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VERIFYING NUCLEAR DISARMAMENT

Lessons Learned in South Africa, Iraq and Libya

ROBERT E. KELLEY

January 2023

STOCKHOLM INTERNATIONAL PEACE RESEARCH INSTITUTE

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Preface

One of the most important aspects of field work is to document the results and summarize the lessons learned. This is especially true when the tasks are unprecedented and of international importance. Yet, in the case of nuclear weapon-specific inspections in the 1990s and 2000s in South Africa, Iraq and Libya, only very high-level summaries are readily available. The details of how inspections were handled, what tools were used and the gritty day-to-day problems facing inspectors are not available for the public or, for that matter, future generations of inspectors facing similar problems.

None of the examples cited above was a normal 'inspection' in the legal context. They were inspections or visits made by the International Atomic Energy Agency (IAEA) under widely differing mandates with varying sets of tools appropriate to each very different task. It is important to emphasise this point because there is a common misunderstanding that success in one or all of the above countries guarantees that the next new, similar task can be successfully undertaken. As shown in this report, the tasks of the past do not provide a single template to follow. It also true that the experiences in these three countries have been poorly preserved and are not available to address new challenges.

SIPRI is fortunate to have as a distinguished associate fellow Bob Kelley, who participated in all three of the weapon-focused inspections in South Africa, Iraq and Libya. He was asked to document the different processes used to resolve the particular puzzle in each of the three states. In doing so, he has created an essential document of record for use by any teams responding for the international community and the IAEA to similar nuclear weapon-related challenges in the future. The report also allows the public, media and policymakers to see the different obstacles faced and the resources required to reach verifiable conclusions.

Dan Smith
Director, SIPRI
Stockholm, January 2023

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Abbreviations

AEC	Atomic Energy Corporation (South Africa)
CNSC	Canadian Nuclear Safety Commission
DOE	Department of Energy (United States)
EMIS	Electromagnetic isotope separation
FFCD	Full Final and Complete Declaration
FMSO	Foreign Military Studies Office (United States)
HEU	Highly enriched uranium
IAEA	International Atomic Energy Agency
INFCIRC	Information Circular (IAEA)
INVO	Iraq Nuclear Verification Office (IAEA)
NBSR	National Board for Scientific Research (Libya)
NEST	Nuclear Emergency Search Team (United States)
NMD	National Monitoring Directorate (Iraq)
NPT	Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty)
P5	The five permanent members of the United Nations Security Council (China, France, Russia, the United Kingdom and the United States)
TPNW	Treaty on the Prohibition of Nuclear Weapons
UN	United Nations
UNMOVIC	United Nations Monitoring, Verification and Inspection Commission
UNSCOM	United Nations Special Commission
WMD	Weapons of mass destruction

Summary

In the period from 1991 to 2004 there were three challenges to the international nuclear non-proliferation community and the International Atomic Energy Agency (IAEA). Three countries—South Africa, Iraq and Libya—had taken their ambitions to build nuclear weapons to a high threshold of implementation. This report provides an account and analysis of the inspection campaigns to disarm and denuclearize these three states from the perspective of a direct participant.

South Africa voluntarily declared in 1993 that it had successfully built weapons. Its programme had been active in the 1980s and resulted in seven nuclear explosive devices that were secretly dismantled by 1991. South Africa invited the IAEA to visit all of the sites associated with the past programme with the goal of verifying the details of the programme and giving assurance that it had been dismantled. Verifying the production and disposition of nuclear materials was a complicated task but well within the capability of the IAEA's professional nuclear accountancy cadre. Verifying the development, deployment and destruction of actual weapons was outside the IAEA's capability. It was especially difficult given the facts that the weapons had already been dismantled and largely destroyed and that most records were also destroyed. Resolution of this issue was carried out by a few people under cooperative visits and analysis. It was completely the opposite of the huge mission in Iraq going on simultaneously.

Iraq lost a war in 1991 to a United Nations-sanctioned coalition that was partially fought to end suspected activity related to weapons of mass destruction (WMD). The UN Security Council created a large quasi-military operation to uncover and neutralize WMD activity, including chemical, biological and nuclear weapons and missiles designed to deliver them. The IAEA was chosen to be the arm of this team to investigate any nuclear activity in Iraq. The challenges of working in a hostile post-war climate in Iraq with a highly uncooperative government were new to the IAEA, which depended on a large UN logistical support team. Significant outside help was required to expand the team to investigate nuclear weapons, gas centrifuge enrichment and military applications and to make a large effort to document the complete extent of the Iraqi programme. This went far beyond the IAEA's usual mission of verifying nuclear material inventories.

In 2003 Iraq completely reversed course and cooperated extensively with the IAEA in a futile attempt to delay another invasion. By then the IAEA had built a large standing team to deal with Iraq and was able to thoroughly document the absence of a nuclear programme of any kind in Iraq, the previous programme having been completely destroyed in the early 1990s. This was still in concert with the UN in its overall WMD-elimination mission.

