile not be an expensive way to deliver a few hundred kilos of high explosive (compared with cruise missiles)? And insofar as non-nuclear means of mass destruction can be loaded onto ballistic missiles, does not the urgency of halting vertical and horizontal[8] proliferation of ballistic missiles far outweigh any "forgone" conventional opportunities that the superpower missile force might offer?[9] In short, the whole

8 *Vertical* = escalating acquisition by superpowers; *horizontal* = acquisition by lesser powers.

9 For a silly but informative discussion of the speculative thinking about substituting conventional for nuclear warheads on US intercontinental ballistic missiles, see G. Quester, "Substituting

argument is so specious that it is hard to believe that anyone but Australia took it seriously.

Of course, the dual capable missiles referred to as being of interest to Forum members are *tactical* missiles. But the Forum nations were hoping to ban the testing in the Pacific of *strategic* missiles. Since no Forum member has strategic missiles armed with conventional warheads, the issue of tactical missile testing is irrelevant to and a diversion from the problems raised by a missile test ban zone.

Finally, a ban is not only aimed at restricting the rights of great powers in international law. Tiny nations like Nauru, with a population of about 9,000 souls, have few illusions about their ability to restrict US, Soviet or anyone else's claims. Rather, they proposed to "invite nuclear weapon states not to conduct missile tests", thereby placing *political* pressure on the great powers and their allies. Symbolic statements can be very potent, as the Belauan and New Zealand examples have shown.

It is obvious that Australia blocked the South Pacific Islanders' attempt to pursue their entirely legitimate and desirable goal of stopping ballistic missile tests in their region. By using false and misleading arguments, Australia sabotaged what otherwise might have been the world's first missile test-free zone to be declared since the Antarctic Treaty was signed. Australia's stance is particularly reprehensible considering the outcry against the plans to test MX into the South Tasman Sea near Tasmania in February 1985, five months before the Sadleir report was filed and at the very time that Forum nations were negotiating over the terms of the SPNFZ.[10] Australian Prime Minister Bob Hawke was forced by his own party to withdraw permission for the tests.

When the MX tests became public, US plans to test Trident missiles near New Zealand's Chatham Islands were also revealed. The then New Zealand Prime Minister, David Lange, declared that "if the United States sought New Zealand's agreement to firing such missiles

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Conventional for Nuclear Weapons: Some Problems and Some Possibilities", in his *The Future of Nuclear Deterrence,* (Lexington Books, Massachusetts, 1986), p.217.

10 "Peace Groups Plot Splash Site", *Wellington Evening Post,* 18 March 1985.

into the Chathams area it would not be given".[11] Unfortunately, this stance was not converted into active support for the Islanders' anti-testing position against that of Australia.

C. Reviving a Pacific Missile Test Ban

In spite of these machinations, a ban on missile testing remains worthy of active consideration by peace movements and governments throughout the Pacific, for reasons adduced in the next section. Kwajalein is no less important now than it was in 1975 when the People's Treaty was drafted, or in 1985 when Vanuatu and other nations tried to ban missile tests via the SPNFZ treaty.

Moreover, the issue of strategic colonialism is just as relevant today as in the past. No island community willingly accepts becoming a missile bullseye. Can anyone imagine the inhabitants of Malta or Iceland accepting their islands being turned into "safe" Instrumented Terminal Areas?

The increased use of "Broad Ocean Areas" for missile impacts is an added reason for opposing missile testing in the Pacific. Rather than the United States having a "right" under international law to test in the high seas, a good case has been made that US missile testing on the high seas constitutes illegal interference in other nations' freedom of navigation on the high seas.[12]

Two other nations beside the United States test strategic missiles in the Pacific. Very occasionally, China tests into international waters near the Solomons and reportedly into the Yellow Sea. (China has also tested missiles into the Indian Ocean.) The Soviet Union used to carry out three to four tests or test series a year into the North Pacific. Once (in 1975), the Soviets launched a missile to 6° south of the

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11 "Chatham Missiles Hit Lange's 'No'", *Wellington Evening Post*, 12 November 1984.

12 J. Van Dyke, "The Legitimacy of Exclusionary and Warning Zones on the High Seas" (mimeo), paper prepared for Greenpeace, 25 August 1989.

equator in the vicinity of Fiji.[13] Over the last three years, however, the Soviet rate of testing in the Pacific has dropped almost to zero.[14]

The time is propitious, therefore, to revive the issue of a total ban on missile testing by all nations in the Pacific. Such a ban could perhaps be implemented by modification of the SPNFZ treaty, although this would be difficult, given Australian dominance in the South Pacific Forum. Island states such as Vanuatu, Solomons, Nauru and PNG might resume their enlightened efforts to draft and implement a new treaty that encompassed North and South Pacific test zones. Financial and other tangible support would have to be offered to the Marshall Islands to recompense them for the losses that they would incur from the removal of USAKA.

Peace movements and other non-governmental organisations have an important role too. Awareness of the issues could be fostered worldwide by some high-profile direct action against the missile tests similar to the Greenpeace blockade of Trident missile launches from submarines off Cape Canaveral in the Atlantic. It is important that Soviet and Chinese missile tests also be targeted.

D. Pros and Cons of a Ballistic Missile Flight Test Ban (BMFTB)

The arms control community has long been aware of the contribution of missile tests to the arms race. The following sections describe their numerous proposals, but generally minimal political efforts, to bring the missileers to heel since the missile programs began.

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13 O. Wilkes, "Missile Testing in the Pacific: The 'Soviet Threat', Part 3", *New Zealand Monthly Review*, June 1986.

14 Britain tests its SLBMs on the Eastern Test Range. France tests its IRBMs and SLBMs into the North Atlantic, with a down-range tracking station on Santa Maria Island in the Azores. A French delegation of military officers and government officials visited Kwajalein in 1985, possibly to explore shifting French missile tests there.

Early Proposals

In May 1958, the US President's Science Advisory Committee advised that a total BMFTB could, if it were implemented within six months, prevent the Soviet Union from developing ICBMs.[15] By the same token, this action would have prevented the United States from developing its own ICBMs. Unfortunately, no-one grasped the opportunity.

In 1964, the idea of a test ban was resurrected briefly in official circles when President Lyndon Johnson proposed that the two superpowers explore a verifiable freeze on strategic nuclear weapons as the follow-up to the Kennedy-Khrushchev Limited Nuclear Test Ban Treaty of 1963. The 1964 freeze proposal suggested that both superpowers be prohibited from flight-testing new or modified strategic missiles, including land-based surface-to-surface missiles with ranges greater than 1,000 km; all submarine-launched ballistic missiles with ranges greater than 100 km; and all strategic anti-missile systems. Operational tests[16] of specific missiles in the constrained categories would have been permitted, but only if these missiles were already in production at the time of the freeze, and then only at declared facilities, after advance notice, and in the presence of observers. Space vehicle operations would have been unconstrained but observed.[17]

A series of studies were commissioned by the State Department, the Joint Chiefs of Staff, and the newly created Arms Control and Disarmament Agency on possible types of strategic arms control envisaged in the freeze proposal. These studies included the

15 John Foster Dulles, to James Killian, Special Assistant to the President for Science and Technology, 2 May 1958, (Dwight D. Eisenhower Library).

16 At the time, they were called "confidence and training" tests.

17 Bendix Corporation, "Detection of Significant Modifications in Soviet Missile Design Through Observation During Testing", summary final report to Office of Assistant Secretary of Defense, International Security Affairs, US Department of Defense, by Office of National Security Studies, Aerospace Systems Division, Ann Arbor, Michigan, 27 October 1967.

requirement that both sides would have to hold exhibition firings of all constrained missile types and that access into limited re-entry areas be permitted or that re-entries be only into international waters. These approaches were held to make a freeze more easily verifiable.[18] One study confidently held that these provisions (not included in the original 1964 proposal) would ensure that the Soviets could not cheat. The study concluded that lesser access would still leave the United States able to detect suspicious missile events, but that it might not be able to identify in detail the kinds of missile modifications being clandestinely tested.[19] These and other proposals were shelved due to opposition from the burgeoning US space establishment, which did not want arms controls interfering with its program. NASA was particularly concerned that space technology for booster rockets and multiple satellite launches would be inhibited.[20] The latter issue was intimately linked to development of MIRVed missiles, then on the drawing boards.

At this time, US Defense Secretary Robert McNamara was trying to stop the Air Force from deploying thousands of land-based missiles. To this end, he permitted them to develop missiles carrying multiple warheads.[21] Some officials in the first Nixon Administration wanted to limit development and testing of this new hydra-headed technology, but Henry Kissinger brushed them aside in 1969 while negotiating the first strategic arms limitations treaty with the Soviet Union.[22]

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18 T. Wolfe, *The SALT Experience*, (Ballinger, Cambridge, 1979), p.1; Bendix Corporation, "Detection of Significant Modifications ...", p.2.

19 Bendix Corporation, "Detection of Significant Modifications ...", p.2.

20 F. Hussain, *The Impact of Weapons Test Restrictions*, Adelphi Paper 165, (International Institute for Strategic Studies, London, 1981), p.33.

21 F. Kaplan, *The Wizards of Armageddon*, (Simon and Schuster, New York, 1983), p.364.

22 S. Hersh, *The Price of Power*, (Simon and Schuster, New York, 1983), pp.151-152; and J. Kahan, *Security in the Nuclear Age: Developing U.S. Strategic Arms Policy*, (Brookings Institution, Washington, DC, 1975), pp.99-141.

Later, many American strategic analysts regretted Kissinger's push for technological superiority to support his "hard ball" arms control bargaining, for it boomeranged against the United States by enabling the Soviets to put multiple warheads on their land-based missiles, thereby vastly increasing the Soviet nuclear threat to the US missile force.[23] MIRV was first tested in 1969 and then rapidly adopted by both superpowers. The net result was that while the 1972 SALT I Treaty limited the number of missiles either superpower could deploy, it sanctioned a huge increase in the number of *warheads* fielded by both sides.

Once the world had been made that much more dangerous by MIRVed missiles, the superpowers could no longer ignore missile tests in arms control agreements. Until this point, they had advised each other of missile tests on an *ad hoc* and incomplete basis. While avoiding restraints on tests *per se*, they agreed in their 1971 "Accident Measures" agreement that each would notify the other in advance of any land-based missile launch which would extend beyond its national territory in the direction of the other party. An errant missile test that could be misinterpreted by the other side was to be the subject of instant notification.

In 1973, the US-Soviet Incidents at Sea agreement required further that both sides issue warnings to aviation (NOTAMs) and to shipping (HYDROPACs) for missile launches that would splash down in international waters. The areas projected to be hit by the launch vehicle and associated debris must be specified, but not the launch point, the type of vehicle, or the purpose of the launch.

Under SALT II (see below), each party was obligated to notify the other of multiple ICBM launches or of single ICBM launches extending beyond its national territory. Unlike the warnings required in the Incidents at Sea agreement, SALT II notifications required detailed information such as launch locations and specification of test range to be used.[24] (This designation also prevented the construction of launch silos elsewhere under the claim that they are for missile tests

23 G. Smith, *Double Talk: The Story of SALT I*, (University Press of America, Lanham, Maryland, 1985), p.178.

24 W. Rowell, *Arms Control Verification*, (Ballinger, Cambridge, 1986), p.56.

rather than operational missiles.) Both sides have provided this information since July 1979, although the Soviets have been more tardy than the United States. None of these agreements covered ICBM launches that descended to earth within the territory of the launching nation. Nor must the two superpowers notify each other directly or specifically when they fire SLBMs. They only issue standard NOTAMs/HYDROPACs, which announce standard air space/oceanic "closure areas" if what goes up comes down in international waters. The reason for the closures need not be specified.[25]

Partial Ballistic Missile Flight Test Ban in SALT II

President Jimmy Carter was reportedly very impressed by the advantages that might have flowed from a partial BMFTB incorporated into SALT II, then under negotiation with the Soviet Union. In this case, however, it was the *Soviet* leaders, piqued at Carter's re-orientation away from President Gerald Ford's Vladivostok proposals, who objected to the measure. Under Carter, the United States introduced two proposed controls into the negotiations with the Soviet Union. First, it proposed to limit the number of re-entry vehicles that could be carried on each missile. Second, it called for a sweeping ban on new missiles and on modification of existing ones. Although SALT II was never formally ratified by the United States, agreement was struck with Moscow in the negotiations to limit the United States and the Soviet Union to no more than 25 flight tests (the first 12 of which define the system, the rest defining the system as one of a new missile type) of only one new type of land-based ballistic missile.

SLBMs were not constrained, however. Restrictions on testing of existing ICBMs were also established, including no testing with more re-entry vehicles than installed prior to May 1979, and no

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25 C. Weinberger, "Direct Communications Links and Other Measures to Enhance Stability", in B. Blechman, *Preventing Nuclear War: A Realistic Approach*, (Indiana University Press, Bloomington, Indiana, 1985), p.178.

changes of more than 10 per cent in throw-weight, launch-weight,[26] length or width of new missiles. No new system with a throw-weight greater than that of the Soviet SS-18 missile could be tested.[27] Mobile launchers could be deployed but not tested under a protocol of SALT II.[28]

Physicist Sidney Drell was a key advisor to President Carter on missile test restraints. He later co-authored with Theodore Ralston a study of restrictions on missile tests, the concepts of which were probably similar to those that he earlier presented to Carter.[29] Drell and Ralston state that a number of benign effects would flow from restraints on ballistic missile tests. These would include retarding the development of a long list of anti-ballistic missile technologies and destabilizing missile technologies such as multiple and manoeuvrable re-entry vehicles; anti-satellite systems; depressed trajectory systems; and new classes of missiles. They suggested that the testing phase of a weapon's development provides the best opportunity to verify restrictions. Success in these areas would also provide the confidence that facilitates other arms control initiatives.

