Workshop on Legal Cooperation to Control Non-State Nuclear Proliferation: Extra-Territorial Jurisdiction and UN Resolutions 1540 and 1373

This is a paper from the Nautilus Institute workshop "Cooperation to Control Non-State Nuclear Proliferation: Extra-Territorial Jurisdiction and UN Resolutions 1540 and 1373" held on April 4th and 5th in Washington DC with the Stanley Foundation and the Carnegie Endowment for International Peace. This workshop explored the theoretical options and practical pathways to extend states' control over non-state actor nuclear proliferation through the use of extra-territorial jurisdiction and international legal cooperation.

Other papers and presentations from the workshop are available online at: http://www.nautilus.org/projects/non-state-proliferation/1540-Workshop

TRACKING NUCLEAR CAPABLE INDIVIDUALS

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Presented at the
Workshop on Cooperation to Control Non-State Nuclear Proliferation:
Extra-Territorial Jurisdiction and UN Resolutions 1540 and 1373
Washington DC
April 4 - 5, 2011

Abstract

This paper draws on a South African case study to highlight the difficulty associated with winding down a nuclear weapons program and in determining the ultimate disposition of the human resources mobilized in that program and the specific issues confronted in the case of South Africa that may be salient in other cases in the coming decades. The question of whether the South African case study results can be extrapolated to the larger enterprise of nuclear abolition was considered. It was shown that there are a number of unique characteristics of the South African case that has to be kept in mind.

A conceptual framework of the nuclear weapons acquisition process is used to classify and demarcate the nuclear weapons institutional, industrial and technological landscape and the magnitude and scope of the pool of knowledge and technology involved. The paper highlights the difference between the total number of skilled personnel mobilized in a nuclear weapons program, and the number of scientists and technicians who represent a proliferation threat by virtue of their knowledge and potential mobility.

This case also highlights the fact that nuclear non-proliferations laws and regulations are necessary, but not sufficient, to prevent illegal nuclear trade. An area of concern is the large number of suppliers of components, equipment, materials and services to nuclear weapons programs. Many of these non-state actors have knowledge, skills or capabilities of proliferation concern - as shown in the South African case with the Khan network.

The paper prefigures the issue of tracking this residual capacity in other nuclear weapons states which represents a very large absolute number of scientifically and technically qualified people, but when reduced to those who have knowledge specific to the nuclear weapons enterprise, may be a much smaller and potentially "manageable" number.

The paper extrapolates the South African case study results to the larger enterprise of nuclear abolition and how this problem might be handled by both national authorities, and by the international community as a whole. Ideas are advanced as to how a registry of such individuals and organizations might be established, maintained and used. National registration for Defense export control appears to be a general practice in many countries and a very preliminary survey suggests that some countries might

already have registers of nuclear capable individuals and organizations. Such information can therefore be used to track and monitor the activities of these individuals and organizations.

Introduction

This paper draws on the South African case study to highlight the difficulty associated with winding down a nuclear weapons program and in determining the ultimate disposition of the human resources mobilized in that program and the specific issues confronted in the case of South Africa that may be salient in other cases in the coming decades.

The fate of the global pool of all nuclear capable individuals remains a major non-proliferation concern. Such individuals have specialized knowledge and skills that are of interest to potential proliferators. The recruitment or soliciting of information from them by coercive or other means, e.g., by agents of other states or terrorist groups, is a potential problem that the international community should address.

The paper will highlight the difference between the total number of skilled personnel mobilized in a nuclear weapons program, and the number of scientists and technicians who represent a proliferation threat by virtue of their knowledge and potential mobility, or relationship to on-going non-state proliferation networks - as happened in the South African case with the A Q Khan network.

The number of nuclear capable countries or the "Nuclear Club" as listed in Table 1 is large. The total number of nuclear capable individuals in these countries represents a very large number of scientifically and technically qualified people, probably in the hundreds of thousands, but when reduced to those who have knowledge specific to the nuclear weapons enterprise, may be a much smaller and potentially "manageable" number.