Libya voluntarily gave up a failing programme upon witnessing the 2003 invasion of Iraq. The public disclosure of its clandestine nuclear programme came in late 2003. Western intelligence agencies had a good window into Libyan cooperation with the Khan nuclear proliferation network. But all were surprised that Pakistan, as well as coaching Libya in how to enrich uranium, had provided a

set of drawings and instructions for how to build a nuclear explosive device with the enriched uranium. The IAEA was strongly encouraged by Western states to aggressively investigate the Libyan programme. But there was also a desire for the inspections to be seen as international in nature and not purely the effort of one or two states hostile to Libya. As in South Africa, the IAEA had all the tools it needed to verify clandestine activities involving undeclared nuclear materials. It also fielded its own team of experts on gas centrifuge enrichment because of the considerable experience that it had gained in Iraq. Again, nuclear weapon expertise was largely lacking within the IAEA, but the member states agreed for two appropriately cleared inspectors from two nuclear weapon states to carry out an inspection mission dedicated to the weapon-resolution task. They viewed the weapon design documents and used the knowledge gained to search for capabilities to build the device.

Six lessons from the experiences of nuclear disarmament verification in South Africa, Iraq and Libya stand out.

1. Do not destroy evidence before a thorough analysis is possible.
2. Rights granted by mandates are hard to recover if they are given away.
3. Inspectors with broad industrial experience are necessary.
4. Security culture needs improvement to a high standard of classified work.
5. Successful denuclearization may not be universally accepted.
6. Credibility relies on inspector integrity.

It has been 18 years since the end of the weapon inspections in Libya. There have been no similar activities in the interim but the potential for new inspections in another state remains. The record documented here of the tools, mandates, inspectors and access required in the three very different cases can be a guide for future inspectors who may not have access to details of past successful denuclearization efforts.

1. Introduction

Most of the world's states have respected the norm against developing nuclear weapons and are parties to the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT).[1] To reach this point has required some states to disarm and denuclearize. Some that had nuclear weapon research and development programmes in the 1950s and 1960s dismantled them before joining the NPT once it opened for signature. When Belarus, Kazakhstan and Ukraine inherited large nuclear weapon arsenals upon the dissolution of the Soviet Union in 1991, they voluntarily relinquished them and joined the NPT. The nuclear activities of all these states are now under international verification arrangements—the safeguards of the International Atomic Energy Agency (IAEA).

Despite their importance, none of these cases involved systematic international verification of disarmament and denuclearization. The three major cases where such verification did take place were in South Africa, Iraq and Libya. In each of these cases there was concrete evidence of nuclear weapon design activity in addition to clandestine attempts to produce fissile materials for a bomb. This report provides an account and analysis of these three disarmament and denuclearization inspection campaigns from the perspective of a direct participant.

One model of weapon inspections does not fit all cases. Many are quick to say, 'If the IAEA could disarm South Africa, Iraq and Libya, then surely it can do the same again'. Such a sentiment is welcome, but it ignores the fact that the situations in these three countries differed radically. The inspection mandates, field conditions, inspection teams and international support could not have varied more.

South Africa, facing radical internal changes, dismantled a secret programme and then voluntarily asked the IAEA to come in and verify what had taken place and certify that weapons were no longer there. There was no international mandate. Instead, there was a cooperative agreement between the IAEA and South Africa. South Africa also wanted to comply because it was seen as being in the national interest, rather than because of coercion or involuntary disclosure, and external partners understood and accepted that.

Iraq lost a war and was inspected for many years under United Nations Security Council mandates by quasi-military missions. Nuclear inspections were part of a massive, coordinated UN process to discover and eliminate weapons of mass destruction (WMD)—nuclear, chemical and biological—and the missiles to deliver them.

Libya had an enigmatic nuclear programme to acquire fissile materials and acquired nuclear weapon knowledge in the process. Libya voluntarily gave up a failing programme upon witnessing the United States-led invasion of Iraq in 2003 and its implications for Libya's ambitions. As in the case of South Africa, there was

[1] Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), opened for signature 1 July 1968, entered into force 5 Mar. 1970, IAEA INFCIRC/140, 22 Apr. 1970.

Box 1.1. Project Sapphire

In a mission known as Project Sapphire, in 1994 the United States repatriated approximately 600 kilograms of highly enriched uranium (HEU) from Kazakhstan.[a] Securing this extremely valuable nuclear weapon material was deemed to be of supreme national security importance. It was brought to the USA covertly without criticism.[b]

In Iraq, the disarmament inspection team had had great difficulty repatriating HEU in 1993. Intuitively, it was important to get weapon-usable material out of Iraq. But environmental groups in France and Russia objected to importing what they described as 'nuclear waste'.

No nuclear weapons were involved in Project Sapphire, so in practice it was a case of denuclearization, not disarmament. It involved removing extremely valuable nuclear material from a precarious situation where security was poor and proliferation interest was high. There were rumours that Iran was interested in acquiring the material in Kazakhstan.[c] Notably, the source of these rumours was similar to the source of claims that materials were buried in Iraqi graveyards (see chapter 5).

[a] Hoffman, D. E., Savranskaya, S. and Blanton, T. (eds), *Project Sapphire 20th Anniversary*, National Security Archive Electronic Briefing Book no. 491 (George Washington University, National Security Archive: Washington, DC, 17 Nov. 2014).

[b] *New Scientist*, 'Kazakhs trade uranium for aid', 3 Dec. 1994.