Drell and Ralston did not favour a comprehensive BMFTB. Rather, they argued for a limited BMFTB as the best way to preserve mutual nuclear deterrence. They saw restraints on missile testing as improving stability, maintaining deterrence at lesser levels of overall destructive power, and saving money. Thus, they called for confidence-building test restraints, such as: declared times at which tests may be conducted; declared test ranges and facilities; prior notification of test activity; prohibitions on concealment, deception, interference, and denial of data (such as encryption of RV telemetry).

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26 *Throw-weight* = "payload" of a missile; that is, the total weight of RVs, post-boost vehicle, etc. *Launch-weight* = gross weight of missile before launch.

27 T. Wolfe, *The SALT Experience*, pp.285-86; S. Drell and T. Ralston, "Restrictions on Weapon Tests as Confidence-Building Measures", in B. Blechman, *Preventing Nuclear War: A Realistic Approach*, (Indiana University Press, Bloomington, Indiana, 1985), p.20.

28 US National Academy of Sciences, *Nuclear Arms Control: Background and Issues*, (National Academy Press, Washington DC, 1985), p.34.

29 S. Drell and T. Ralston, "Restrictions on Weapon Tests", pp.86-98.

All of these steps required agreement with the Soviets on acceptable verification standards as to the type, quantity and quality of data to be provided; and joint observation of tests. Perhaps the only provision that they did not list that might be added in the post-INF era would be on-site inspection.[30]

As described earlier, many of these ideas were included in SALT II, as well as the provision that the superpowers would give each other 24 hours' notice of the time, place of launch, and missile impact area at sea. The goal of this kind of total BMTFB is, as Drell and Ralston put it, "to return to confidence in second-strike weapons, [and to provide] a firmer basis for ensuring peaceful intent than hard-target, first-strike weapons".[31] It should be noted, however, that restraints such as an annual quota of tests or a limit on RV numbers complicate negotiations and make monitoring more costly and difficult than would the procedures needed for a total BMFTB. The more states join such a regime, the greater the demands for verification, and the more important it becomes that the procedures are simply defined and easy to implement.

In May 1988, the Reagan Administration struck a new agreement with the Soviets on notifying each other of missile launches. The superpowers committed themselves to give at least 24 hours' notice of the planned date, launch area, and impact zone for strategic missile launches, and whether the test is to be fired from land or submarines.[32]

For and Against a Comprehensive Missile Test Ban

Against. The most detailed (and widely quoted) examination of the impact of a *comprehensive* missile test ban (CMTB) is probably that of Farooq Hussain, published by the conservative International Institute of Strategic Studies in 1981.[33] He was not convinced that a CMTB would limit technical progress in missile technology. He predicted that even a comprehensive test ban would not stop ICBMs

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30 *Ibid.*, p. 91.

31 *Ibid.*, p. 96.

32 *Arms Control Today*, July-August 1988.

33 F. Hussain, *The Impact of Weapons Test Restrictions*, pp. 19-51.

acquiring 30-metre accuracy within five years. Since we now know that ICBMS have not acquired 30-metre accuracy in nine years in the total absence of any kind of test ban, Hussain's reservations on this and other aspects of a ban are not very credible.

Hussain believed, for example, that new guidance units and new electronic circuitry alone could make existing missiles far more accurate than they currently were, without any need for flight testing. He noted that the number of developmental tests needed to develop a new missile was declining with time, presumably because alternative non-flight methods of testing were being developed. Therefore, he concluded, a ban on flight testing would also become less effective with time. However, he neglected to mention that the volume of data collected per test has increased much faster than the rate of testing is declining. Moreover, the major gains in accuracy and reliability of missile systems are now obtained from testing increasingly sophisticated RVs re-entering the atmosphere at ever steeper angles, and not from boost-phase and mid-course technologies that Hussain regards as uncontrollable.

It has frequently been suggested that partial bans, allowing operational tests but not developmental tests, might be more achievable and more palatable to the superpowers, since it would allow each side to maintain confidence in its own missiles while being deterred from launching war by the visible evidence that the other side's missiles were working too. Hussain, however, argues that partial bans would be even less of a hindrance to arms racing than a total ban. To buttress this claim, he notes how the Trident was largely developed using SFTs made with retired ICBM boosters, and draws the reasonable conclusion that a banned new missile could be developed by piggy-backing its various components on permitted flights of a deployed missile. Worse still, he says, Soviet space boosters are so similar to military boosters that the Soviet Union could use space shots to evaluate missile innovations.

Hussain also notes that much of US RV research has been done with SFTs, using relatively short-range missiles which simulated ICBM conditions by carrying RVs beyond the upper reaches of the atmosphere, turning, and then boosting the RVs back into the atmosphere at ICBM velocities.

While all these considerations are valid concerns in the context of a partial test ban treaty, there is no reason to not circumscribe these kinds of surrogate flights under a total test ban. The only issue then is how to restrain, monitor and verify RV component testing in space vehicles, especially re-entries with high beta values (see Chapter 3 and below).

For. The most cogent recent analysis of a comprehensive test flight ban is that of Robert Sherman, published by the Arms Control Association in 1987.[34] Sherman writes that it is still not too late for a comprehensive BMFTB to be worthwhile. Deterrence, he suggests, prevails because each side's deterrent forces can still ride out a first strike by the other. But this condition may not prevail much longer, he argues, especially if Soviet missiles become more accurate.

Sherman wants to exempt development of Midgetman from any ban because he believes that this missile would increase the deterrent value of US forces and reduce the first strike capability provided by more MX missiles. He views preventing the testing of depressed-trajectory SLBMs as particularly important. This capability could give the Soviet Union a first-strike edge over the United States by putting US bomber air fields and command posts at risk of destruction before the United States could mobilize its own retaliatory forces.

Sherman argues that no military planner will place reliance on missiles which have not been tested. His assertion follows from the fact that a missile's lethality is a combination of its warhead size, the reliability of the overall delivery system, and the accuracy with which it lobs the warhead onto a target. (An accurate system that cannot get off the ground has zero lethality.)

There are numerous examples of missiles that performed well in computer tests and ground tests, and then failed in flight tests. Since Sherman wrote, there have been two further examples to add to his list - the Trident-2, which performed brilliantly from the launch pad, but turned out to be almost unlaunchable from a submerged submarine, and the ignominious maiden flight of the Midgetman. By reducing

34 R. Sherman, "Deterrence through a Ballistic Missile Flight Test Ban", *Arms Control Today*, December 1987, pp. 8-13.

missile reliability, Sherman argues that a comprehensive ban would stop ballistic missile development dead in its tracks.

Sherman also argues that a comprehensive flight-test ban would also gradually erode the perceived reliability of those forces that are most suited to a damage-limiting first strike. Under a flight test ban, missile reliability would decline, but deterrence would hold because, as he puts it:

> Deterrence requires that our weapons have the maximum product of reliability times survivability. The more reliable the adversary's weapons, the less survivable our own weapons. Generally, high reliability reduces deterrence because it lowers the deterer's survivability more than it raises his reliability... Deterrence and stability are highest when strategic missiles on each side are "semi-rusted"--that is, when only about 30-70 percent can be expected to work properly.[35]

Sherman does not anticipate any major problems in verifying a comprehensive BMFTB. Ballistic missile tests are high-profile events. One flight might be missed by verification sensors, but a series of flights would be detected. The re-entry phase would be the easiest and arguably the most important to control. High-speed missile re-entries are quite different from, and easily distinguished from, the slow re-entries used in space exploration. He regards the most serious verification problem associated with a comprehensive BMFTB as controlling the upgrading of guidance systems to make missiles more accurate and more reliable. Sherman appears to be unaware, however, that the "action" in testing these parameters no longer rests in the space phase of the trajectory. Moreover, these advances in technology cannot be tested with any confidence in low beta space re-entries, for these types of re-entry do not reproduce the stresses suffered in high beta re-entries relevant to state-of-the-art missile tests.[36]

35 *Ibid.*, p. 9.

36 Re-entry vehicle beta coefficients are explained in the next section.

E. Combining Zonal, Partial, and Comprehensive BMFTBs

The previous sections considered three types of BMFTBs, namely, BMFT-free zones, partial BMFTBs, and global, comprehensive or BMFTBs. The superpowers have already negotiated partial restraints on missile tests within a global framework. Of course, these approaches can be combined so that some areas become missile test-free, or partially free from "open slather" testing in a given area as a transition to a global and comprehensive BMFTB treaty.

By itself, a BMFT-free zone in the Pacific could slow the nuclear arms race. But it would not stop improvements in ballistic missiles that arguably destabilize deterrence and enhance counterforce first-strike capabilities. The United States would still be able to test in the Atlantic, and the Soviet Union would still be able to test within its own enormous territory. A Pacific missile test ban could give an unfair advantage to the Soviet Union, since it would retain whatever instrumented terminal areas it has on Kamchatka Peninsula or elsewhere, while the United States would have only the quite inadequate land area of Ascension available as an instrumented terminal area - and even that could be denied to them by a future British government less enthusiastic about nuclear arms racing than the present Conservative government. Any campaign to create a missile test-free zone in the Pacific, therefore, should be designed to lead on to a comprehensive global missile test ban.

Like the nuclear non-proliferation treaty or NPT, a comprehensive BMFTB treaty will have to control vertical *and* horizontal proliferation of long-range ballistic missiles. Since this report has not dealt with other great-power ballistic missile testing, and not at all with horizontal proliferation of ballistic missiles (by small states), we will not outline possible comprehensive BMFTBs here in any detail.[37] Probably the most potent way to stop horizontal

37 For details, see: US Congressional Research Service, *Missile Proliferation: Survey of Emerging Missile Forces*, 88-642F, Washington, DC, 9 February 1989; R. Shuey, *Missile Proliferation: A Discussion of U.S. Objectives and Policy Options*, 90-120F, Washington DC, 21 February 1990; A. Mack, *Missile Proliferation in the Asia/Pacific Region*, Working Paper 92, (Peace Research Centre,

missile proliferation would be to offer a superpower missile proliferation ban plus access non-military space technology (including booster rockets) in return for missile non-proliferation commitments. But the likely contours of a ban on superpower missile tests (arguably the most urgent axis of proliferation in any case) can be deduced from our examination of US activities at Kwajalein.

High-Beta RV Ban

Of all the ballistic missile technologies being flight-tested, improvements in RV technology have the biggest potential to destabilize deterrence as it currently exists.[38] Certainly boosters, the boost phase, and post-boost vehicles can also be "improved" by further tests. But from the time that MIRV was first developed, research associated with RVs has been the cutting edge that has most degraded crisis stability and accelerated the routine arms race.[39] Moreover, improvements in RV technology also provoke the other side to abandon the existing restraints on anti-ballistic missile systems.

Above all, then, RV testing must be slowed and stopped. If negotiators discover that they have to distinguish between warhead RVs and objects from other space craft re-entering the atmosphere (such as film capsules from spy satellites), then the ban could specify that that no re-entry can use a high-beta RV.

Canberra, May 1990); A. Karp, "The Frantic Third World Quest for Ballistic Missiles", *Bulletin of the Atomic Scientists*, June 1988, pp.14-20; J. Nolan, "Ballistic Missiles in the Third World - The Limits of Non-proliferation", *Arms Control Today*, November 1989, pp. 9-14; and J. Nolan, *Trappings of Power: Ballistic Missiles in the Third World*, (Brookings Institution, Washington DC, 1991).

38 This statement is not to down-play the importance of other destabilizing activities such as SDI, anti-submarine warfare, or launch-on-warning technologies.

39 See M. Bunn, "Maneuvering Reentry Vehicles: Missions, Implications, and Prospects for Arms Control", paper presented to AAAS annual meeting, panel "From MaRVs to Microwaves", 15 February 1988.

The term beta is shorthand for ballistic coefficient. Expressed simply, the beta measures the weight of an RV compared with its streamlining. The heavier and more streamlined an RV, the steeper the angle at which it comes down through the atmosphere and the greater its velocity when it hits the ground or the ocean. Much of the RV research undertaken today is aimed at raising the beta of RVs, and adapting their contents to fit into high-beta enclosures that can withstand the enormous deceleration and temperatures associated with re-entry.[40] The military prefer RVs with high betas because these RVs are less vulnerable to various ABM measures, and because they are less affected by wind during re-entry (and hence are more accurate).[41]

Luckily, high-beta RVs are easily recognisable from their shape, as determined by imaging radars, and by their behaviour as they plunge down through the atmosphere. These RVs are therefore easily monitored with existing surveillance capabilities, and verifying a ban on high-beta RV testing would not be difficult.

F. Conclusions

Direct action and mobilised public opinion work. In August 1982, the Marshallese reportedly stopped a missile test by occupying Roi-Namur.[42] In 1985, two MX tests into the South Tasman Sea were stopped. In 1989, Greenpeace forced postponement of the first Trident-2 underwater launch.

Would stopping missile testing at Kwajalein achieve anything? If we accept the official rationale that Kwajalein is "vital" to developing more accurate, reliable, and more capable missiles, then shutting down

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40 M. Bunn, "Technology of Ballistic Missile reentry Vehicles", in K Tsipis and P. Janeway (eds), *Review of U.S. Military Research and Development*, (Pergamon-Brasseys, Washington DC, 1984).