Table 1: The Nuclear Club

Category	States
Nuclear Non- Proliferation Treaty (NPT) declared nuclear weapons states	United States, Russian Federation (successor state to the Soviet Union),United Kingdom, France, China
Non-NPT undeclared nuclear weapons states	Israel
Non-NPT declared nuclear weapons states	India, Pakistan, North Korea
Nuclear weapons states that disassembled its arsenal before joining the NPT	South Africa
NATO nuclear weapons sharing states (U.S. nuclear weapons)	Belgium, Germany, Italy, Netherlands, Turkey, Canada (prior to 1984), Greece (prior to 2001)
Former Soviet Union nuclear weapons sharing states (Russian nuclear weapons)	Belarus (prior to 1996), Kazakhstan (prior to 1995), Ukraine (prior to 1996)
Aspiring nuclear weapons states	Iran, Burma
Nuclear capable and/or former weapons aspirant states that have renounced nuclear weapons (but who might reconsider).	Germany, Netherlands, Sweden, Romania, Turkey, Brazil, Argentina, Mexico, Egypt, Iraq, Syria, Libya, Saudi Arabia, Japan, South Korea, Taiwan

To appreciate the magnitude and scope of this pool of knowledge and technology it is useful to first establish a conceptual framework of the system. This will be done by considering the nuclear weapons acquisition process and the systems architecture.

Nuclear Weapons Acquisition Paradigms

Sundbo (1998) identified three paradigms of technological innovation. The first is the entrepreneurship paradigm or *forward integration of the system of innovation*. The innovation process is triggered by a scientific discovery and followed by technology development, new product and process development, production and manufacturing, and the eventual adoption & deployment of the products. This paradigm was characteristic of the first nuclear weapons programs of the major nuclear powers.

Sundbo's second paradigm is the technology-economics paradigm. In this case inventions are the result of systematic research and development by established industries and are of a more incremental nature. Technology push is the dominant force in this paradigm. This paradigm is characteristic of ongoing innovation in nuclear weapons industries.

Sundbo's third paradigm of innovation is the strategy paradigm. This is characterized by strategic management of innovations and the emergence of global innovation networks. This paradigm appears to be relevant for collaboration between some of the major nuclear powers such as the US and UK, as well as collaboration between some aspiring nuclear weapons states, e.g. the A Q Khan network countries Pakistan, China, North Korea, Iran, Iraq and Libya.

Kim and Jung (1998) identified a fourth paradigm of industrial development that is particularly relevant for developing countries, namely the *backwards integration of the system of innovation* based on transfers of products, technology and know-how from the developed world to a developing country as shown in Fig. 1. Buys (2002) identified the following five stages of industrial development in developing countries as technological learning and capacity building progresses:

Stage I: Local distribution, marketing, sales and after-sales services of foreign products and services.
Stage II: Local production and manufacturing of products and services using foreign process technology.
Stage III: Local improvement of products and processes using foreign technology.
Stage IV: Local development of new products and processes using foreign technology.
Stage V: Local technology development using foreign knowledge.
Stage VI: Local research and a complete system of innovation.

In the innovation system model *technology* is defined as all *technical knowledge and techniques*, where *technical* has the meaning of “based on the natural sciences” and *techniques* refers to the means utilized to perform some useful function, i.e. transport, communication, design, manufacture, services, etc. Technology is embedded in technology carriers, also known as technology platforms. These are things like knowledgeable and skilled people, specifications, procedures, processes and equipment. Whereas *research* is the generation of new scientific knowledge, *technology development* is activities such as education and training, development of technology demonstrators (prototypes), patenting and writing of specifications, instructions and procedures.