[c] Anderson, J. and Binstein, M., 'O'Leary calls Project Sapphire a gem', 12 Dec. 1994.

no UN Security Council resolution. Instead, the IAEA was acting on information provided by the USA and the United Kingdom.

There is one common element in each case, however: all three states have now been brought into compliance with the NPT.

Internationally supervised disarmament and denuclearization may happen again in the future. The international community was hopeful that a temporary thawing of relations between the Democratic People's Republic of Korea (DPRK, or North Korea) and the USA and the bilateral summits in 2017 and 2018 could have led to North Korea consenting to verifiable denuclearization.[2] The 2017 Treaty on the Prohibition of Nuclear Weapons (TPNW), which entered into force in 2021, envisages verification of the irreversible elimination of nuclear weapon programmes of its states parties, 'including the elimination or irreversible conversion of all nuclear-weapons-related facilities'.[3] While no nuclear-armed state has yet shown any sign of joining the TPNW, the treaty's states parties clearly hope that one will.

The establishment of any new inspection regime will have to consider the same basic elements: its mandate; the selection of inspectors; and logistical questions such as the required language skills, how to handle documents and necessary technical tools. Each will be affected by, and must be adapted to, how cooperative the inspected state is. They must also be adapted to the three principal phases of any denuclearization. First would be the initial dismantlement and rendering safe of any nuclear weapons, assuming that this had not been done before the

[2] Kile, S. N., 'North Korean–United States nuclear diplomacy', *SIPRI Yearbook 2020: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2020); and Kile, S. N., 'North Korean–US nuclear diplomacy', *SIPRI Yearbook 2019: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2019).

[3] Treaty on the Prohibition of Nuclear Weapons (TPNW), opened for signature 20 Sep. 2017, entered into force 2 Jan. 2021, Article 2(1).

inspectors arrive. The second phase would consist of the removal of the nuclear materials from the country as rapidly and safely as possible (for which the experience of the US Project Sapphire in Kazakhstan in 1994 will be relevant; see box 1.1). Once weapons are destroyed and nuclear materials are put into monitored civil programmes, the third—and longest—phase is to verify correctness and completeness of states' declarations of the quantity and location of materials. The IAEA is the natural organization to do this—for this is its primary job in nuclear material safeguards today and has been since 1970.

This report reviews these basic elements—the mandates, resources and effort of the IAEA—when applied to neutralize nuclear weapon ambitions in South Africa (chapter 2), Iraq (chapter 3) and Libya (chapter 4). Following these reviews, the report identifies the lessons learned in each case (chapter 5). The report closes with some conclusions that highlight six main lessons for future disarmament verification (chapter 6). Before turning to the first case study, the following two sections clarify the definitions of disarmament and denuclearization and the role of trust, and the different forms of inspection and visit.

Definitions of disarmament and denuclearization and the role of trust

There are no uniformly agreed upon international legal definitions of the terms 'nuclear disarmament' and 'denuclearization'. For the purposes of this paper, nuclear disarmament is taken to mean the reduction, limitation or abolition of nuclear weapons or nuclear forces or both. Denuclearization is defined as elimination of military infrastructure and materials necessary for nuclear weapon production. Denuclearization also covers the disposition of special nuclear materials: highly enriched uranium (HEU) and the isotopes of plutonium normally used in weapons.

Specific modalities of nuclear disarmament and denuclearization always depend on trust between the involved parties. In South Africa, trust was high and the state returned to normal IAEA safeguards. This meant that it could continue to hold large amounts of HEU as long as they were verified by the IAEA under ordinary safeguards verification rules. Libya did not enjoy such trust and even a storage cylinder of uranium hexafluoride was removed from the country by the USA. The IAEA removed tonnes of material from Iraq after the 1991 Gulf War. The USA removed even more material from Iraq after the invasion of 2003.

Note that 'trust' is not a choice of the IAEA. The IAEA applies its safeguards universally and any country in compliance with a safeguards agreement can theoretically hold weapon-grade uranium. It is international pressure outside the IAEA that forced Libya, for example, to give up its nuclear materials.

Different forms of inspection and visit

The most common type of inspection is an IAEA safeguards inspection under a standard agreement between the IAEA and a state. Such an agreement can be based on the model in the IAEA's information circular INFCIRC/66 of 1965 or that in INFCIRC/153 of 1972.[4] Very basic INFCIRC/66-type agreements are considered to be obsolete today, although four states still have one: India, Israel, North Korea and Pakistan. Under such an agreement a state agrees to put only part of its nuclear materials and facilities under safeguards. This is true even if other activities are publicly known and even support a weapon programme, as in the case of India.[5] The terms of an INFCIRC/153-type agreement require much more comprehensive declarations on the part of a state.

In theory, the IAEA has the right to call 'special inspections' under either type of agreement.[6] In practice, the IAEA has forfeited this right by not exercising it for 50 years or so. Two minor exceptions (Romania in 1992 and North Korea in 1993) prove the point that the IAEA is reluctant to try to use special inspections.[7] Demanding such an inspection would have an impact on the rights of a sovereign state; the crisis that could result from such a confrontation could be major. The years of confrontation in Iran are a good example of a major crisis resulting from IAEA demands.