41 Of course, as Des Ball points out, the military also like low beta RVs because the high beta RVs can be destroyed by the impact of hail and even rain during re-entry. The Minutemen 2 and 3 missiles can be reprogrammed now to high or low beta RV according to weather conditions above targets.

42 S. Firth, *Nuclear Playground*, (Allen & Unwin, Sydney, 1987), p.67.

Kwajalein will slow down US arms racing. Without Kwajalein, the United States would find it more worthwhile to negotiate seriously with the Soviet Union for reduction in arsenals and an end to the technological arms race. Peace movements would be in a much stronger position to push the Soviet Union to stop its missile testing. The Pacific could be declared a missile test-free zone. Indigenous people on the Kamchatka Peninsula might be encouraged to declare their own homelands a ballistic missile test-free zone. Peoples in the South Atlantic could be motivated also to establish missile test-free and nuclear-free zones. In the long run, there are no insuperable obstacles to implementing a missile test ban. Eventually, the convergent interests of all states will probably impel them to establish such controls. The Pacific would also become a safer, more peaceful place in which to live.

CHAPTER 6

EPILOGUE

This chapter provides additional information on two aspects of missile testing in the Pacific. These are:

(a) details of the role of Pacific Missile Test Center (PMTC) in supporting Trident missile tests; and

(b) the new STARS SDI-related missile launch test facility in Kaui.

A. PMTC and Trident Tests

The PMTC at Point Mugu in California began to upgrade its facilities to support Trident missile tests in 1977. PMTC built its Missile Tracing Facility, a computer, data processing, and telemetry center that provides real-time data processing for range safety, land-based telemetry and destruct systems used in Trident missile tests. PMTC engineers also designed the Pacific Trident Missile Test Instrumentation System consisting of systems installed at Point Mugu, San Nicolas Island, many remote sites, a Launch Support Ship, the Terminal Area Support Ship, and in the launch and impact areas. The system became operational in 1980.[1] The architecture of the Trident Pacific Operational System is shown in Figure 6.1.

The PMTC has supported many Navy missile development programs, including Tomahawk, Harpoon, Sidewinder, and Standard testing.[2] The first follow-on Trident test supported by PMTC took place in September 1983, and tests totalled fifty by the fall of 1989.[3]

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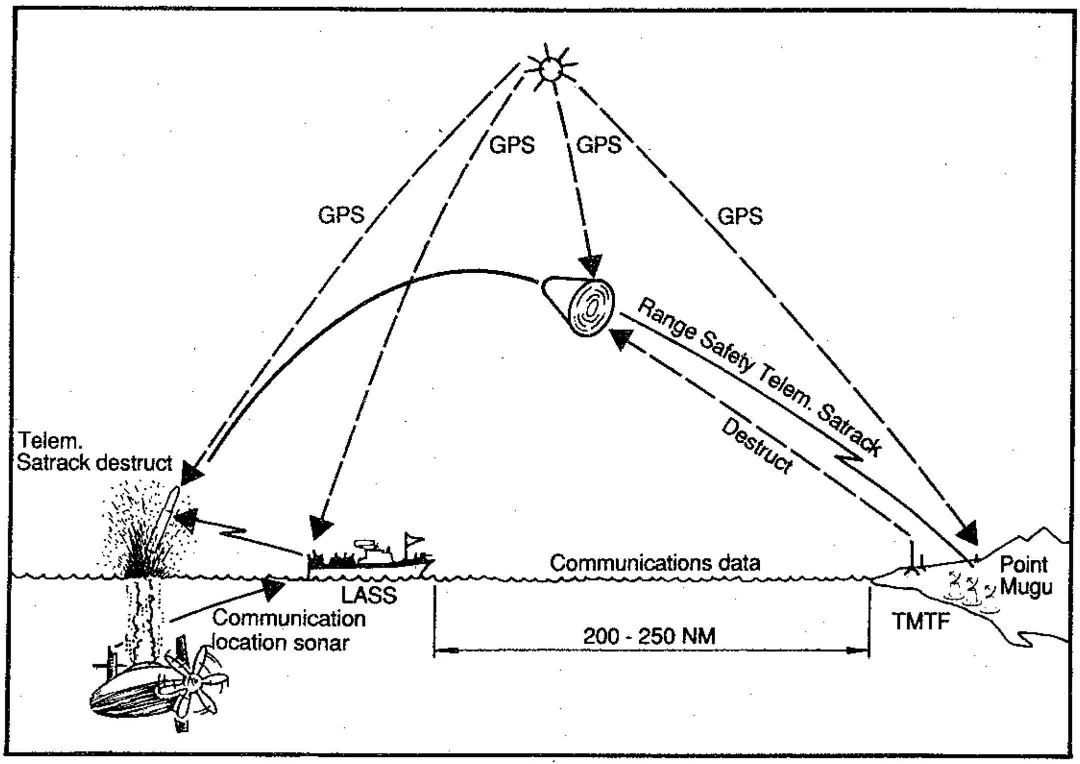
1 Pacific Missile Test Center, *Days of Challenge, Years of Change: A Technical History of the Pacific Missile Test Center*, (US Government Printing Office, Washington DC, 1989), p.230.

2 Pacific Missile Test Center, *Annual Report, Fiscal Year 1982*, (Point Mugu, 1982) p.8-10.

3 "Fleet Operational Support Category", in Pacific Missile Test Center, *Command History*, (PMTC, Point Mugu, 1 March 1990).

Figure 6.1: Trident Pacific Operational System



LASS = Launch and Support Ship
TMTF = Trident Missile Tracking Facility
GPS = Global Positioning System
Source: Pacific Missile Test Center, *Days of Challenge, Years of Change: A Technical History of the Pacific Missile Test Center*, (US Government Printing Office, Washington DC, 1989), p.230.

PMTC's major asset is its sea test range, which extends about 250 km offshore from PMTC and covers about 68,600 km^2 of ocean (see Figure 6.2). PMTC also operates the specialized P-3 aircraft that collect telemetered, optical, and locational data on missile launch and re-entry locations.

According to PMTC, the Sea Test Range offers the following capabilities to military users:

> A ... highly instrumented sea test range off the California coast for multiple air- or surface-launched missile live firings against multiple air or surface targets. Test aircraft and flight test planning and support are provided. The Extended Area Test System (EATS) provides a capability to extend the range capabilities of tracking (60 or more participants), telemetry (10), miss-distance (10), target control, and communications (14) 250 nautical miles or more seaward of San Nicolas Island from Baja, California, to Point Conception, augmenting land-based capabilities. EATS also provides telemetry and impact scoring in the broad ocean area (BOA).[4]

B. STARS and Kaui

Chapter 4 noted briefly that SDI entailed rocket tests launched from Kaui in Hawaii. The program, known as the Strategic Target System (STARS), proposes to use retired Polaris A3 booster systems to supplement tests using Minuteman I missiles fired at Kwajalein from Vandenberg and in short supply.[5] As the A3 has only an intermediate range, it must be fired from somewhere west of Vandenberg if it is to reach Kwajalein. The Navy's Kaui Test Facility (KTF) offered instrumentation and launch facilities, while the trajectory from KTF to

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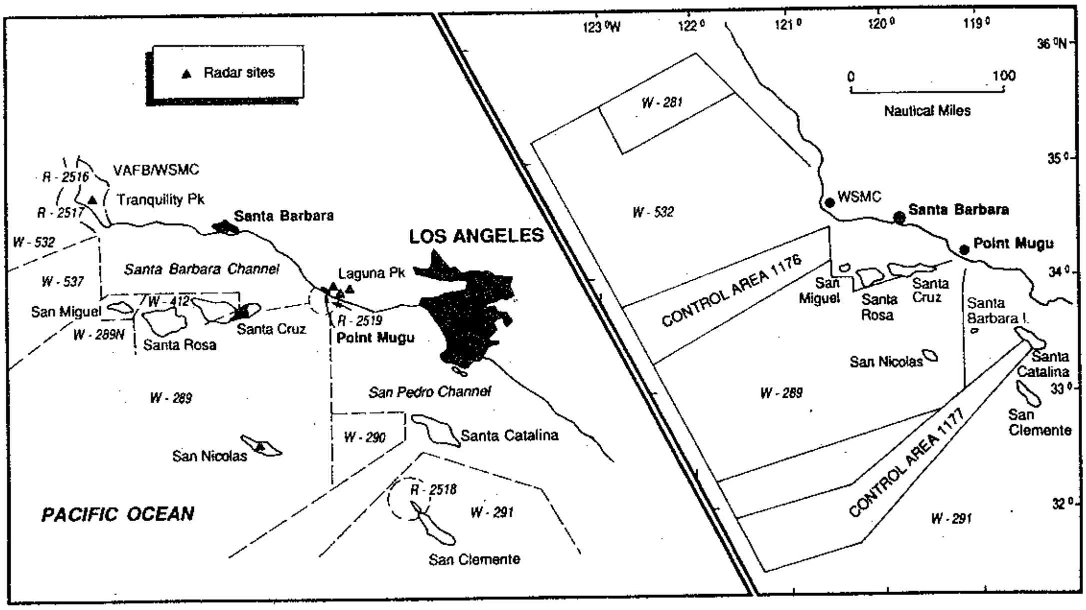
4 *Ibid.*

5 US Congress, House Committee on Appropriations, Sub-committee on Military Construction Appropriations, *Military Construction Appropriations for 1987*, Part 2, (US Government Printing Office, 1987), p.1045.

Figure 6.2: PMTC Offshore Test Range



Source: Pacific Missile Test Center, *Annual Report, Fiscal Year 1982*, Point Mugu, p.7.

Kwajalein was similar to the standard experimental flight profile of the Minuteman rockets and most desired by the SDI experimenters.[6]

The STARS system would loft payloads from the KTF on a 280° launch azimuth into near space in a sub-orbital trajectory that would terminate in a Broad Ocean Area north of Kwajalein, or into the Kwajalein splashdown zone 3,763 km "downrange" from KTF. The payloads would be sensors or targets that would simulate re-entry vehicles. Starting in May 1991, the SDI program anticipated up to four STARS launches per year for a decade.[7]

STARS would work by firing the first two A3 stages of the three-stage rocket upwards and the third Orbus-1 Solid Rocket Motor Guidance and Control stage during the descent, thereby simulating an ICMB re-entry (see Figure 6.3). Most launches would carry "target delivery systems" but some would be probes to measure other bodies in space or to measure background conditions relevant to strategic defenses.[8]

According to the Army, there are no alternative ways to simulate, analyze, or test strategic defense systems that can "adequately replicate the effects of natural environmental conditions" and KTF-Kwajalein SDI range is unique.[9]

In May 1991, the State of Hawaii and the Sierra Club challenged the legality of the STARS launch because the missile's exhaust plume releases hydrogen chloride and freon gases that destroy the earth's fragile and degrading ozone layer.[10] The Army had argued that these gases result only in temporary and local ozone depletion, and that STARS would contribute a tiny proportion of the total releases that are destroying the ozone.[11] However, a US District Court

6 US Army Strategic Defense Command, *Strategic Target System (STARS): Environmental Assessment*, July 1990, p.4.

7 *Ibid.*, p.S-1.

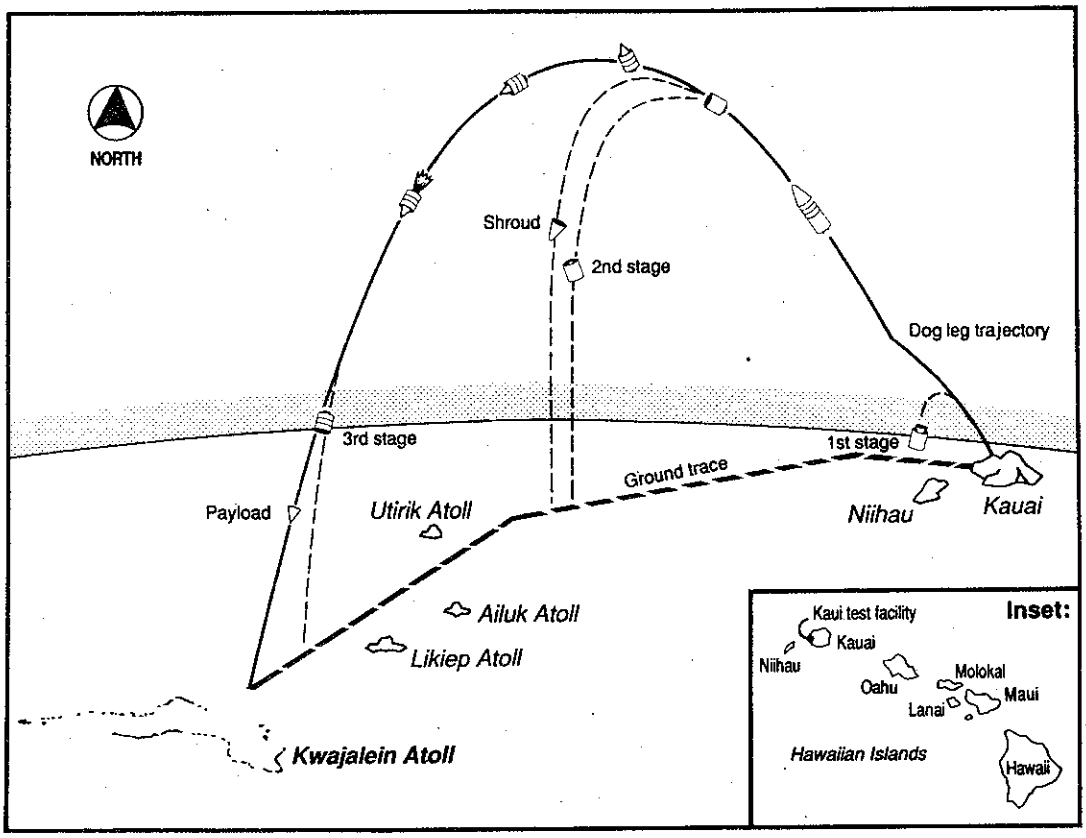
8 *Ibid.*, p.3.