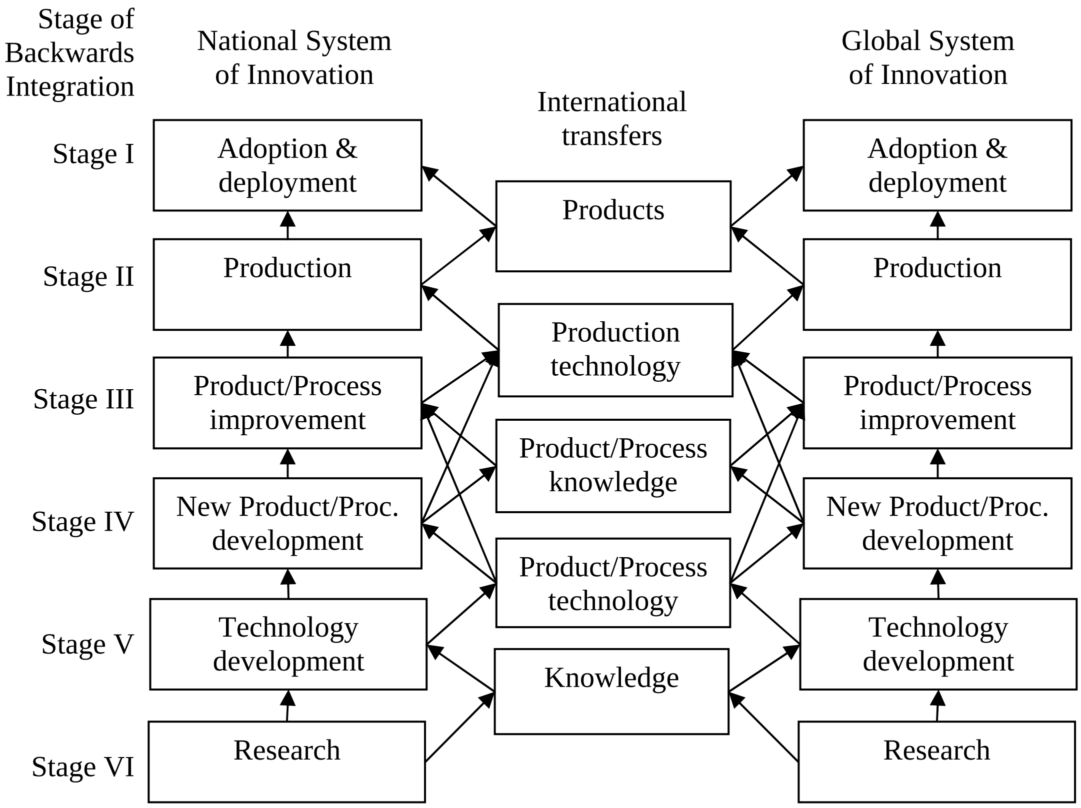

Figure 1: Innovation System Model

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South Africa's nuclear industry developed at the same time as that of the developed countries using the entrepreneurship paradigm, in contrast to some of its other industries (e.g. automotive industry) that followed the backwards integration paradigm. The following brief history of the South African nuclear program (Table 2) illustrates this point.

Table 2: History of South Africa's nuclear program (1923 – 1990).

1923	Discovery of uranium-bearing ore in South African gold mines.
1944 - 1945	Supply of uranium ore for the WWII Manhattan project.
1946	Establishment of the Council for Scientific and Industrial Research and start of local nuclear research.
1946 - 1957	Local research and development of uranium extraction technology.
1948	Establishment of the Atomic Energy Board (AEB) to control the nuclear research program.
1952 - 1959	Major supplier of uranium for the USA and UK nuclear weapons stockpile.
1955	Locally designed and constructed 16 MeV cyclotron nuclear research

	accelerator in operator.
1956	Founder member of the International Atomic Energy Agency (IAEA) and represents Africa on the Board of Governors.
1957 - 1974	Nuclear technology development cooperation program with USA and UK.
1961 - 1969	Local research and development of uranium enrichment technology. Invention of the cyclone uranium enrichment method.
1961	Establishment of the National Nuclear Research Centre at Pelindaba.
1962 - 1969	Local research and development of a new nuclear power reactor concept (PELINDUNA project).
1965	US supplied SAFARI-1 research reactor in operation.
1965 - 1968	South African scientists participate in international conferences on the peaceful use of nuclear explosives.
1970- 1977	Establishment of the Uranium Enrichment Corporation (UCOR). Construction of uranium enrichment plant at Valindaba.
1971 - 1979	Research, design and manufacture of peaceful nuclear explosives (PNE).
1977	Start of highly enriched uranium (HEU) production for the PNE and nuclear weapons programs.
1978 - 1989	Research, development and manufacture of nuclear weapons.
1985	French supplied Koeberg nuclear power station in operation.
1977- 1990	Local production of nuclear fuel for the SAFARI and Koeberg reactors.

The history of South Africa's nuclear industry is comparable to that of the developed world and is therefore different from that of many developing aspirant nuclear weapons states. Most of its nuclear technology was either locally developed or in collaboration with the US and UK. By the time the UN Security Council instituted nuclear sanctions against the country (Resolution 418 of 1977), South Africa was already self-sufficient in the nuclear field and these sanctions were therefore ineffective. That is not to say that South Africa had no need to import foreign nuclear technology. But before this can be discussed, we have to first consider the nuclear weapons system architecture.

Nuclear Weapons Systems Hierarchy

In this section the nuclear weapons system architecture will be investigated by means of a systems hierarchy model. The purpose is to provide a framework for the classification and demarcation of the nuclear weapons institutional, industrial and technological landscape. Different types of actors are engaged on one or more of the hierarchical levels of this model. The nuclear non-proliferation challenges and possible responses are also different for the different types of actors.

The systems hierarchy is a concept used in systems engineering to describe a technical system in terms of its subsystems and interactions (Kossiakoff and Sweet 2003:31-49). The structure of the system is usually represented in the form of a block diagram that defines the system hierarchy and system/component classifications and internal structure of the system in terms of its parts, ports, and connectors (INCOSE 2006:7.8). A systems hierarchy for nuclear weapons systems is shown in Fig. 2.