To circumvent the confrontational nature of a special inspection, the IAEA uses what is termed a 'transparency visit'. In many cases neither the IAEA nor the host state wishes to call attention to a particular set of questions from the IAEA. The transparency visit is informal and generally cooperative, but each side can claim that it is a voluntary activity. Diplomatic flare-ups are much less likely if the two sides can resolve an issue privately, even in cases where the IAEA can establish that a state was in violation of an agreement.

Many states have signed a voluntary additional protocol to their safeguard agreement with the IAEA, based on the Model Additional Protocol of 1997.[8] This gives the IAEA more powers to ask questions and inspect suspicious facilities.

On only one occasion has the IAEA participated in a series of UN-led inspections. This was in Iraq from 1991 to 2003. These inspections were a post-war demilitarization activity that went far beyond any IAEA safeguards activity. Denuclearization of nuclear weapons is not part of the IAEA's mandate: the IAEA

[4] IAEA, 'The agency's safeguards system', Information Circular INFCIRC/66/Rev.2, 16 Sep. 1968; and IAEA, 'The structure and content of agreements between the agency and states required in connection with the Treaty on the Non-Proliferation of Nuclear Weapons', Information Circular INFCIRC/153, June 1972.

[5] See e.g. Anthony, I. and Bauer, S., 'Controls on security-related international transfers', *SIPRI Yearbook 2009: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2009), pp. 467–71.

[6] IAEA, *IAEA Safeguards Glossary*, 2001 edn, International Nuclear Verification Series no. 3 (IAEA: Vienna, 2002), para. 11.13.

[7] Carlson, J., 'Special inspections revisited', Paper presented to annual meeting of the Institute of Nuclear Materials Management, Phoenix, AZ, 10–14 July 2005.

[8] IAEA, 'Model protocol additional to the agreement(s) between state(s) and the International Atomic Energy Agency for the application of safeguards', INFCIRC/540, Sep. 1997.

had only a small fraction of the expertise to deal with issues like nuclear weapon design and testing. In Iraq, it was heavily reliant on outside consultants from member states to find and neutralize weapons and enrichment programmes about which it lacked technical expertise. The authority to inspect these activities came directly from a UN Security Council resolution and the results were reported to the Security Council, not the IAEA.[9] Even the resolution of routine nuclear materials safeguards in post-war Iraq were temporarily resolved under this Security Council mandate.

[9] UN Security Council Resolution 687, 8 Apr. 1991.

2. Voluntary transparency visits in South Africa

South Africa was not a signatory to the Non-Proliferation Treaty at the time of its nuclear weapon programme from 1970 to 1991. It was thus not obligated to refrain from a weapon programme. Prior to 1991 South Africa had only limited safeguards obligations and was not obliged to declare all nuclear material on its territory. Instead, it had an old facility-specific INFCIRC/66-type agreement, under which three facilities were regularly inspected: the Safari-1 research reactor, operated by the Atomic Energy Corporation (AEC) at Pelindaba, 33 kilometres west of Pretoria; the AEC's hot cell complex, also at Pelindaba; and Koeberg nuclear power reactor units 1 and 2, operated by the Electricity Supply Commission 30 km north of Cape Town.[10] None of these facilities was ever found to have any nuclear weapon activity at any time.

The International Atomic Energy Agency had concluded three agreements with South Africa, in 1965, 1967 and 1977, which detailed obligations made by South Africa with the United States and France that were to be monitored by the IAEA.[11]

In 1991 South Africa signed the NPT and an INFCIRC/153-type agreement with the IAEA, thereby agreeing to inspections of all of its fissile materials and nuclear facilities.[12] Its initial report under this agreement was notable because a large, previously undeclared inventory of HEU was declared and put under safeguards.[13] International observers correctly concluded that this material had come from a nuclear weapon programme, but South Africa was not obligated to declare the source or purpose of the material. In 1991 additional facilities involved in enrichment of uranium were declared and put under safeguards. In 1993 South Africa made an announcement that it had dismantled nuclear weapons and that the programme had ended.[14]

South Africa invited the IAEA to visit its former nuclear weapon programme. It was under no obligation to do so under the NPT and its new safeguards agreement but chose to do so as a major transparency gesture. The IAEA visits were a

[10] von Baeckmann, A., Dillon, G. and Perricos, D., 'Nuclear verification in South Africa', *IAEA Bulletin*, vol. 37, no 1 (Mar. 1995).

[11] IAEA, 'The text of the safeguards transfer agreement relating to the bilateral agreement between South Africa and the United States of America', INFCIRC/70, 14 Dec. 1965; IAEA, 'The text of the safeguards transfer agreement relating to the bilateral agreement between South Africa and the United States of America', INFCIRC/98, 22 Sep. 1967; and IAEA, 'The text of the agreement of 5 January 1977 between the agency, France and South Africa for the application of safeguards in respect of the Koeberg Nuclear Power Station', INFCIRC/244, 23 Feb. 1977.

[12] IAEA, 'Agreement of 16 September 1991 between the Government of the Republic of South Africa and the International Atomic Energy Agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons', INFCIRC/394, Oct. 1991.

[13] The initial report is a state's official statement listing all nuclear material available in that state and subject to safeguards. It is required by an INFCIRC/153-type safeguards agreement. From the initial report, the IAEA establishes and later maintains, a unified inventory of all nuclear material for the state. IAEA (note 6), p. 26.