9 *Ibid.*, p.25.

10 M. O'Callaghan, "'Star Wars' Missile Tests Banned by Judge", *The Age* (Melbourne), 16 May 1991, p.7.

11 US Army Strategic Defense Command, *Strategic Target System (STARS): Environmental Assessment*, pp.70-71.

Figure 6.3: Strategic Target System



Source: US Army Strategic Defense Command, *Strategic Target System (STARS): Environmental Assessment*, July 1990, p.7.

Judge ordered the Army to halt all STARS tests until it conducts a study of the issue.[12]

The STARS program may be the first trial of whether strategic missile tests pass global environmental tests. The Federation of American Scientists has recently signalled that this issue will be given greater political attention in Washington DC. The Aerospace Corporation has begun a series of laboratory tests and monitoring programs of rocket launches to measure damage to the ozone layer.[13] The issue has also been raised in the working groups under the Montreal Protocol to prevent ozone depletion.

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12 See D. Ezra, US District Court Judge, "Order ... Granting Summary Judgement for the State, and Ordering an Injunction of the STARS Project Pending Supplementation of the Army's Environmental Assessment', Honolulu, 9 May 1991.

13 Missiles may account for about 1 per cent of current ozone depleting gases, a fraction that will increase sharply as the Montreal Convention controlling CFC releases is implemented. See S. Aftergood, "Environmental Impacts of Solid Rocket Propellants" (mimeo), Federation of American Scientists, Washington DC, 1991, p.9; W. Broad, "Some Say the Rockets' Red Glare Is Eating Away At the Ozone Layer", *New York Times*, 14 May 1991; G. Hatch, "Study on Ozone Aims At Rockets", *Los Angeles Times*, 25 July 1991.

APPENDIX 1

SPACE-AGE GUIDE TO THE ISLANDS OF KWAJALEIN ATOLL

The main text of this report has addressed the impact of missile tests at Kwajalein Atoll on the arms race. This appendix looks at the impact of the arms race on Kwajalein Atoll. The United States has probably fired more ballistic missiles at Kwajalein than at any other place on earth. The US military are unsure how accurately they can target Soviet missile silos, but they are quite confident about their ability to hit Kwajalein. "If we fought a war with Kwajalein we would win hands down" as a Defense Department witness once told a Congressional Committee.[1]

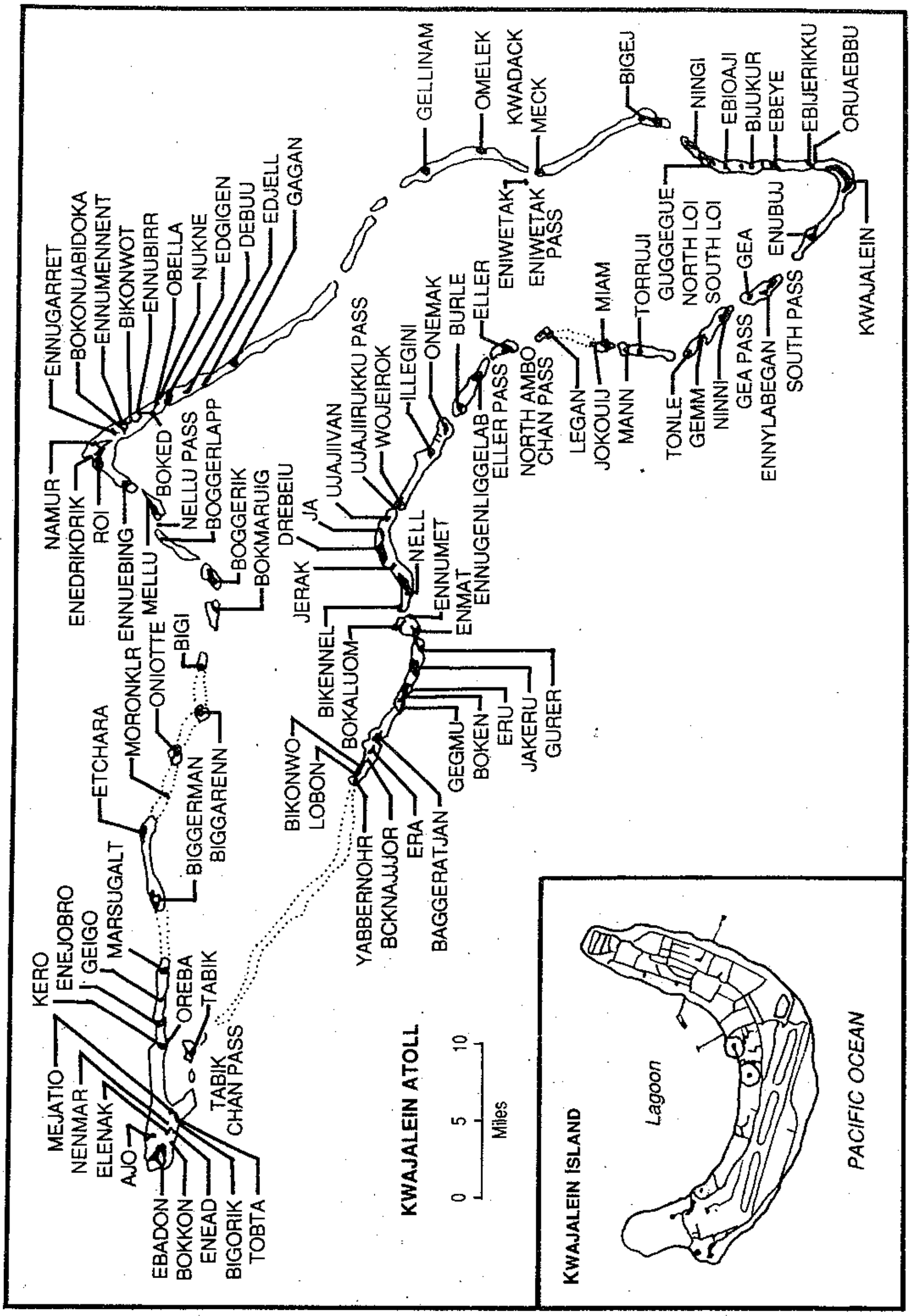
The major islands of Kwajalein Atoll are here described in clockwise order, starting with Kwajalein Island, at the southernmost point (see Figure A1.1). The 11 islands used by USAKA are marked with asterisks. The various bits of equipment are all described in Chapter 1 of the main report, and the Star Wars activities are explained in Chapter 4. There are probably more acronyms than coconut palms on Kwajalein: these are explained in Appendix 4.

*Kwajalein Island: HQ, Operations Control Center, "Downtown"

Kwajalein Island is where the 3,000 Americans involved with USAKA mostly live and work, and it is where most of the 1,000 Marshallese employees of USAKA commute to work each day. Kwajalein has 679 family housing units and 868 single housing units, plus accommodation for transients, with more housing being built. For those 3,000 Americans, there are most of the comforts of home - US supermarkets, US Post Office, US TV, and, most important, a golf course. All this is on one-third of the island. Another one-third is taken up by the airfield. It is slightly over 2 km long, with a runway 60 m wide. The remaining third of the island is crammed with fuel tanks, water tanks, offices, laboratories, workshops, warehouses, radars,

1 US Congress, Senate Armed Services Committee, *Hearings on Military Procurement, Fiscal Year 1978*, part 10, p.6539.

Figure A1.1: Islands of Kwajalein Atoll



communications and all the other usual paraphernalia of a military facility.

There are only 21 km of road on Kwajalein Island, and no private cars. There are as many bicycles as there are people, and many military vehicles.

Numerous facilities on Kwajalein Island are being built or upgraded for Star Wars; in particular, at the western tip, the $300 million experimental ground-based radar (GBR-X).

Logistical support facilities on Kwajalein Island include the following items:

* airfield (with hot spots for unloading explosive cargoes)
* port and cargo handling facilities
* explosive storage magazines ("igloos")
* accommodation, commercial premises, etc. for 3,000 personnel and dependants
* warehouses, freezers, cool stores, etc.
* electrical generation plant
* desalination plant
* fuel storage
* water storage

Technical support facilities include:

* range operations control center
* frequency control and analysis van
* calibration laboratory
* reference standards
* master timing center
* master countdown control
* photographic laboratories

* range safety system
* air traffic control radar
* ground station for GPS/Navstar satellite navigation system

Communication systems include:

* AN/FSC-78 defense satellite communications system (DSCS) terminal
* high frequency transmitters and antenna
* command control antenna for sending destruct messages to off-course RVs

Aircraft based on Kwajalein Island include:

* high-altitude Learjet observatory (HALO), for optical observation of missile re-entries
* UH-1H helicopters

Vessels based at Kwajalein Island include:

* diving and recovery systems mounted on LCU "Neptune" (a landing barge)
* 2-person yellow submarine for hunting down RVs on the lagoon bottom
* commuter ferries

Sensor systems on Kwajalein Island include:

* 3 missile tracking radars
* 1 RADOT and 1 super RADOT
* 2 ballistic cameras

Meteorological systems include:

* weather radar
* UHF sounding systems
* defense meteorological satellite (DMSP) terminal
* geostationary meteorological satellite terminal

Launch system includes:

- * Small rocket launcher for weather rockets etc.

***Ennylabegan: Telemetry-land**

Six antennae for receiving data from RVs are located here, far enough away from Kwajalein Island to be free of electronic interference. The biggest antenna, 9 metres in diameter, is enclosed in a 17-metre radome. A ground station receives, records, separates, displays, distributes and processes data from re-entering vehicles. In a complicated mission such as an SDI intercept, the Ennylabegan station may be receiving data at 800 kilobits per second, and soon it may be capable of receiving at 2 megabits per second. Its 28 receivers can handle 14 downlinks from as many RVs, interceptors, and assorted other space objects.

High frequency receiving antennas for the Kwajalein control center are located on Ennylabegan. In general, Ennylabegan is set aside as an electronically "quiet" island for listening to things.

Gea

Non-USAKA island, depopulated under 1964 mid-atoll agreement. Former population: 5.

Gea Pass

Immediately to the north of Gea, this is the deepwater channel used by shipping en route to Kwajalein Island.

Torruji

Non-USAKA island, depopulated under 1964 mid-atoll agreement. Former population: 39.

***Legan: Optics and Splashes**

Legan is one of the most centrally located islands in the mid-atoll corridor, hence is used for optical devices, and for a splash-detection radar, mounted in a radome atop a 33-metre tower.

Optical devices include:

* 2 super RADOTS
* 2 ballistic camera stations
* 1 spectral ballistic camera

Radars include:

* splash detection radar

Ennugenliggelab, Burle, Onemak

Non-USAKA islands, depopulated under 1964 mid-atoll agreement. Former populations: 9, 61, 38 respectively.

***Illeginni: Greater Crater-land**

This island is also rather centrally located, hence has optical equipment and, sadly, serves as the land impact site whenever there is a need to bring RVs down on land rather than letting them splash down into the lagoon or into a BOA. Currently, some Minuteman-3 RVs hit Illeginni, seemingly to test their fusing systems (which in war serve to actually detonate the nuclear blast at a pre-determined height above the ground). Some MX RVs will come down on Illeginni for the same reason.

Just where the RVs come down on Illeginni is a bit of a mystery. Illeginni is quite a small island, less than a kilometre long and 200 metres wide. US Army maps[2] show it to be pretty well covered

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2 AAA Engineering and Drafting Inc. and Sea Grant Program, University of Hawaii at Manoa, *Kwajalein Atoll, Coastal Resource*

with buildings, antennae and a helicopter pad. Most of the land not built on is shown as sea-bird rookeries. Black-naped terns roost, but don't breed.[3] If the RVs really come down on the island - and according to the Draft Environmental Impact Statement[4] they come down on the north (lagoon) side - then it says something for USAF confidence in the accuracy of Minuteman that such a small island can serve as a target. Minuteman-3 accuracy is usually given as about 200-300 metres CEP. That the RVs are brought down on the lagoon-side coral reef, which is about 300 metres wide, is more likely. If so, that would explain why the environmental impact statement says nothing about the lagoon-edge reef of Illeginni - to suppress information about the damage done to the reef. The EIS describes the seaward and lagoonward reefs of every other island, and it describes the seaward reef of Illeginni.[5]

Illeginni is a veteran of Star Wars-1, the ABM program of the sixties. A Sprint ABM launcher was built here to test the remote control concept being exercised by the mission-control bunker on Meck (see below). The mound built to contain the silos is still here. Back in those days it was one of the most beautiful islands in the entire atoll:

> Those who worked there remember the island itself as a special place. It was quiet and exotic, and unlike Meck, it boasted of coconut, breadfruit, and ironwood trees, a good deal of tropical foliage, and an especially beautiful view of the lagoon ... Visitors and residents there considered the island a refreshing break from what they often described as the hurry and bustle of "downtown" Kwajalein.[6]

Atlas, (US Army Corps of Engineering, Pacific Ocean Division, 1989).