A System of Innovation (Fig. 1) is found at each level of the Systems Hierarchy (Fig. 2). For example, for a complete Nuclear Weapons System (Level 5, Fig. 2), the nuclear weapons are products (Fig. 1). For a Uranium enrichment system (Level 1, Fig. 2), the HEU is the product and the centrifuges are the production technology (Fig. 1).

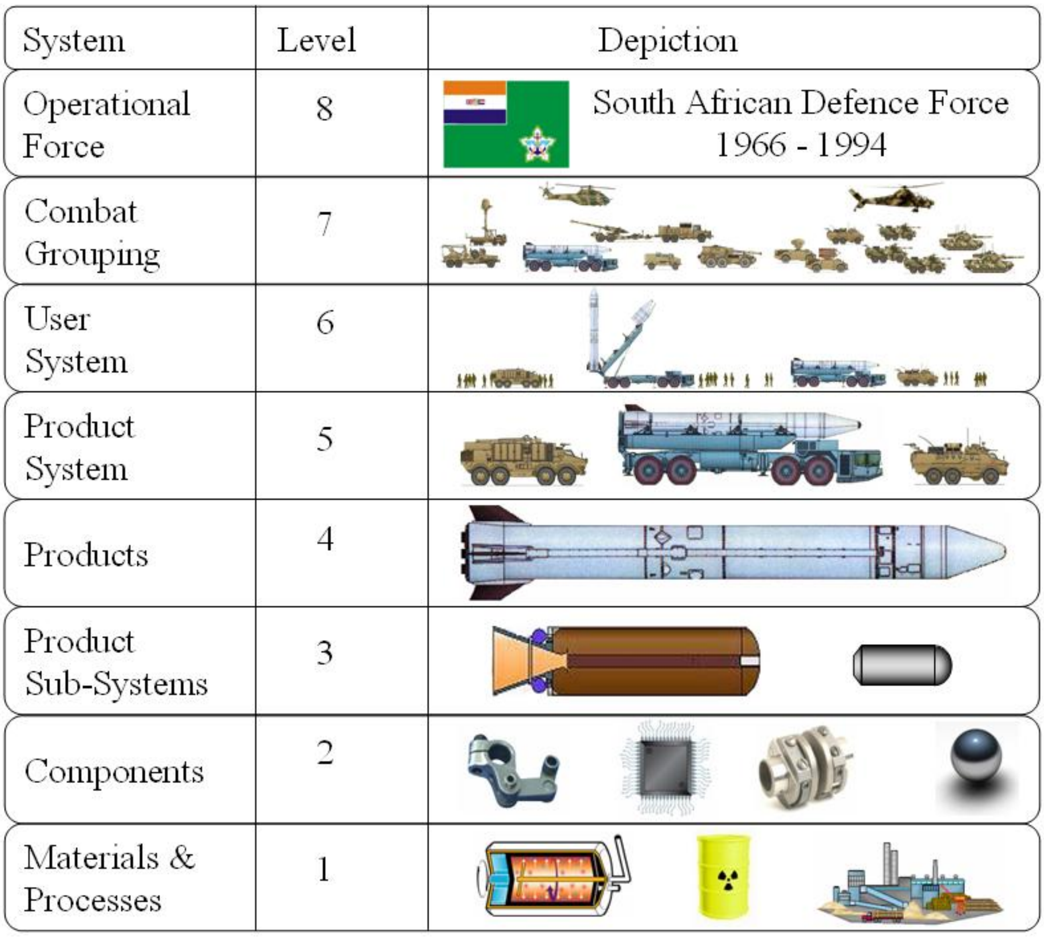

Figure 2: Nuclear Weapons System Hierarchy

System-level acquisition responsibilities are allocated to specific role-players, for example, the South African Defense Force was responsible for the acquisition of Level 7 and 8 systems. A Defense Force Project Office was responsible for acquisition at Level 6, The Armaments Corporation (ARMSCOR) at Levels 5 and 4 and Kentron Circle/Advena for nuclear warheads at Level 3. The higher levels of the systems hierarchy (Levels 3 to 8) are the domain of state actors. It is only on the lower levels (Levels 1 and 2) where non-state actors become active role players as suppliers and sub-contractors. The reason for their involvement is that it is far more cost and time efficient to use commercial sub-systems, components, materials and processes, also known in the armaments acquisition jargon as Commercial Off-the-Shelf (COTS) items and technologies, than doing in-house research, development and manufacture thereof, particularly where small quantities are required. These are also typically dual-use items.

Denying rogue states access to nuclear related COTS or dual-use items and technologies can delay such programs and might, in the case of smaller states, make the acquisition of nuclear weapons prohibitively expensive. A major non-proliferation concern is therefore non-state actors which covertly and illegally trade and supply such equipment and technology required to establish and maintain nuclear weapons programs.