[14] For details see Kelley, R. E., *A Technical Retrospective of the Former South African Nuclear Weapon Programme* (SIPRI: Stockholm, Oct. 2020).

cooperative bilateral activity. There were a few agreed restrictions, but in general transparency and complete cooperation was the norm.[15]

Mandate

Resolution of the defunct South African enrichment programme was obviously a matter for the IAEA: it would be dealing with legacy issues from the tonnes of material involved in the enrichment programme. The IAEA was an international organization with a good reputation in nuclear materials management that could comment on South Africa's past activities and be credible.

The IAEA's mandate in South Africa was a simple voluntary agreement. South Africa was not in technical violation of any international agreement. In particular, it was not in violation of any agreement with the IAEA. Nevertheless, the production of nuclear weapons using nuclear materials produced in (legally) undeclared facilities was unprecedented for the time. The solution was for South Africa to volunteer to accept an intrusive inspection regime with access to areas it did not legally have to grant.[16] This was the type of arrangement that became known informally in later years as a 'transparency visit'.

South Africa made a written declaration of its nuclear material-production and weaponization activities. All of the declarations about weapon activity proved to be true as far as could be determined. South Africa agreed to allow the weapon inspection team to visit other industrial and scientific organizations as deemed necessary by the IAEA. All requests were granted. No help from undeclared activities outside the weapon programme was found to be significant.

Selection of inspectors

The IAEA was unhappy about the loss of control over the Action Team in Iraq (see chapter 3), therefore the transparency visits to resolve weapon issues in South Africa were staffed entirely by IAEA employees with only one exception.[17] Many of the IAEA staff involved in South Africa in 1993 were also inspectors in Iraq, where inspections had begun in 1991.

Prior to the transparency visits, a US expert briefed the IAEA team members on facilities and activities known to the USA. The briefing was somewhat more detailed than could be found in open-source materials. South Africa had a strained relationship with the USA, which had been involved in apartheid-related sanctions and an arms embargo in South Africa. The USA had also reneged on fuel-supply arrangements for the Safari-1 reactor.[18]

Remarkably, South Africa separately offered its missile programme for inspection at the same time as the nuclear programme. The visits were carried out by US personnel who physically destroyed many South African missile

[15] For a full account of the visits see Kelley (note 14).
[16] Kelley (note 14).
[17] Kelley (note 14).
[18] South African Nuclear Energy Corporation (Necsa), 'SAFARI-1: History, 1977', [n.d.].

Box 2.1. The Trilateral Initiative

The Trilateral Initiative was a programme under consideration from 1996 to 2002. Its goal was to define an inspection system where two nuclear weapon states—the Russia Federation and the Unites States—would make nuclear material-reduction agreements and the progress would be verified by the International Atomic Energy Agency (IAEA).[a] After six years the programme was declared to be a success but it was never implemented.[b]

The relevance of the Trilateral Initiative is in inspector choice and in security of nuclear weapon design information. Employees of the IAEA have no formal vetting or security clearance. A sticking point throughout the trilateral planning was access by inspectors from up to 180 countries to nuclear weapon design information of the Soviet Union and the USA. Without security clearance, these inspectors certainly had no need to know about nuclear weapon design details that could be revealed to them in many ways, especially when matching masses of special nuclear materials with particular weapon systems and dimensions.

Various 'information barriers' were invented and tested to allow decisions to be made by machines without exposing classified information to inspectors. Loopholes in these methods may have been acceptable to Russia and the USA under controlled conditions, but leakage of design information to inspectors from non-nuclear weapon states was judged to be too risky.

[a] Haas, E., Sukhanov, A. and Murphy, J., 'Trilateral Initiative: IAEA authentication and national certification of verification equipment for facilities with classified forms of fissile material', IAEA-SM-367/17/04, Symposium on International Safeguards: Verification and Nuclear Material Security, IAEA, 29 Oct.–2 Nov. 2001.

[b] Shea, T. E., 'The Trilateral Initiative: A model for the future?', *Arms Control Today*, vol. 38, no. 5 (June 2008).

capabilities. This need for this unverified bilateral activity was due to the fact that there is no international inspectorate like the IAEA in the missile field.

While South Africa admitted to building and destroying nuclear explosive devices, the IAEA does not normally have nuclear weapon expertise in its employee ranks. It is a violation of the IAEA Statute to disseminate weapon designs.[19] Fortunately, the IAEA had on its payroll one vetted weapon engineer from the United States (the present author) to carry out a complete investigation into South Africa's claim that it had built and destroyed nuclear weapons in secret. This was a matter of about 30 person-days in the field.

The issue of exposing IAEA inspectors to nuclear weapon information is not a new one. For example, the Trilateral Initiative of 1996–2002 attempted to deal with the issue of IAEA inspectors having access to nuclear weapons materials (see box 2.1). Over 100 non-nuclear weapon states are typically represented in the IAEA's inspector cadre. The issue was whether IAEA inspectors could participate in dismantlement of nuclear weapons without exposing them to nuclear secrets. The programme was declared as a success in 2002 and then dissolved without any further action.