3 *Proposed Actions at US Army Kwajalein Atoll: Draft Environmental Impact Statement (DEIS)*, US Army Strategic Defense Command, June 1989, Tab 3.5-1, p.3-63.

4 *Ibid.*, p.2-12.

5 *Ibid.*, pp.3-71, 3-81.

6 *ABM Research and Development at Bell Laboratories*, (Kwajalein Field Station, Bell Laboratories, October 1975), p.92.

Optical devices include:

- fixed camera tower
- closed circuit TV, tower-mounted

Radars include:

- one passive receiver antenna for the multistatic measurement system, the transmitter for which is located on Roi-Namur

Telemetry includes:

- one receiving antenna, and re-radiation system

Wojeirok, Nell, Ennumet, Eru, Gegihu

Non-USAKA islands, depopulated under 1964 mid-atoll agreement. Former populations: 23, 15, 39, 33, 28 respectively.

Mejato

Where the people of Rongelap Island live now. They were irradiated in 1954 by the Bravo thermonuclear test at Bikini, and evacuated from there by the *Rainbow Warrior*.

Ebadon

Third largest island on the Atoll, recently re-settled by Marshallese.

***Roi-Namur: "America's Radar"**

The second biggest island on the atoll, after Kwajalein, it is by far the most important island on the whole atoll for missile and ABM testing. Roi-Namur was the site for a major part of the World War II

Japanese military presence, including a submarine base and an airfield. It was selected in 1959 as a site for project PRESS, far enough away from Kwajalein Island that the powerful radars would not cause radio-frequency interference to the Nike missiles launched from Kwajalein Island.

Today, Roi-Namur is especially important as the KREMS radar site. Five of the most sophisticated and powerful radars in the entire world are located on Roi-Namur. The big 50-metre ALTAIR radar is fondly referred to by its 102 operators as "America's radar".[7] Also on the island is an airfield, and accommodation for American staff and dependants.

When Star Wars gets underway on Kwajalein, Roi-Namur will have the role of launching refurbished Polaris target missiles to be shot down by the mock SBI interceptors launched from Meck.

Apart from the KREMS radars, there are many other systems on the island.

Optical devices include:

* 1 RADOT
* 1 super RADOT
* 1 fixed camera tower
* 1 spectral ballistic camera
* closed-circuit TV

Infrared includes:

* 1 laser
* 1 passive infrared tracker

(both in astronomy-type domes)

Telemetry includes:

* 2 telemetry antennae

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7 G. Zorpette, "Kwajalein's New Role: Radars for SDI", *IEEE Spectrum*, March 1989, p. 6.

Weather includes:

- 1 UHF sounding station
- 2 wind-finding radars, used to track weather balloons

Launch facility includes:

- 2 small rocket launchers - used for "Have Jeep" launches (whatever they may be)
- 1 site for meteorological rocket launches
- 3 ordnance storage bunkers

***Ennugarret: Microwaved Land Crabs?**

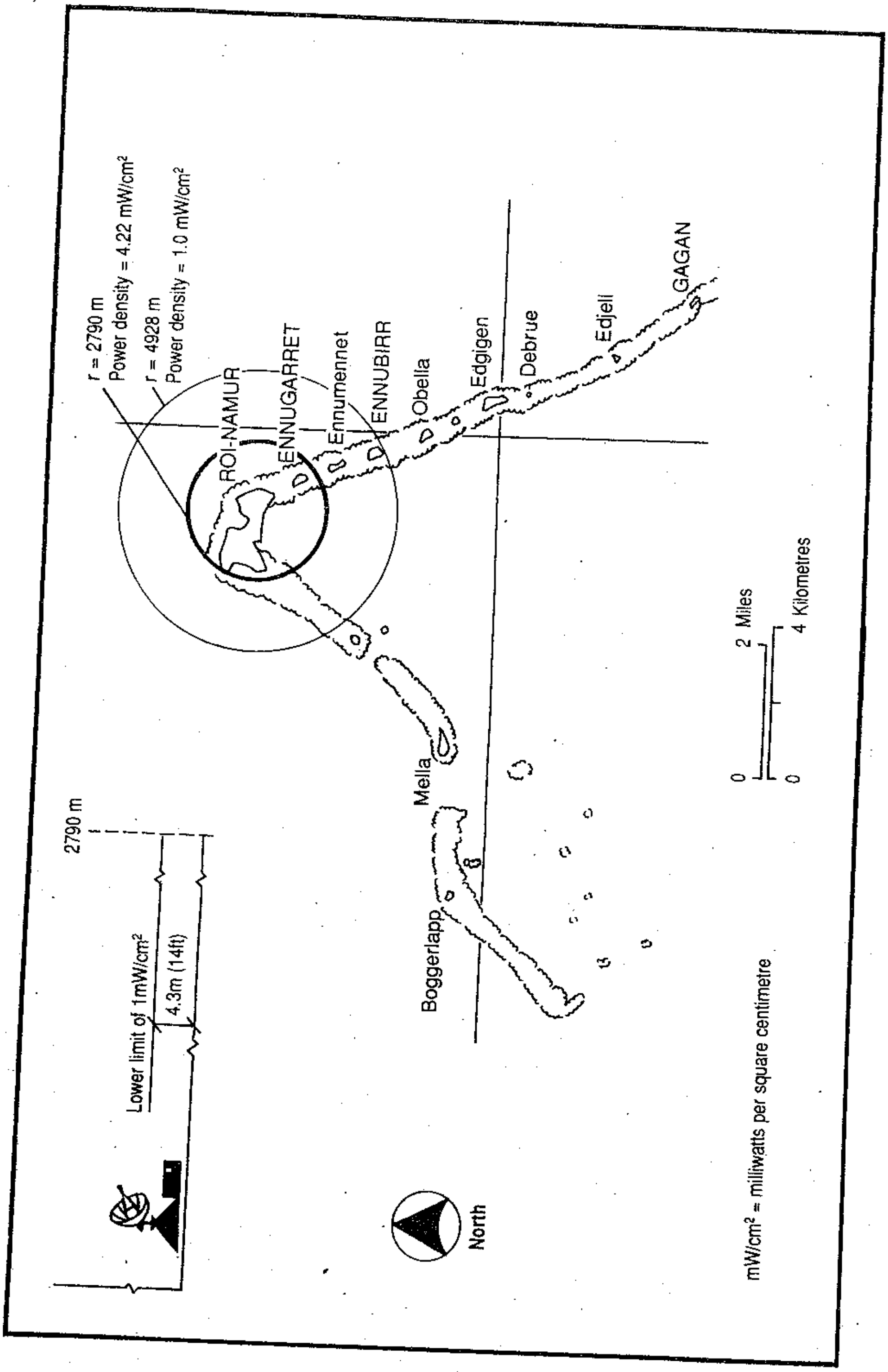
This is the only one of the 11 USAKA islands which thus far has no facilities. It is also uninhabited, because of the microwave radiation hazard from all those big radars on nearby Roi-Namur. On Roi-Namur itself, all human activity is carried on beneath the radar beams. Ennugarret, being a little further away, is swept by the beams. The only animal life on the island, according to the resource survey carried out by the US Army, is land crabs.[8]

Ennubirr: Mini-Soweto?

Dormitory island for Marshallese workers on Roi-Namur. Population: 500. It is to be hoped that it is far enough away from Roi-Namur that the people are not being microwaved by the radars. A map of "Altair (UHF) radio frequency hazard" (Figure A1.2) shows Ennubirr as being just within the danger zone defined by the 1 milliwatt per square centimetre contour,[9] which is the "Personal exposure limit" (PEL) set by the US Defense Department.[10] However, the hazard does not exist lower than 14 feet above ground level, so one would have to climb a coconut palm or stand on a house roof to get this dose, so maybe there is no cause for alarm.

8 AAA Engineering, *Kwajalein Atoll, Coastal Resource Atlas*, p. 53.
9 *DEIS*, figure 3.15-3.
10 *DEIS*, p. 3-190.

Figure A1.2: ALTAIR Radio Frequency Radiation Hazard



***Gagan: Telemetry and Optics**

Optical includes:

* 1 super RADOT
* 1 ballistic camera
* 1 spectral ballistic camera

Telemetry includes:

* 2 antennae

Weather includes:

* balloon inflation

***Gellinam: Scores HITS**

Radar includes:

* passive receiver antenna for the Multistatic measurement system, the transmitter for which is located on Roi- Namur

Impact locators include:

* 1 splash detection radar tower
* shore terminal for hydro-acoustic impact timing system (HITS)

***Omelek: Rocket-land**

Even before the current Star Wars build-up, there were about 60 rockets per year being launched from Omelek.[11]

A twin launcher for old Polaris or Poseidon missiles will be constructed on Omelek for the GSTS Star Wars experiment. The

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11 US Congress, House Appropriations Committee, *Hearings on Military Construction,Fiscal Year 1984*, part 1, p.803.

missiles will be launched in pairs to get "stereo views" of target missiles from Vandenberg. The planned construction of the launch facility could require destruction of one of the better bits of forest left on the entire atoll.

Optical includes:

* closed-circuit TV

Launch facilities include:

* small rocket launch facility - used for launching sounding rockets immediately before every missile test
* 2 meteorological rocket launchers
* ordnance storage bunker

***Eniwetak: Optics**

This island should not be confused with the atoll of the same name elsewhere in the Marshalls where US nuclear tests were carried out in the 1950s.

Optical includes:

* 1 RADOT
* 1 super RADOT
* 1 ballistic camera
* 1 spectral ballistic camera

***Meck: Star Wars Arena**

Meck has traditionally been ABM-land; it has survived two Star Wars already, and is well into the third.

During Star Wars-1 in the sixties, silos were built here for Nike-X, Sprint and Spartan launches. Experimental versions of phased array ABM radars were also operated here. A mission control room with all sorts of mission displays and communication consoles controlled real space battles overhead between RVs and interceptors.

In the late 1970s, Star Wars-2 was fought over Meck, but without actual intercepts taking place. A state-of-the-art phased array radar, mounted flush in a great concrete monolith, hardened against direct nuclear attack,[12] was built to show that ABM radars could work even in a nuclear environment. Star Wars-2 represented "the most near-term ballistic missile defense capability the US ha[d] for defending missile fields", and, perhaps even more important for the US Army, it was "also the easiest program to gain Defense Department and congressional approval".[13]

New missile launch facilities were built in the early 1980s for Star Wars-3 to support HOE launches, the second one of which, in 1984, was regarded as the first "successful" missile intercept of the current Star Wars. Now a silo is under construction on Meck to hold and launch refurbished Minuteman missiles in tests of the non-nuclear ERIS system. In the next Star Wars, Roi-Namur will be the Evil Empire against which Meck does battle. Simulated space-based interceptors (SBI) will hurtle out into space from Meck at target missiles launched from Roi-Namur.

Meck was the scene of the most recent re-occupation by Marshallese landowners. The *New York Times* headline made it sound like it was one of the key battles of Star Wars-3: "Pacific Islanders Occupy 'Star Wars' Test Site". As usual in US newspaper accounts describing Marshallese actions, the landowners were described by the *New York Times* as "militant".[14]

The Star Wars have left Meck devastated. As the US Army's *DEIS* put it:

> The island is almost entirely altered by mission support activities. Its visual character is dominated by

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12 C. Robinson, "Missile Defense Radar System Tests Set", *AWST*, 20 September 1976, pp. 42-51.

13 According to an unnamed Army official, quoted by Robinson, *ibid.*

14 R. Trumbull, "Pacific Islanders Occupy 'Star Wars' Test Site", *New York Times*, 17 November 1985.

currently used and deactivated mission support facilities; little vegetation remains.[15]

Bigej

Non-USAKA island, depopulated under 1964 mid-atoll agreement. Former population: 38.

Gugeegue, Ebwoj, North Loi, South Loi

These very small islands are all being developed for Marshallese accommodation, to take the pressure off Ebeye. Eventually, they will be linked with Ebeye by causeway. Twenty-seven families already living on Gugeegue commute by boat. These islands will eventually accommodate about 2,000 people.

Gugeegue was formerly part of the missile range, and was covered with HF radio transmitting antennae.

Ebeye: Atomic Apartheid

Home to about 8,300 Marshall Islanders, about 1,000 of whom now have jobs at USAKA. There are 835 houses on Ebeye, which works out to 10 people per home. The population density is 17,000 per km^2. A US Coast Guard station occupied a quarter of the island until well into the seventies.

15 *DEIS*, p. 3-175.

APPENDIX 2

KWAJALEIN CHRONOLOGY

70 mn yrs ago

--- Kwajalein Atoll formation begins, as a submarine volcano.

1500 BC

--- First human settlements begin in Marshall Islands.

16th century

--- Kwajalein sighted by Spanish explorers.

1804

--- Kwajalein "officially" discovered by British.

1874

--- Marshall Islands become Spanish colony.

1885

--- Marshall Islands become German colony.

1914

--- Marshall Islands come under Japanese administration.

1935

--- Japan begins fortifying Marshall Islands.

1941

Dec Japanese submarines leave Kwajalein for attack against Pearl Harbor.

1943

--- Kwajalein becomes HQ for Japanese Sixth Base Force and Fourth Fleet.

1944

Feb After heavy bombardment, Kwajalein taken by US forces.

1946

Jul Operation Crossroads nuclear tests at Bikini. Kwajalein serves as rear base. Afterwards 50 target ships towed to Kwajalein Atoll for study of nuclear effects.