South Africa and the AQ Khan Network

An example of a failure of the international nuclear non-proliferation control regime is the AQ Khan network. For a detailed description of this case see Albright (2010).

In October 2003, a ship was intercepted in an Italian port en route to Libya. The cargo contained parts of a centrifuge enrichment plant. This led to the discovery of the AQ Khan network and the involvement of Krisch Engineering in South Africa. Krisch Engineering is a private company that manufactures forgings, condenser tubes, distillation and induction heating equipment, valves and vacuum pumps.

During the 1970s and early 1980s the firm Krisch Engineering Co (Pty) Ltd was the local agent in South Africa for the German firms AEG Telefunken and Leybold Heraeus GmbH and was a supplier of commercial equipment used in the uranium enrichment plants of the Uranium Enrichment Corporation of South Africa (UCOR). Gerhard Wisser, a German national, was head of Krisch Engineering and Daniel Geiges, a Swiss national, was Wisser's chief engineer. Johan Meyer, a native South African, was an employee of UCOR and worked with Krisch in the1970's. He left UCOR to establish Roxound Engineering Works in 1980 and became a subcontractor to UCOR supplying process piping for their enrichment plants. The contracts came to an end with the completion of the enrichment plants in the mid-1980. These former subcontractors of UCOR were then contracted by Gotthard Lerch, a former employee of Leybold Heraeus, to supply gas centrifuge technology to foreign customers such as India and also to Pakistan and Libya as part of the AQ Khan network. Meyer's firm Tradefin Engineering was subcontracted by Wisser to manufacture the gas centrifuge components destined for Libya.

Wisser, Geiges and Meyer were arrested by the South African Police in September 2004 after the Khan network was exposed. In 2007 Gerhard Wisser was convicted on seven counts including the manufacture and export of three autoclaves in 1994/1995 to Pakistan and the manufacture and attempted export of components for the Libyan gas centrifuge plant between 1999 and 2003. He was sentenced to eighteen years' imprisonment, suspended for five years and forced to pay millions of dollars in fines. Geiges was sentenced to thirteen year's imprisonment, all suspended as he was terminally ill with cancer and died in 2008. Meyer was not charged because of his cooperation with the authorities.

Why did this breach of the non-proliferation regime happen? Only the Nuclear Energy Corporation (NECSA) is mandated to manufacture and export nuclear related materials or equipment in South Africa with the written authorization of the Minister of Minerals & Energy. The manufacture, procurement and export of any nuclear dual-use goods by industry require authorization and a permit from the South African Council for the Non-Proliferation of Weapons of Mass Destruction. Wisser and his accomplices did not comply with this legal requirement. But, as criminologists know, in the criminal mind the belief that you will not be caught outweighs the fear of punishment. Nuclear non-proliferations laws and regulations are necessary but not sufficient to prevent illegal nuclear trade. The world will not be safe until all nuclear weapons, their technology and materials are secured and safeguarded.

Tracking nuclear capable individuals: The South African case study

A research study in 2004 by the author (Buys 2007) investigated the fate of South Africa's former nuclear explosives/weapons program personnel after the termination of the program.

Only the personnel that were employed by the *Reaktor Ontwikkeling*[1] (RO) Division of the former AEB[2] and ARMSCOR's Kentron Circle/Advena[3] Nuclear Weapons Facility were included in the study as these were the only personnel directly involved in nuclear explosives/weapons work. The research population was former employees of State Corporations, i.e. state actors working at Level 3 of the systems hierarchy (see Table 1). Although many other personnel were indirectly involved in the program at Levels 1 and 2 of the Systems Hierarchy - e.g. personnel of AEB, UCOR, ARMSCOR, subcontractors and suppliers - these were not included in this study. Many actors working at Level 1 of the Systems Hierarchy were also non-state actors such as private companies, agents and brokers.

The research design was a questionnaire survey. The research population consisted of the approximately 400 personnel that were employed by RO and Kentron Circle/Advena. An attempt was made to obtain their contact information from the archived personnel records held by the employers, but it was soon realized that after more than thirteen years the contact information was outdated. The sample frame therefore consisted of an informal list maintained by an 'old boys club' of former employees, which contained contact information of 255 individuals. Survey questionnaires were completed and returned by 118 individuals. This sample size was sufficient to make significant findings about the population.

This research provides detailed information on the fate of South Africa's former Nuclear Explosives/Weapons Program personnel after the termination of the program in 1991. Some of the findings of the study were that there is a strong and direct association between the mode of termination of employment and type of post-termination employment. Only a few (10%) of those that resigned were unemployed thereafter, but the majority (63%) of those that were retrenched was unemployed or went into retirement.