Hundreds of person-days were also spent on reconciling and reviewing uranium enrichment and disposition numbers. Characterization of some HEU waste took until 2012. The logistical effort in South Africa was tiny compared to the quasi-military operation in Iraq. For example, inspectors used commercial rental cars and stayed in ordinary hotels that they chose themselves.

[19] Statute of the International Atomic Energy Agency, approved 23 Oct. 1956, entered into force 29 July 1957, as amended up to 28 Dec. 1989, articles II, III.A.5, III.B.1.

Languages, documents and technical tools

Language was a small barrier in South Africa. Almost all of the South African counterparts spoke excellent English, the working language of the IAEA. There were occasional problems with jargon, but they were not serious.

There was one problem with documentation: many of the political-level documents and government edicts were in Afrikaans. Few people were available who were capable of translating such documentation; none on the IAEA teams. One IAEA inspector from Norway translated the gist of a number of documents, stating that the Afrikaans was similar enough to Norwegian to understand. No sensitive documents were removed from South Africa for translation.

A larger problem was the failure of the IAEA to summarize the many days of field inspection and to maintain documents.[20] This makes it difficult to reconstruct how the inspectors worked, where they went and what they observed in detail. Summary reports were written for policymakers and to bolster South Africa's goal: to conclude that the programme was terminated completely and responsibly. This served the political goal but gave no basis to carrying out such a task again. Reacting to the experience in Iraq (see chapter 3), the IAEA determined that South Africa would be handled internally. Inspection reports and photos were restricted to a limited internal distribution in Vienna and were not shared with member states. No repository of information exists outside Vienna. This would have been a bulwark to retain knowledge until the IAEA inexplicably lost the files on day-to-day operations in South Africa, sometime in the late 1990s. When some of the missing files were located in 2008, they were shredded.[21] All of the inspectors who went to South Africa have retired and many are deceased. Their experiences have been almost irretrievably lost. The IAEA is not in a position to say that knowledge of its actions and experience in 1993 South Africa has been adequately preserved.

Environmental sampling is the process of collecting extremely small samples from buildings, equipment and natural areas. The samples can be microscopic in size, collected by careful wiping techniques.[22] A few particles found in sophisticated analysis equipment can be studied to provide evidence of undeclared activities involving nuclear materials. Environmental sampling played almost no role in South Africa. On one occasion HEU was unexpectedly found on a firing site. It was traced to cross contamination in a workshop where both natural and HEU were handled.

Commercial satellite imagery was not available at the time, but it was not needed.

[20] Kelley (note 14).

[21] Kelley (note 14).

[22] Fedchenko, V. and Kelley, R., 'Applications of nuclear forensic analysis', ed. V. Fedchenko, SIPRI, *The New Nuclear Forensics: Analysis of Nuclear Materials for Security Purpose* (Oxford University Press: Oxford, 2015), pp. 231–32.

Cooperative attitude

South African authorities were highly cooperative in granting access to its citizens, facilities and records. The South African government made a standing invitation to the IAEA to receive full access 'to any location or facility associated with the former nuclear weapons programme and to grant access, on a case by case basis, to other locations or facilities that the IAEA may specifically wish to visit'.[23]

Two exceptions were agreed in advance. First, the IAEA could not investigate foreign sources of supply of materials and information used in the programme. This included equipment, documentation, computer codes, materials and foreign expertise in South Africa. The reason was that South Africa had been under sanctions during the weapon programme and many of the activities that could be disclosed could lead to prosecutions under international law of people and companies still in South Africa.

The second limitation was that the IAEA could not have access to, or ask questions about, the military delivery systems that were used or might be used. This could have led to disclosure of conventional military capabilities. It is important to remember that South Africa had just reached a ceasefire in a costly war in Angola and was sensitive to a renewed threat. As noted above, destruction of missiles was undertaken under a bilateral agreement with the USA.

These restrictions were considered to be reasonable at the time. They did not impede resolution.

Post-denuclearization activities

The scope of the dismantlement of weapons and disposition of nuclear materials for civil use was clear within six months in South Africa. An understanding of South African material inventory and enrichment facilities was reasonably complete in the same time frame. Officially, verification of the correctness of South Africa's initial report to the IAEA was completed by 1995.[24] Characterization of difficult problems (e.g. the contents of mixed waste drums and highly contaminated filters from the enrichment plants) went on for years, but this was an accounting problem, not a concern that the weapon programme would re-emerge.

The IAEA continued to monitor certain dual-use equipment such as machine tools and presses. This equipment was dispersed to other industries over time and was clearly not being used to create a new weapon programme. The weapons that South Africa dismantled were extremely elementary: it would be unlikely to re-create the first primitive bombs. Special oversight of old weapon facilities and equipment was thus discontinued in 2004.[25] It was not necessary under South Africa's safeguards agreement and was using up resources much better used elsewhere.

[23] Harry, R. J. S., *IAEA Safeguards and Detection of Undeclared Nuclear Activities*, ECN-C-96-018 (Netherlands Energy Research Foundation (ECN): Petten, Mar. 1996), p. 15.

[24] von Baeckmann et al. (note 10).

[25] Kelley (note 14), p. 66.