Oct Naval Air Missile Test Center (NAMTC) established at Point Mugu.

1947

--- Marshall Islands become part of United Nations Strategic Trust Territory.

Mar The United States removes entire population of Enewetak Atoll to Meck so their atoll can be used for nuclear tests. Kwajalein serves as support base for Bikini and Enewetak tests, from now until last US nuclear tests in Marshalls in 1958.

1948

--- In aftermath of Operation Crossroads, starving Bikini people are evacuated from Rongerik to Kwajalein; stay for seven months.

1951

Jan United States relocates Marshallese people from Kwajalein Island to Ebeye.

--- US Department of Interior takes over administration of Marshalls. Kwajalein remains under Navy control. Kwajalein used as support base for Korean war.

1954

--- Kwajalein used for supporting nuclear tests at Bikini and Enewetak, continuing until 1958. Irradiated Rongelap and Rongerik people are evacuated to Kwajalein Atoll after irradiation of their home by "Bravo" H-bomb test, March 1954.

1955

Nov USAF assigns responsibility for ICBMs and IRBMs to Air Research and Development Command.

1956

Sep Part of Camp Cooke, California, selected as new USAF West Coast Missile Center.

1957

--- First US ICBM is tested, from Cape Canaveral into South Atlantic.

May Work begins on "soft" ICBM/IRBM base at Camp Cooke, which later becomes Cooke AFB.

Aug First Soviet ICBM test is announced.

Nov "Peashooter", a compressed air tube launcher for testing submarine-launched missiles, tested at San Francisco.

Dec The Director of Guided Missiles, Office of the Secretary of Defense, authorizes establishment of USN Pacific Missile Range (PMR).

1958

--- NAMTC becomes a National Test Range, renamed Pacific Missile Range.

Jan Army searches for Nike-Zeus test site in Atlantic.

--- First SLBM prototype test flight, from Point Mugu, California.

Mar Operation Hardtack, last series of nuclear tests in Marshalls, begins. Finishes after 32 tests, including two at Johnston Atoll, in December.

--- First prototype SLBM launch from "Popup", a submerged tactical launcher facility off San Clemente Island, California.

Jul First Atlas ICBM wing becomes operational in United States.

Aug Navy places Kwajalein on the military base surplus list.

Oct Cooke AFB renamed Vandenberg AFB.

Nov Britain refuses to provide sites for ABM tests in Atlantic; Army starts looking for a site in the Pacific.

Dec First ballistic missile test into the Pacific - an intermediate-range Thor launched by USAF Systems Command from USN's PMR.

1959

Feb Kwajalein selected by US Army as test site for Nike-Zeus anti-missile program. Roi-Namur selected for re-entry studies. Naval station re-named Pacific Missile Range Facility Kwajalein. (Other sites considered included Belau, Christmas Island, and Manus Island [Papua New Guinea]).[1]

--- First launch of a satellite into polar orbit, from Vandenberg.

Jun First contract let for ABM-related construction on Kwajalein.

Jul Transport Company Texas, a contractor, takes over managing Kwajalein from military.

Sep First ICBM launched into Pacific - an Atlas from PMR, splashing down near Wake Island.

---

1 "US Seeks Manus Launch Site", *Missiles and Rockets*, 18 May 1989.

---	Memorandum of Understanding signed between Army and Navy for Army use of Navy facilities at Kwajalein. Kwajalein incorporated into PMR, re-named PMR Facility, Kwajalein (PMRFK).
---	US Army Corps of Engineers begin construction of ABM facilities on Kwajalein.
1960	
Jan	Soviet Union commences missile tests into North Pacific, with impact points well within surveillance range of sensors on Roi-Namur.
Apr	First successful underwater launch of a Polaris off San Clemente. Boosted flight of only 6 seconds.
---	Facilities for Project PRESS under construction on Roi-Namur.
---	Field station established at Kwajalein for Nike-Zeus.
Jul	Second Soviet test in North Pacific.
Oct	Technical staff from Bell laboratories begin to arrive.
---	Radars, radio antennae, buildings, etc. under construction.
1961	
---	Construction of Tradex radar commences, on Roi-Namur.
May	First Titan missile launched into Pacific.
Aug	Kwajalein golf course opened. (The important things get done first!)
Oct	US relocates Marshallese from Lib Island, 80 km south of Kwajalein Atoll, in the new "impact zone", to Ebeye.
Dec	First Zeus missile fired from silos in 20-metre-high artificial "Mount Olympus", on Kwajalein Island. It destructs 11 seconds into flight.
1962	
Mar	Successful Nike-Zeus intercept of simulated ICBM.
Apr	PRESS Tradex radar first goes on-air.
Jun	Failed intercept of real ICBM. This is the first ICBM to be fired at Kwajalein.
Jul	Titan fly-by. Missile tested to full range, impacts 300 km off Philippines coast.

--- First successful ABM intercept, by Nike-Zeus launched from Kwajalein.

--- ICBM launches to Enewetak BOA cease. From now on, most PMR ICBM splash-downs are at Kwajalein.

Sep First Minuteman launch, towards Kwajalein.

1963

--- One American with polio at Kwajalein starts epidemic which spreads through Marshalls.

--- Atlas missile goes off course; emergency destruct mechanisms fail to work; RV splashes down less than 2 km from Roi-Namur.[2]

Mar First test of Program 505 anti-satellite (ASAT) missile launch from Kwajalein. Project 505 continues until January 1966.

May Nike-Zeus missile intercepts US satellite - the world's first anti-satellite weapon test.

Nov On basis of DDRE report released June, Secretary of Defense McNamara orders rationalization of missile range activities. This includes putting all Vandenberg activities under USAF control, and all Kwajalein activities under Army control. PMR becomes WTR (Western Test Range). Atlantic Missile Range becomes Eastern Test Range.

--- First ABRES shot to Kwajalein - an Atlas D. (ABRES program began in 1962.)

1964

Feb Decision made not to deploy Nike-Zeus. Nike-X project begins. Nike-X launch facilities and Missile Site radar to be built on Meck. Nike-Zeus test launches continue, to develop Nike-X technology.

May USAF Western Test Range (WTR) activated.

Jul Kwajalein Test Site established as a national range (meaning that it is to serve all three military services); 99-year lease signed between Kwajalein landowners and US Government. Control transferred from Navy to Army Nike-X project. (Army

---

2 M. Holtcamp, *KREMS: The History of the Kiernan Reentry Measurements Site*, (Kwajalein Missile Range Directorate, Ballistic Missiles Defense Systems Command, Alabama, 1 October 1980).

had been complaining about inadequate support from Navy.) Mid-atoll corridor impact zone announced, incorporating 47 islands, from which traditional landowners will soon be banished.

— Naval Missile Facility, Point Arguello, California, transferred to Vandenberg.

Nov US "shifts" Kwajalein back across the international dateline, so that dates and time conform with US. Kwajalein assigned US West Coast postal zip code.

Dec First operational Polaris patrol in Pacific begins.

1965

Jan Last Atlas test flight into Kwajalein. (Atlas continues to be used for Nike-Zeus targeting, ABRES etc.)

— Marshallese re-located from all other islands of Kwajalein Atoll to Ebeye. New mid-atoll corridor impact zone comes into use.

Jun US Air Force study of forward deployment of IRBMs in western Pacific and related testing requirements completed but not implemented, apparently due to political considerations in possible host nations such as Japan.[3]

Jul USAF takes over Pacific Missile Range ballistic missile operations from Navy.

Aug First launch of Minuteman-2, to Kwajalein.

— Construction of new radars etc. on Kwajalein continues.

1966

Feb First ICBM salvo launch - 2 Minuteman-2s.

Jun Zeus launchings cease after 61 launches.

Dec First inert Poseidon SLBM prototype launched from "Peashooter" at San Francisco.

3 US Air Force Ballistic Systems Division, Aerospace Corporation, *MRBMs in the Pacific*, summary report to US Air Force Systems Command, Norton Air Force Base, 15 June 1965, p.9-4; released under FOIA.

1967

Sep	Nike-X concept abandoned in favour of Sentinel concept, using Spartan and Sprint missiles. Sentinel will be a partial ABM system, intended to defend against only Chinese ICBMs launched against cities.

1968

Mar	Spartan development tests begin at Kwajalein Island.
Apr	Test site renamed Kwajalein Missile Range (KMR).
Aug	Mid-atoll corridor landowners claim "grave injustice".
Sep	First Soviet MRV test.

1969

Mar	Sentinel concept abandoned in favour of Safeguard concept, which will use Spartan and Sprint to defend US ICBM silos only.
Apr	Marshallese landowners conduct first "sail-in"; re-occupy islands.
---	First Minuteman-3 launched.
May	Last Titan-2 flight test.
Aug	US Senate decides, on casting vote, to deploy Safeguard.
Sep	First Safeguard test, against Minuteman-1.
Dec	Last Spartan development test, from Kwajalein Island.

1970

Apr	Spartan missile development completed; Sentinel systems verification and integration commences.
---	Space and Missile Test Center (SAMTEC) takes over WTR.
Jun	First successful simulated Spartan intercept.
---	Altair and Alcor radars become operational.
Aug	Spartan intercepts ICBM.
Dec	New agreement between US and landowners concluded; provides more compensation for landowners.

1971

Mar	First Sprint firings from Meck. (Missile had been developed at White Sands.)
Sep	Re-entry measurement program ends.
Dec	US population at Kwajalein peaks at 4,756.

— Last Minuteman-1 FOT.

1972

May ABM treaty comes into force. US allowed only one ABM complex to defend ICBMs, and one to defend cities.

1973

— First Soviet MIRV test.

Jan World Health Organization survey shows unusually high incidence of cataracts in Marshallese, attributed to microwave radiation from KMR radars.

Aug Last Polaris missiles withdrawn from Atlantic. From now on, all Polaris deployment, 10 SSBNs, is in the Pacific.

1974

Mar First test of Trident technology, to Kwajalein.

May US Congress decides to shut down Safeguard test program.

Aug Final Safeguard test.

1975

Apr ICBM testing transferred from PMR to Air Force at Vandenberg; PMR becomes Pacific Missile Test Center.

— Final Safeguard launches of Spartan and Sprint at KMR.

— Big AN/FSC-78 satellite communications antenna becomes operational, replacing smaller AN/SCT-21.

Jun BMD (Ballistic Missile Defense) operations begin at Kwajalein as an R&D program, intended supposedly to "provide incentive for the Soviets to reach additional arms limitation agreements".

Jul Sewage system on Ebeye collapses, adding to Marshallese dissatisfaction with US administration.

— "Pave Pepper" test of seven warheads on a Minuteman-3.

Oct Trust Territory administration begins "Operation Exodus", intended to persuade non-Kwajalein Marshallese to leave overcrowded Ebeye and return to home islands. Ebeye population is over 7,000, of which 47% are from other atolls, and there are serious health, sanitation, nutrition and social problems. Exodus is a failure; population continues to increase.

1976	
Jan	Congress decides to shut down deployed Safeguard system in US
---	No more interceptor missile launches from Kwajalein until 1983. However, ICBM impacts continue. US negotiates first five-year extension of 1970 mid-atoll corridor agreement.
Nov	New experimental Missile Site Radar (MSR) built on Meck for BMD program.
1977	
Feb	New ABM terminal defense radar begins testing at Meck.
Dec	Marshallese occupy Omelek and Eniwetak Islands (the latter not to be confused with Enewetak Atoll).
1978	
Mar	Marshallese re-occupy Meck.
May	Mark-500 Evader RV tested for Trident.
Sep	Marshallese occupy Roi-Namur.
Nov	Final Polaris DASO launch, in the Pacific.
Dec	Designating Optical Tracker (DOT) launches commence, from Roi- Namur. Part of BMD.
1979	
Apr	Final Polaris FOT launches, in Pacific.
May	President Kabua elected after Republic of Marshall Islands constitution approved.
Jul	Marshallese occupy Roi-Namur again, protesting unlivable conditions on Ebeye, where sewage system has failed totally.
---	Salvo launch of two Minuteman-3 as part of SAC exercise "Global Shield 79".
Sep	Landowners sign three-year lease agreement in return for $US9.9 mn compensation.
Dec	LoAD (BMD) activities commence.
1980	
Sep	Minuteman fly-by. Longest Minuteman flight ever - 10,400 km.[4]

4 Vandenberg Air Force Base and 1 STRAD History, Fact Sheet #90-2, attachment 1. Provided 1990 by Vandenberg AFB.

1981

Jan — Draft agreement under Compact of Free Association gives US "free access to and unrestricted control" of the Kwajalein Missile Range for 30 years, with 100-year authority for military "denial" to any third nation.

--- — Marshalls and US initial Compact of Free Association, which will end UN trusteeship.

May — Site survey of Northern Marianas commences, for BOA-3.

Aug — President Kabua pledges total support for US missile testing at Kwajalein.

Oct — Polaris support capability at Guam terminated. Effectively, this ends Polaris deployment in the Pacific.

1982

Jan — President Kabua signs agreement for US use of Kwajalein, but notes landowners have not consented to use.

Apr — Heritage Foundation "High Frontier" study proposes Kwajalein as launch site for space-based ABM system.

--- — Pacific Range launch area support ship (LASS) *Point Loma* converted from Polaris to Trident support.

May — Compact of Free Association signed in Honolulu. It provides for 15 years' use of Kwajalein, with a 35-year renewal option.

--- — HOE launches commence at Meck (conclude 1984).