As expected, the educational level of the personnel was high. Most (87%) were educated at the tertiary level, 53% were graduates with 25% having master's degrees and 11% doctoral degrees. A large group (35%) had diplomas from Technical Colleges. These were mostly in Mechanical Engineering (36.6%) and Electrical & Electronic Engineering (26.8%).

The study also found a strong association between the personal income and the type of employment of the former NEWP personnel after leaving the program. The income of most (78%) of those that joined another firm increased or was unchanged. The income of most (58%) of those that were transferred was unchanged, and the income of the majority (84%) of those that became unemployed, retired or started their own businesses declined. A major finding of this research is therefore that many of South Africa's former NEWP personnel suffered financially after termination of the program. It is therefore not surprising that the majority (71%) of those that were retrenched was "very dissatisfied".

The question is whether the South African case study results can be extrapolated to the larger enterprise of nuclear abolition. There are a number of unique characteristics of the South African case that has to be kept in mind. It was a modest program with a relatively small number of individuals involved. The estimated maximum staff complement of the Peaceful Nuclear Explosive (PNE) Program was 80 and 223 for the Nuclear Weapons Program.

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[1] Afrikaans for 'Reactor Development'

[2] Later renamed the Atomic Energy Corporation (AEC), currently the Nuclear Energy Corporation of South Africa (NECSA).

[3] Renamed Advena in 1992

When the government terminated the South African nuclear weapons program in 1989, the initial intention was to keep the existence of the program secret. The closure of the uranium enrichment plant and the dismantling of the nuclear warheads were therefore done in secret. Not only was the hardware dismantled and destroyed, the facilities were also dismantled and the records and documentation destroyed. After the government announced the dismantling of South Africa's nuclear weapons program in March 1993, the international verification of the program was made more difficult because of the prior destruction of the documentation and hardware.

Another difficulty that was experienced at the time when the nuclear weapons program was terminated was the downsizing of the defense industry as a consequence of the sharp cutback in defense spending. The personnel could therefore not be accommodated in the rest of the organization and a large percentage (40%) was retrenched. Those that were retrenched received standard retrenchment packages, but many (47.8%) viewed the retrenchment packages they received as unfair. They considered themselves a special case and expected to be treated differently from the other armaments industry workers. One of the arguments offered in support of the view that Nuclear Weapons Program personnel deserves special compensation is that they have acquired unique or specialized knowledge and skills that were so specific to the nuclear explosives/weapons program that it was of no value to the individuals after the termination of the program. However, only about a quarter (25.9%) of the respondents indicated that they had acquired such knowledge or skills.

The only human resource records kept by ARMSCOR and NECSA, the successor organizations of UCOR and the Atomic Energy Board (AEB), are medical and occupational safety records of former employees. These records are classified but are available. For example, in January 2009 the Pretoria High Court ordered NECSA to hand over the relevant records of a former employee who was seeking compensation for cancer he alleged was caused by exposure to ionizing radiation while working at UCOR’s uranium enrichment plant between 1974 and 1983. Although these records are not kept up to date and the contact details may be outdated, they can be used to determine the ultimate disposition of the human resources mobilized in the program.

Not all the personnel mobilized in a nuclear weapons program represent a proliferation threat by virtue of their knowledge and potential mobility. In the case of South Africa only about 400 individuals were involved in nuclear explosives/weapons work at Levels 3 to 5 of the systems hierarchy (Fig.1). Of these an estimated 55% or 220 were scientifically and technically qualified people who had knowledge specific to the nuclear weapons enterprise that is of proliferation concern. This is a manageable number. The problem is however the large number of support personnel that were indirectly involved at Levels 1 and 2 of the Systems Hierarchy - e.g. personnel of the AEB, UCOR, ARMSCOR, subcontractors, suppliers, agents and brokers. These were the suppliers of components, equipment, materials and services. Here the numbers are probably in the thousands. None of them would have had the “full picture”, but many have knowledge, skills or capabilities of proliferation concern.

The number of individuals mobilized in a nuclear weapons program that has specific knowledge of proliferation concern as well as the extent of their knowledge depends on the organizational culture of the organizations involved. In the case of South Africa, the nuclear weapons program was classified Top Secret and even the very existence of the program was kept secret. To maintain this extreme level of secrecy the organization was compartmentalized and a strict “need-to-know” policy was adopted. Individuals only received the minimum information to enable them to do their work. The rule was “if you are not informed, then you have no need to know, so don’t ask or try to find out”. This policy was applied at all levels of government and in all the organizations involved. In addition, when individuals were informed about aspects of the program, there were extensive use of deception plans and cover stories. These were typically half-truths or credible untruths. For example, the personnel of UKOR were told that low-enriched uranium was produced for the Koeberg nuclear power station (a half-truth). Those that worked at the Y-plant where HEU was produced were told that it was for the SAFARI research reactor (another half-truth). Only a select few of UCOR’s top management knew about the nuclear weapons program. Technical details were also only available to those that had a need to know.