Nevertheless, it took almost two decades for verification of South Africa to be completed. The IAEA drew its formal 'broader conclusion' that 'all of the nuclear material in the State had been placed under safeguards and remained in peaceful nuclear activities or was otherwise adequately accounted for' for South Africa for the first time only in 2010.[26]

South Africa was allowed to keep hundreds of kilograms of weapon-usable uranium metal that has been used peacefully in verified medical isotope production.[27] South Africa was deemed to have been fully cooperative and under complete safeguards with an additional protocol.[28]

[26] IAEA, 'Safeguards statement for 2010', 2011, p. 6; and IAEA (note 6), p. 100.

[27] James Martin Center for Nonproliferation Studies, 'Civilian HEU: South Africa', 1 July 2019.

[28] IAEA, 'Protocol additional to the agreement between the government of the Republic of South Africa and the International Atomic Energy Agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons', INFCIRC/394/Add.1, 24 Oct. 2002.

3. Confrontational inspections in Iraq

Iraq invaded the neighbouring state of Kuwait in August 1990. A United Nations-mandated coalition of countries was swiftly assembled by the United States to drive Iraq out of Kuwait. A bombing campaign began in January 1991, and Iraq was quickly forced to withdraw from Kuwait and agree a ceasefire.[29]

For the USA the war had an important secondary purpose besides liberating Kuwait: to terminate all WMD programmes in Iraq, for nuclear, chemical and biological weapons as well as ballistic missiles.[30] For example, the USA had extensive intelligence information on a nuclear weapon programme in Iraq. Some of the information was from clandestine sources of the USA and its allies, but a large fraction was available in open-source publications and newspapers. The invasion of Kuwait was a perfect excuse for the USA to terminate the Iraqi nuclear programme that it was aware of, as well as to begin aggressive in-country inspections under the aegis of the UN to search for other programmes.

Under its INFCIRC/153 agreement, Iraq had agreed to declare all of its nuclear materials and facilities to the International Atomic Energy Agency for inspection.[31] It was clear from intelligence information that Iraq was seriously in breach of its obligations under this agreement, and post-war inspections confirmed this. For instance, some of the first facilities bombed by the USA in January 1991 were suspected by the USA to be nuclear installations. The Al Qaim fertilizer plant, bombed on the third night of the air campaign, turned out to be a major undeclared producer of yellowcake (refined uranium ore). The USA knew this, but the IAEA did not.

The post-war inspections were conducted under the terms of the ceasefire and a series of UN Security Council resolutions. The conditions of the inspections were severe: Iraq was forced to agree to unlimited inspections of any facility and access to any persons the inspectors chose.[32] Iraq had no control over the nationality of inspectors, the equipment they used or the length of the inspections. This is certainly one of the most comprehensive and intrusive inspection regimes ever forced on a defeated state. It led to major confrontations, deception and aggressive tactics on both sides. The inspectors had far more rights than anywhere else in the history of nuclear disarmament since 1945 Germany, and the process was initially neither friendly nor cooperative.

[29] For background see Müller, H., 'The nuclear non-proliferation regime beyond the Persian Gulf War and the dissolution of the Soviet Union', *SIPRI Yearbook 1992: World Armaments and Disarmament* (Oxford University Press: Oxford, 1992), pp. 93–95.

[30] Smith, R. J., 'U.N. told of Iraqi effort to hide nuclear project', *Washington Post*, 31 July 1991.

[31] IAEA, 'The text of the agreement between Iraq and the agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons', INFCIRC/172, 22 Feb. 1973.

[32] UN Security Council Resolution 687 (note 9).

Mandate

Having been defeated in a war that it precipitated, Iraq was forced to accept invasive terms of inspection that included inspections anywhere and anytime, and unrestricted access to people and documents. Even when unrestricted access is mandated by a high-level document, such as Security Council Resolution 687 in this case, in practice in almost every case some agreement on times and places is necessary and convenient to get the job done. A rare exception might be a completely unannounced document seizure or a raid on a trading house (see appendix A for an example).

The overall effort was governed by UN Security Council resolutions. Special powers were granted to a new UN commission, the UN Special Commission (UNSCOM).[33] The IAEA was designated as the arm of UNSCOM that was to investigate all aspects of Iraq's transgressions in the nuclear area. The IAEA managed much of the day-to-day inspection process, particularly with regard to traditional nuclear material accounting and verification. This was done through an Action Team outside the normal IAEA structure that reported only to the IAEA director general and the UN Security Council.[34]

Iraq's gross violations of its IAEA safeguards agreement meant that the IAEA had to perform two major tasks. The first was to account for nuclear materials that Iraq had declared before the war and had submitted to regular IAEA inspections. Three declared facilities needed to be re-inspected. In fact, all three had been bombed and were completely destroyed.

The second task was to look for nuclear material and related facilities that were not declared by Iraq. This was not a normal IAEA safeguards activity at the time. A large amount of undeclared nuclear material was discovered almost as soon as inspections began, along with many covert facilities handling or preparing to handle nuclear materials. In addition, UNSCOM's mandate, and by extension that of the Action Team, included discovering and neutralizing anything that contributed to a nuclear weapon programme even if it were outside the normal safeguards agreement.