Jun — Landowners, now mostly operating as Kwajalein Atoll Corporation, announce they will oppose Compact, noting that they were not consulted in negotiations, that US is granted "denial" rights in perpetuity, and that their compensation has been reduced from $US9 mn to $US1.9 mn. Marshallese commence "Operation Homecoming", in which 1,000 people re-occupy ten islands in mid-atoll corridor. ICBM re-entries etc are not stopped. Some Marshallese leaders arrested. KMR acquires more riot control gear, etc. President Kabua tries to stop Operation Homecoming and to persuade landowners to sign 50-year lease. Press blackout imposed. KMR imposes repressive measures. Payments to landowners cut off. Marshallese are denied access to shops and other services on Kwajalein Island.

Sep	Operation Homecoming into third month. One-year interim use agreement expires.
Oct	New three-year interim use agreement reached. US Defense Department agrees to cut total duration of use from 50 to 30 years.
---	First Trident sub, *Ohio*, departs on operational patrol in Pacific.
1983	
---	Sprint/Sentry missile launcher built on Illeginni for LoADS tests.
Mar	President Reagan makes his "Star Wars" speech, which becomes basis for SDI.
---	US returns six islands to owners.
Apr	US Army starts program to normalize relations with Marshallese on Kwajalein.
Jun	First MX test, into BOA USAKA-N.
Jul	Kwajalein Atoll's first elected local government, "KALgov", is inaugurated. Young activist and veteran of re-occupations, Alvin Jacklick, is elected mayor. Kwajalein Atoll Development Authority (KADA) is established to organise and supervise development initiatives.
Sep	*Ohio* carries out FOT launch of four Trident missiles, utilizing the new Pacific Flight Test Support System--the first Trident operational launches in Pacific.
1984	
---	Long-range planning initiated for upgrading KMR, and to ensure instrumentation stays at state-of-the-art levels.
---	USAKA begins operating as part of PACBAR satellite detection system.
---	Bulk encryption of external communications begins.
Jun	First "successful" SDI test (actually part of BMD): HOE interceptor from Meck intercepts dummy warhead from Vandenberg, 160 km above the earth. Kwajalein population temporarily exceeds 3,500 for duration of HOE test.
1985	
Sep	First SLBM fired into Kwajalein - a Trident, launched from off the California coast.

---	First successful non-nuclear anti-satellite (ASAT) test, at Kwajalein.
---	Interim agreement for Kwajalein lease expires.
Nov	Landowners re-occupy Meck.
---	French delegation visits to study range operations and instrumentation, apparently with view to testing French SLBMs there.[5]
---	Live satellite relay of Armed Forces TV arrives at Kwajalein!
1986	
---	KALgov takes over Ebeye Public Works Department from Marshallese government.
Oct	Compact of Free Association between US and Marshalls implemented. One result is that, at Kwajalein, US minimum wage rate is replaced by Marshallese equivalent - $1.50 per hour.
1987	
Jul	Minuteman-2 RV lost in Kwajalein Atoll. Later, it is suggested that it may have been taken by a Soviet submarine.
Aug	First flight-test of inertial guidance unit for Midgetman scheduled.
1988	
Jan	Tropical storm Roy devastates Ebeye.
Jul	US Secretary of State George Shultz visits Marshall Islands, the highest US official ever to do so; says Marshalls is strategically important to the US.
---	Construction commences for SDI projects.
1989	
Mar	Budgetary deficit forces lay-off of 400 workers, including 150 Marshallese, at Kwajalein.
May	First Midgetman test fails, 70 sec after launch from Vandenberg.
Jun	Draft environmental impact statement for proposed SDI activities at Kwajalein released.

5 *Annual Historical Review*, 1985, p. II-149.

---	US and Marshalls conclude agreement for US to use four more islands in SDI.
Oct	SAMTO disbanded.
---	Most SDI construction on Kwajalein complete.
Dec	Japan refuses Marshalls' aid request to build causeway linking Ebeye with other islands intended for Marshallese accommodation, on grounds that the aid could be construed as assisting the US military.

APPENDIX 3

COMPARISON OF EASTERN AND WESTERN TEST RANGES[1]

Characteristic	Eastern Test Range	Western Test Range
Location	Caribbean & S. Atlantic extends east to 90oE in Indian Ocean	Pacific Ocean, extends west to 90oE in Indian Ocean
Administered by	Eastern Space & Missile Center, USAF for DoD	Western Space & Missile Center
Main launch site	Cape Canaveral, Patrick AFB, Florida	Vandenberg AFB California
Number personnel	2,214 milit/govt ESMC 2,713 milit/ govt tenant 7,698 contractor employees	774 WSMC 6,352 WSMC contractor ? PMTC 3,000 USAKA
	c. 12,000 Total	>10,000 Total
Funding: O&M ($mn) I&M	367.8 (fy 89, planned) 15.5 (fy 89, planned)	165 USAKA ? WSMC ? PMTC
Grand total	418.9 (fy 89, planned)	?
Foreign participants	Britain (Polaris OT, Trident) France (down-range tracking for Korou space launches)	Japan (down-range tracking for space launches)
Foreign territory	Bahamas Antigua Ascension Island (Brit) South Africa Seychelles (space launch monitoring) Various airfields for ARIA	Republic of the Marshall Islands, Commonwealth of the Northern Marianas, Kiribati (potential)

1 Based largely on *SAMTO Test and Evaluation Support Resource Plan (FY 82-89)*, RCS:SYS-TEU (A) 7603, Space and Missile Test Organization (SAMTO), Vandenberg, California, 30 December 1982.

Characteristic	Eastern Test Range	Western Test Range
Launch facilities	"flat pad" launches ship motion simulator SSBN basin	"flat pad" launches ICBM silos
Tracking:		
- boost	5 radar, 10 optical	7 radar, 4 optical
- mid-course	4 radar, 0 optical	1 radar, various optical (AMOS)
- re-entry	4 radar, 1 optical	11 radar, 21 optical
Telemetry:		
- boost	3	6
- mid-course	5	>1?
- re-entry	5	
Range instrumentation ship	available	not available
Instrumented terminal area (ITA)	Ascension Island	Kwajalein
Width of ITA	c. 15 km	c. 80 km
Potential ITAs	None	Northern Marianas Phoenix Islands
Broad ocean areas (BOAs) for re-entry[2]	C-15 East C-15 West C-9 C C-11 A C-12 Ascension C-16 C-17 C-18	USAKA-East USAKA-North MX BOA-1 BOA-2 Trident Wake Oeno
RV recovery	Not possible	Kwajalein lagoon
Land impact	Not possible	Illeginni Island
Usable azimuths	c. 110°-130° i.e. c. 20°	219°-297°, i.e. 78°.[3]

2 ETR BOAs from S. Clark and F. Lamb, "Eastern Space and Missile Center Capability", AIAA Second Flight Testing Conference, 16-18 November 1983, Las Vegas, fig. 6.

3 S. Woodbury and R. Gorman, "Program Overview of Peacekeeper Flight Test Planning", AIAA Second Flight Testing Conference, 1983. This figure is for MX. If Oeno is included, then the usable azimuth is about 110°.

Characteristic	Eastern Test Range	Western Test Range
Min. range (to functioning BOA or ITA)	c. 1,300 km	7,770 km (to MAC)
Max. usable range	c. 12,000 km	?
Ballistic missile tests	Poseidon DASO, OT Trident-1, DASO, OT Polaris (UK), DASO, OT Pershing-2 (terminated by INF Treaty)	Minuteman-2, OT Minuteman-3, OT M-X DT, OT SICBM Trident OT
Number of BMTs	Approx 50/year, of which 30 are SLBM[4]	
Other weapon tests	SRAM ASMS SSMs F14/Phoenix	Tomahawk SLCMs ASAT Aircraft opns B-1 E-3A B-52 F-15 ALCM Harpoon SRAM
Space transport system	Shuttle launch, tracking, telemetry & recovery IUS emergency landings	Shuttle launch facilities mothballed
Exploring space	Titan (equat/low incline, synchr & deep space launches)	Titan (polar launches to south)
Space tracking	Some space-object identification (SOI) by radars at Antigua & Ascension	Major role in space catalogue maintenance, SOI (imaging radars, optical, laser). Space tracking role increasing.
Intelligence role	Minor	Important for tracking, telemetry intercept, and imagery of Soviet ballistic missile re-entries

4 The number of Navy launches is classified, but the number can be derived by simple arithmetic. See *SAMTO Test and Evaluation Support Resource Plan (FY 82-89)*, pp.II-3-15.

APPENDIX 4

GLOSSARY OF ACRONYMS AND SOME TECHNICAL TERMS

A&S	Aging & Surveillance [tests]
ABM	Anti-Ballistic Missile
ABRES	Advanced Ballistic Re-entry Systems
ABRV	Advanced Ballistic RV
AFB	Air Force Base
AIAA	American Institute of Aeronautics and Astronautics
AIM	Active Inert Missile
ALCM	Air Launched Cruise Missile
ALCOR	ARPA-Lincoln C-band Observables Radar
ALTAIR	ARPA Long-Range Tracking And Instrumentation Radar
AMOS	ARPA Maui Optical Station
AOA	Airborne Optical Adjunct (SDI experimental aircraft)
ARE	Aerothermal Re-entry Experiment (part of SDI)
ARIA	Advanced Range Instrumentation Aircraft (Boeing 707)
ARIS	Advanced Range Instrumentation Ship
ARK	Alternatives to Kwajalein
ARPA	Advanced Research Projects Agency (of Defense Department; now DARPA)
ASAT	Anti-Satellite (weapon system)
ASDI	Advanced SDI

ASMS	Advanced Strategic Missile Systems (successor to ABRES)
ASROC	Anti-Submarine Rocket (short-range, ship-based, nuclear)
Athena	US medium-weight rocket for space launches, etc.
Atlas	First US ICBM, liquid-fuelled
AWST	*Aviation Week & Space Technology*
BEAR	Beam Aboard Rocket
beta	Ballistic coefficient: the weight of an RV compared with its streamlining
BMD	Ballistic Missile Defense
BMDO	Ballistic Missile Defense Organization
BMEWS	Ballistic Missile Early Warning System
BMFTB	Ballistic Missile Flight-Test Ban
BMTFZ	Ballistic Missile Test-Free Zone
BOA	Broad Ocean Area
bus	See PBV
CEP	Circular Error Probable (radius within which 50% of shots will fall)
CINCPAC	Commander-In-Chief, US Pacific Command
CINCPACFLT	Commander-In-Chief, US Pacific Fleet
CMTB	Comprehensive Missile Test Ban
DARPA	see ARPA
DASO	Demonstration And Shakedown Operation (test)
DDRE	Director of Defense Research and Engineering

DEIS	Draft Environmental Impact Statement (In this case, by the Army on proposed SDI activities at Kwajalein)
DMS	Defense Market Survey (information service to Defense contractors)
DMSP	Defense Meteorological Satellite Program
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOT	Designating Optical Tracker or Deep Ocean Transponder
DSCS	Defense Satellite Communication System (global, general-purpose)
DT&E	Development Test and Evaluation
EDX	Exo-atmospheric Discrimination Experiment
EIA	Environmental Impact Assessment
ERCS	Emergency Rocket Communications System
ERIS	Exo-atmospheric RV Interceptor System.
ERPA	Evader Replica Penetration Aid
ESMC	Eastern Space and Missile Center
ETR	Eastern Test Range
FBM	Fleet Ballistic Missile
FEIS	Final Environmental Impact Statement (see DEIS)
FOIA	[US] Freedom of Information Act
FOT	Follow-On Test
fy	fiscal year
GBR-X	Ground-Based Radar - Experimental

GPS	Global Positioning System (of USAF; uses Navstar satellites)
GSTS	Ground-based Surveillance and Tracking System
HALO	High-Altitude Learjet Observatory
HALO-IRIS	See IRIS
"Have Jeep"	Series of Hydac rocket launches from Roi-Namur, 1988-90
HEDI	High Endo-atmospheric Defense Interceptor (for SDI)
HITS	Hydro-acoustic Impact Timing System
HOE	Homing Overlay Experiment (for BMD)
horizontal proliferation	Acquisition of arms by lesser powers (see "vertical")
HYDROPAC	Notice to mariners (to keep out of specified ocean)
ICBM	Intercontinental Ballistic Missile
IEEE	Institute of Electrical and Electronic Engineers
INF	Intermediate Nuclear Forces
IOT	Initial Operational Test (of missile)
IRBM	Inter-Regional Ballistic Missile or Intermediate-Range Ballistic Missile
IRIS	Infra-Red Instrumentation System
ITA	Instrumented Terminal Area
JCS	(US) Joint Chiefs of Staff
JPASO	Joint Pacific Area Scheduling Office
KADA	Kwajalein Atoll Development Authority
KALgov	Kwajalein Atoll's first elected government (1983)

KARS	Kwajalein Advanced Range Study (performed in 1984)
km	kilometre(s)
KMR	Kwajalein Missile Range
KREMS	Kiernan Re-entry Measurements Site (radars etc. on Roi-Namur)
KV	Kill vehicle: the warhead on an ABM interceptor missile
LASS	Launch Area Support Ship
LCU	Landing Craft, Utility
LoAD	Low-Altitude (ABM) Defense
LWIR	Long-Wave Infra-Red
MAC	(USAF) Military Airlift Command or Mid-Atoll Corridor
MaRV	Manoeuvering Re-entry Vehicle
MAST	Manoeuvering Systems Technology
Midgetman	Small intercontinental ballistic missile (SICBM) (single warhead, mobile-based, under development)
MILS	Missile Impact Location System (sea-bed hydrophones)
Minuteman	ICBM, mainstay of US land-based strategic nuclear forces
MIRV	Multiple Independently Targetable Re-entry Vehicle
MIT	Massachusetts Institute of Technology
MMS	Multi-static Measurement System (a Roi-Namur based radar)
MMW	Millimetre Wave radar (on Roi-Namur)
mn	million