International Registry of Nuclear Capable Individuals and Organizations

In this section ideas are advanced as to how an international registry of nuclear capable individuals and organizations might be established, maintained, and used.

Security Council resolution 1540 (2004) requires of all States to adopt and enforce appropriate effective laws and enforce effective domestic controls to prevent the proliferation of nuclear, chemical, or biological weapons and their means of delivery and related materials. Although the Nuclear Suppliers Group (NSG) seeks to contribute to the non-proliferation of nuclear weapons through the implementation of guidelines for the export of nuclear and nuclear related dual-use items and technologies, their guidelines do not require registration of nuclear capable individuals and organizations.

Resolution 1540 provides for the establishment of a Committee to gather comprehensive data of measures taken by States to implement this resolution. According to the Committee’s report presented to the Security Council on 30 July 2008, 155 states have submitted their national reports on the implementation of the Resolution to the Committee by 1 July 2008. Annex XI.B of this report provided an assessment of implementation for 192 Member States with regard to nuclear weapons and related materials. It stated that 36 States reported having measures in place to undertake reliability checks of personnel working with nuclear weapons and related materials and 83 states reported having licensing requirements in place for nuclear facilities or personnel who use nuclear-related materials.

It therefore appears as if many Member States already gather, license and register their nuclear-capable facilities and personnel. For example, in the case of South Africa, the Non-Proliferation Act (Act No. 87 of 1993) requires those persons in control of any activity with regard to controlled goods or who have controlled goods in their possession or custody or under their control to register with the Council for the Non-Proliferation of Weapons of Mass Destruction. Additional requirements regarding the processes and procedures for registration, including the registration form, has been prescribed in Government Notice No. R.16 of 03 February 2010.

Any person who engages in the United States in the business of either manufacturing or exporting defense articles, defense services or related technical data, is required to register with the Office of Defense Trade Controls. Registration is not required for persons whose manufacturing and export activities are licensed under the Atomic Energy Act of 1954, as amended. National registration for Defense export control appears to be a general practice in many countries. For example the Montenegro Law on Foreign Trade in Weapons, Military Equipment and Dual-use Items determines that foreign trade in controlled goods may only be conducted by a person entered into the Register of persons for conducting foreign trade in controlled goods. To what extent this is also the practice in the nuclear field is unclear. For example Australia's Weapons of Mass Destruction (Prevention of Proliferation) Act (1995) does not require registration. Neither does India's Weapons of Mass Destruction and their Delivery Systems (Prohibition of Unlawful Activities) Act, Act 21 of 2005.

This very preliminary survey suggests that some States might already have registers of nuclear capable individuals and organizations. Such information can therefore be used to track and monitor the activities of these individuals and organizations. The non-proliferation regime will be strengthened if such information could be shared between States. The question is if this is achievable in practice and what are the stumbling blocks to such collaboration?

Resolution 1540 calls upon all States to take cooperative action. This requirement was expanded and elaborated on by the International Convention for the Suppression of Acts of Nuclear Terrorism (2005). Article 7-1(b) of the Convention makes provision for exchanging information and coordinating administrative and other measures taken to detect, suppress and investigate the offences set forth in article 2 of the convention and also to prevent such offences.

A stumbling block to sharing national information regarding nuclear capable individuals and organizations, is confidentiality, as such information would be classified from a national security perspective. The public disclosure of such information would also be undesirable as it could make the registered individuals and organizations targets for proliferators. The International Convention for the Suppression of Acts of Nuclear Terrorism (2005) recognizes this danger and therefore does not require State Parties to provide any information which would jeopardize the security of the State concerned or the physical protection of nuclear material (Article 7-3). It does, however, require of states and international organizations to take appropriate measures to protect the confidentiality of any information which they receive in confidence (Article 7-2).

The IAEA safeguards could be strengthened by requiring of states to submit their national information to an international register of nuclear capable individuals and organizations established, maintained, and used by the IAEA. Such a register could be a valuable resource to monitor and investigate suspicious affiliations and trade relations.

Conclusions

This paper drew on a South African case study to highlight the difficulty associated with winding down a nuclear weapons program and in determining the ultimate disposition of the human resources mobilized in that program.