MRV	Manoeuvrable Re-entry Vehicle
MSR	Missile Site Radar
MSX	Mid-course Sensors Experiment
MTIS	Missile Tracking Instrumentation System
MX	Missile-Experimental (no longer experimental; 50 deployed, officially called Peacekeeper, an ICBM)
NAMTAC	Naval Air Missile Test Center
NASA	National Aeronautics and Space Administration
NAVSTAR	See GPS
NFIP	Nuclear-Free and Independent Pacific
Nike-X	Second US ABM, never deployed
Nike-Zeus	First US ABM
NOTAM	Notice To Airmen (to keep out of specified airspace)
NPT	(Nuclear) Non-Proliferation Treaty
OAMP	Optical Aircraft Measurement Program (for SDI)
OT	Operational Test
OUSDRE	Office of the Under-Secretary of Defense for Research and Engineering
PACBAR	Pacific Barrier (3 radars for detecting Soviet satellites)
PACOM	US Pacific Command
PBV	Post-Boost Vehicle (= "bus")
PEL	Personal Exposure Limit
penaid	Penetration aid (to help RVs penetrate opponent defenses)

Pershing-2	US Army IRBM, dismantled under INF treaty
PMR	Pacific Missile Range
PMRFK	PMR Facility, Kauai (launch site, Hawaii) or PMR Facility, Kwajalein
PMTC	Pacific Missile Test Center
PNG	Papua New Guinea
Polaris	First US SLBM, deployed in Pacific 1964-1981
Poseidon	US SLBM, follow-on to Polaris, not deployed in Pacific
PRESS	Pacific Range Electronic Signature Studies
radome	a big cover (e.g. over radar installation)
RADOTS	Recording Automatic Digital Optical Tracker System
R&D	Research and Development
RDTE	Research, Development, Test and Evaluation
RSLP	Re-entry Systems Launch Program
RV	Re-entry Vehicle
SAC	Strategic Air Command
Safeguard	US ABM system employing Spartan and Sprint missiles, deployed briefly in 1970s
SALT	Strategic Arms Limitations Talks [or Treaty]
SAMTEC	Space And Missile Test Command [or Center]
SAMTO	Space and Missile Test Organisation

SATRACK	Satellite Track (uses GPS beacons to track missile trajectories)
SBI	Space-Based Interceptor (for SDI)
SDI	Strategic Defense Initiative (i.e. Star Wars)
SDIO	SDI Organisation
SDR	Splash Detection Radar
Sentinel	US ABM concept, not deployed, succeeded by Safeguard system
SFT	Supplementary Flight Test
SICBM	Small ICBM, see Midgetman
SIOP	Single Integrated Operational Plan (for allocating all US strategic nuclear weapons to targets)
SIPRI	Stockholm International Peace Research Institute
SLBM	Sea-Launched [or Submarine-Launched] Ballistic Missile
SLCM	Sea-Launched Cruise Missile
SMILS	Sonobuoy Missile Impact Locating System
SOFAR	Sound Fixing And Ranging
SOI	Space-Object Identification
SPADATS	Space Detection And Tracking System (of USAF)
Spartan	US ABM missile, deployed briefly in mid-1970s
SPNFZ	South Pacific Nuclear-Free Zone
Sprint	US short-range ABM missile, deployed together with Spartan
SRAM	Short-Range Attack Missile (strategic nuclear, air-launched)

SRI	Stanford Research Institute
SSBN	Nuclear powered ballistic-missile submarine
SSM	Surface-to-Surface Missile
SSTSS	Strategic Systems Test Support Study
STARS	Strategic Target System (old SLBMs fired from PMRFK as SDI targets at Kwajalein)
START	Strategic Arms Reduction Talks (between US and Soviet Union)
STRAD	Strategic Aerospace Division (USAF. 1-STRAD is host command at Vandenberg AFB)
T&E	Test and Evaluation
Thor	Early USAF IRBM, used for nuclear explosions in space in 1962
Titan	Largest US ICBM, liquid-fuelled, phased out 1987
TOO	Targets Of Opportunity
tradex	type of radar (see Chapter 1)
Trident	Current US SLBM
UDS	Universal Documentation System
UHF	Ultra-High Frequency
USAF	United States Air Force
USAKA	US Army, Kwajalein Atoll
USN	United States Navy
USNO	US Naval Observatory (Washington DC; maintains time standards)
USNS	US Naval Ship (used for Military Sealift Command ships)
VAFB	Vandenberg Air Force Base

vertical proliferation	Escalating proliferation of arms by superpowers (see also "horizontal")
VLF	Very Low Frequency
WSMC	Western Space and Missile Center
WTR	Western Test Range

APPENDIX 5

DATA ACQUISITION SYSTEM LOCATIONS

The data acquisition system is comprised of optical, radar, telemetry and impact location sensors situated throughout the Kwajalein Atoll as illustrated in Figure A5.1. Data recorded by these sensors is processed to provide position and performance information on orbital and flight-test vehicles.[1]

Processing of metric optics and radar data yields position, velocity, acceleration and altitude data which is used to evaluate propulsion, air frame, guidance and control systems.

Impact data is processed to provide exact impact co-ordinates and miss distance from the target to determine guidance accuracy and vehicle dispersion.

Processed telemetry data reveals the internal functions, control and physical environment parameters of the test vehicle.

The type and quantity of Range data acquisition sensors and systems are listed below by island location.

Kwajalein Island

Optical:	One Super RADOT Station
	One RADOT Station
	One Ballistic Camera (BC-4)
	One Spectral Ballistic Camera (SBC) Station[2]
	CCTV

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1 US Army Strategic Defense Command, *USAKA Range Instrumentation and Support Facilities Manual*, (Huntsville, Alamaba, June 1987); released under FOIA.

2 One permanent Spectral Ballistic Camera (SBC) mount is located at Legan, Roi-Namur, Gagan and Eniwetak. Tripod-mounted Spectral Ballistic Cameras can be co-located on any island that has a BC-4 Camera. A maximum of four SBC sites can be instrumented at any given time.

Radar:	Two MPS-36 C-Band Radars One FPQ-19 C-Band Radar One TPX-42 IFF L-Band Radar
FCA:	One Mobile FCA/RF Measurements Van
Weather:	One WSR-74 S-Band Weather Radar Two UHF Meteorological Sounding Systems (MSS) One Defense Meteorological Satellite Program (DMSP) System
Launch Facility:	One KISHA Small Rocket Launcher
Ennylabegan	
Telemetry:	Receive, record, decommutate and display telemetry station One 9-metre S-Band auto/slave track antenna One 7-metre S-Band auto/slave track antenna Four 3-metre S-Band auto/slave track antennae One 3-metre antenna can be converted to L-Band slave track
Legan	
Optical:	Two Super RADOT Stations Two Ballistic Camera Stations (BC-4) One Spectral Ballistic Camera (SBC) Station (see footnote 2)
Impact Location:	One X-Band Splash Detection Radar (SDR)
Illeginni	
Optical:	One Fixed Camera Tower (FX) CCTV
Radar:	One Multistatic Measurement System (MSS) passive L-Band radar
Telemetry:	One TM omni-directional S-Band receive and non-IRIG L-Band transmit RHC Re-Radiation System

Roi-Namur

Optical:	One RADOT Station One Super RADOT Station One Ballistic Camera (BC-4) One Fixed Camera Tower (FX) One Spectral Ballistic Camera (SBC) Station (see footnote 2) CCTV
Radar:	One C-Band metric and signature radar (ALCOR) One L/S-Band metric and signature radar (TRADEX)(L-Band Illuminator for MMS, see p.21) One UHF/VHF metric and signature radar (ALTAIR)(UHF Illuminator for MMS) One 35/95 GHz Millimetre Wave (MMW) radar
Telemetry:	Receive and record fixed telemetry station 3-metre S-Band auto/slave track antenna L-Band slave track possible by converting antenna feed assembly Receive and record self-contained Transportable Telemetry Station with 5.5-metre S-Band antenna
Weather:	One UHF Meteorological Sounding Station (MSS) Two X-Band Wind Finding Radars (WFRs)
Launch Facility:	Two small rocket launchers (ASL-20K) Mounting location and firing circuit for HAD 5K meteorological rocket launcher

Gagan

Optical:	One Super RADOT Station One Ballistic Camera (BC-4) One Spectral Ballistic Camera (SBC) Station
Telemetry:	Receive and record telemetry station One 3-metre S-Band auto/slave track antenna system. Cannot be converted to L-Band One stationary S-Band 1.2-metre antenna

Gellinam

Impact location: Hydro-acoustic Impact Timing System (HITS) shore station[3]
One X-Band Splash Detection Radar (SDR)
One Multistatic Measurement System (MMS) passive radar

Omelek

Optical: CCTV
Launch Facility: Small rocket launch facility
Two 5K HAD meteorological rocket launchers

Eniwetak

Optical:
One RADOT station
One Super RADOT station
One Ballistic Camera (BC-4)
One Spectral Ballistic Camera (SBC) Station

Meck

Non-Instrumented

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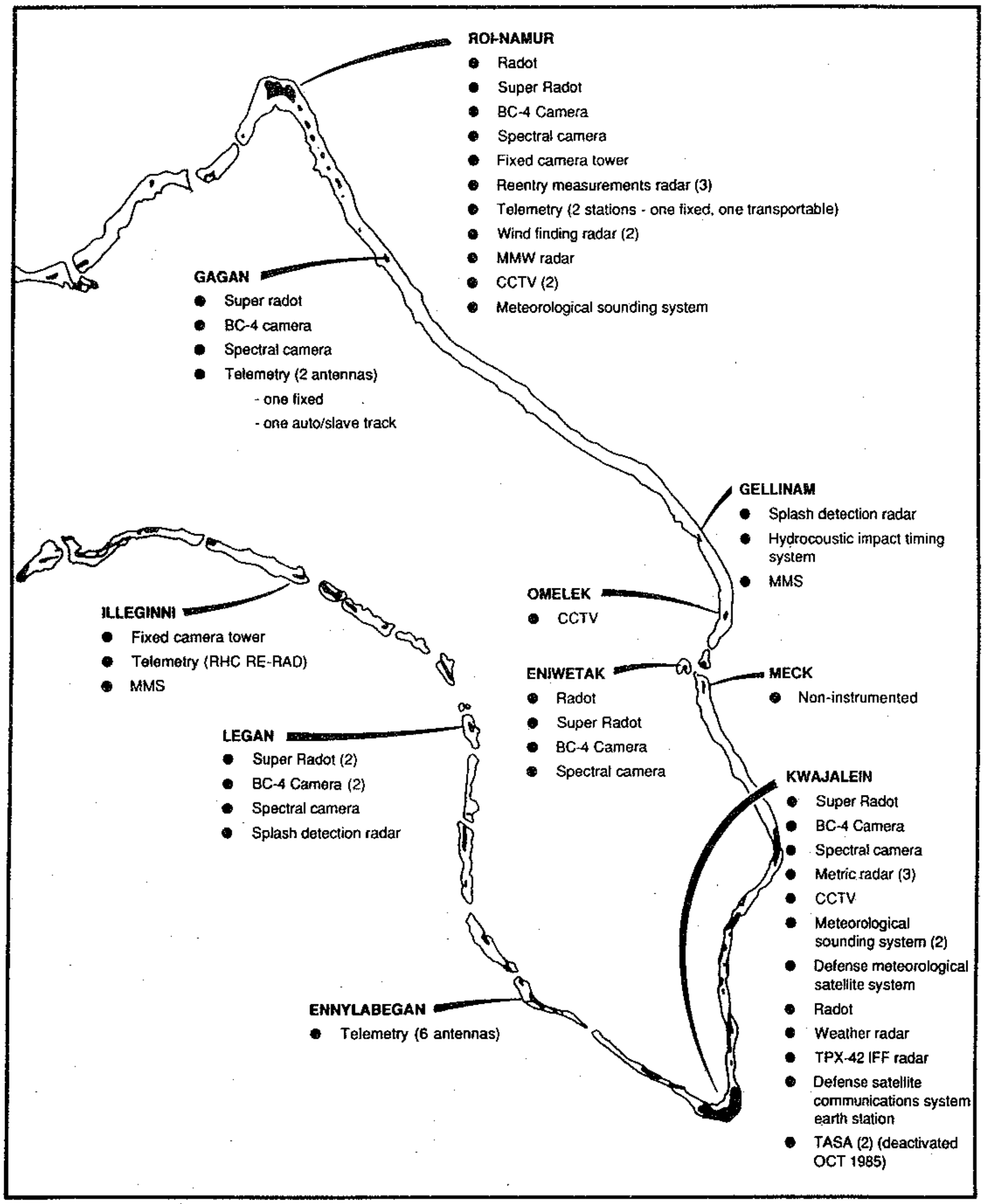
3 As of 1987, on "STANDBY" status. Requires a minimum of 7-10 days' notification prior to being placed back on "OPERATIONAL" status.

Figure A5.1: USAKA Data Acquisition Sensors



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