A conceptual framework of the nuclear weapons acquisition process, based on the theory of technological innovation and the systems architecture or hierarchy model, was used to classify and demarcate the nuclear weapons institutional, industrial and technological landscape and the magnitude and scope of the pool of knowledge and technology involved.

It was shown that the total number of scientifically and technically qualified individuals in nuclear capable countries is very large. There is, however, a difference between the total number of skilled personnel mobilized in a nuclear weapons program and the number of scientists and technicians who represent a proliferation threat by virtue of their knowledge and potential mobility. In the case of South Africa only about 400 individuals were involved in nuclear explosives/weapons work, of which an estimated 55% had knowledge of proliferation concern.

The question of whether the South African case study results can be extrapolated to the larger enterprise of nuclear abolition was considered. It was shown that there are a number of unique characteristics of the South African case that have to be kept in mind. It was a modest program with a relatively small number of individuals involved. In addition, the South African program was secret and as a result of the strict “need-to-know” policy the amount of information available to individuals was restricted. This might not be the case in other countries.

Denying rogue states access to controlled or dual-use items and technologies can delay such programs and make the acquisition of nuclear weapons prohibitively expensive. An area of concern in this regard is the large number of suppliers of components, equipment, materials and services to nuclear weapons programs. Many of these non-state actors have knowledge, skills or capabilities of proliferation concern - as shown in the South African case with the Khan network. This case also highlights the fact that nuclear non-proliferations laws and regulations are necessary, but not sufficient, to prevent illegal nuclear trade.

Ideas were advanced as to how a registry of such individuals and organizations might be established, maintained and used by both national authorities and the international community as a whole. National registration for Defense export control appears to be a general practice in many countries and a very preliminary survey suggests that some countries might already have registers of nuclear capable individuals and organizations. Such information can therefore be used to track and monitor the activities of these individuals and organizations. The IAEA safeguards could be strengthened by requiring of states to submit their national information to an international register of nuclear capable individuals and organizations maintained and used by the IAEA.

Will we have to wait for hundreds of thousands of people to die in a nuclear 9/11 before the international community will realize that the time has come to abolish nuclear weapons altogether? The complete abolition of all nuclear weapons might not be possible or even desirable in the foreseeable future. The deterrence value of nuclear weapons cannot be denied. It can be argued that nuclear deterrence in the cold war era prevented a third world war. An achievable goal would be to ensure that all nuclear weapons, their technology and materials are secured and safeguarded. To this end an international registry of nuclear capable individuals and organizations should be established, maintained and used.

References

United Nations, 2004. *Resolution 1540 (2004)*. Adopted by the Security Council at its 4956th meeting, on 28 April 2004

United Nations, 2005. *International Convention for the Suppression of Acts of Nuclear Terrorism*. Adopted by the General Assembly of the United Nations on 13 April 2005.

Resolution 1540 Committee, 2008. *Report of the Committee established pursuant to Security Council resolution 1540 (2004).* Annex to the letter dated 8 July 2008 from the Chairman of the Resolution 1540 Committee addressed to the President of the Security Council.

International Council on Systems Engineering, 2006. *INCOSE Systems Engineering Handbook* v.3, 2006, INCOSE-TP-2003-002-03, June 2006, Edited by: Cecilia Haskins

Kossiakoff, A. and Sweet, W., 2003. Chapter 2: Structure of complex systems, in *Systems Engineering: Principles and Practice*. New York: Wiley.

SANPA, 2007. Statement Issued by the South African National Prosecuting Authority, 4 September 2007.

Department of Trade and Industry, 2010. Regulations relating to the registration of persons in control of any activity with regard to controlled goods or who have controlled goods in their possession or custody or under their control, Notice R.16, *Government Gazette* No. 32891, Vol. 536, Page 3, 3 February 2010, Pretoria.

South African Council for the Non-Proliferation of Weapons of Mass Destruction, 2010. http://www.dti.gov.za/nonproliferation/legislation.htm

Albright, D., 2010. *Peddling Peril - How the Secret Nuclear Trade Arms America's Enemies*, Free Press, March 2010.

Buys, A.J., 2007. *Proliferation Risk Assessment of Former Nuclear Explosives/Weapons Program Personnel: The South African Case Study*, Graduate School of Technology Management, University of Pretoria, Issue 2, 31 May 2007. (This research project was funded by the Ploughshares Fund.)

Buys, A.J., 2002. *Industrial Development in South Africa by Backwards Integration of the National System of Innovation*, Proceedings of the 11th International Conference on Management of Technology (IAMOT 2002), Miami, Florida, USA, 10-14 March 2002.