Inspection activities began with a declaration from the Iraqi side regarding all nuclear activities in Iraq. The declaration was a few paragraphs long and only described previously known activities safeguarded by the IAEA before the Gulf War.[35] None of the illicit activities found within a few weeks of the beginning of inspections were described. The declaration was completely unsatisfactory. Inspections detected many nuclear facilities, supporting facilities and tonnes of undeclared nuclear materials, both imported and illicitly produced domestically. Facilities to produce nuclear weapons, such as high explosives, are not normally declared to the IAEA. They were highly relevant to the Action Team under the Gulf War resolutions. Information on them was never volunteered but was slowly

[33] Flodén, G. et al., 'Iraq: The UNSCOM experience', SIPRI Fact Sheet, Oct. 1998.

[34] Goldschmidt, P., 'The IAEA safeguards system moves into the 21st century', Supplement to *IAEA Bulletin*, vol. 41, no. 4 (Dec. 1999).

[35] Thorne, L., 'IAEA nuclear inspections in Iraq', *IAEA Bulletin*, vol. 34, no. 1 (Mar. 1992).

acknowledged by Iraq over a period of years as inspections unequivocally revealed them.

The Action Team was given the task by the Security Council of the 'removal or rendering harmless' of nuclear materials and equipment that could contribute to any illicit nuclear activities.[36] There was a presumption on the part of UNSCOM that the inspection process starting in early 1991 could be as short as 90 days. Iraq was also labouring under the (false) assumption that inspections would be over quickly and it could return to banned military programmes. By the end of 1991, the Action Team was actively destroying industrial equipment such as gas centrifuges and instrumentation. There was a fear in the Action Team and UNSCOM that the process of inspections might be terminated before rendering harmless could be completed. In retrospect many items were destroyed before they were completely examined. This meant that valuable intelligence was lost forever because objects were not characterized—for example, in the case of gas centrifuge carbon-fibre rotors, the evolution of Iraqi designs was lost in the haste to destroy. Major buildings were destroyed because of visibly unique nuclear purposes, but analysts never learned the details or success of Iraq experiments inside. The process lasted much longer than 90 days. Major nuclear-related buildings were blown up in April and May 1992 and different forms of inspection lasted up to the bombing of Iraq in March 2003.

UNSCOM was reorganized and renamed the UN Monitoring, Verification and Inspection Commission (UNMOVIC) in 1999, and the Action Team was renamed the Iraq Nuclear Verification Office (INVO) in December 2002.[37] The term 'Action' was deemed too much like the former UNSCOM 'cowboy' approach to inspections. The change brought the nuclear effort closer to being an arm of IAEA safeguards, but definitely still outside the IAEA safeguards system.

Selection of inspectors

The inspection process in Iraq was enormous compared to any other endeavour undertaken by international denuclearization teams. The IAEA was chosen to manage nuclear inspections but under a special arrangement. The IAEA's Action Team reported only to the IAEA director general and in parallel to the UN Security Council. The overall inspection of Iraq was managed from New York, but the Action Team had almost total autonomy in the field and in its choice of inspection modalities. Friction was common but not debilitating. For example, UNSCOM insisted on having a New York-based nuclear expert attached to every Action Team inspection.

The Action Team drew on two reserves for its inspectors.

For routine activities, it drew on personnel from the IAEA Department of Safeguards. They handled issues such as resolving the whereabouts of nuclear research reactor fuel that was in Iraq before the war, verifying that all nuclear

[36] UN Security Council Resolution 687 (note 9), section C.

[37] Cirincione, J. et al., *WMD in Iraq: Evidence and Implications* (Carnegie Endowment for International Peace: Washington, DC, Jan. 2004), chapter 2.

material known to be in Iraq before the war was accounted for. This, the 'IAEA arm' of the Action Team, quickly became responsible for discovering and quantifying tonnes of nuclear material that Iraq had acquired or produced illegally. Although breaching Iraq's safeguards agreement, it was given special status as a UN war-resolution issue for the duration of inspections, about 12 years.

The second group of inspectors came from the nuclear laboratories, the military and the intelligence communities of a few member states. The USA provided many of the inspectors for the first Action Team inspections in Iraq. Virtually all US inspectors came from the Field Intelligence Elements (FIE) of the US Department of Energy (DOE), and so had the status of member of the US intelligence community.[38] All were trained in intelligence analysis and nuclear weapon technology. They carried out their inspection activities aggressively and often independently of the IAEA group working on nuclear materials.

The Action Team had two deputy leaders throughout its tenure. One, Dimitri Perricos from Greece, was from the IAEA Department of Safeguards on loan to the Action Team and was not officially reporting to the Department of Safeguards. The other was always a US citizen: it is common in the UN system for a second-in-command to be a US citizen. In 1991, this was David Kay, an IAEA employee. From 1992 until 2004, the US deputy was always a seconded employee of a US DOE national laboratory and the intelligence community. They were the present author, from Los Alamos National Laboratory; Paul Stokes, from Sandia National Laboratories; and Jay Hyland, from Pacific Northwest National Laboratory. This fact is conveniently left out of histories written by outsiders that depend on few information sources.[39]

The USA worked hard to choose inspectors and to guide the inspection process. The USA initially offered the DOE's Nuclear Emergency Search Team (NEST) to do the inspections. This team had worldwide deployment capability to deal with nuclear terrorism and large amounts of equipment to deploy, up to and including helicopters and fixed-wing DOE aircraft with radiation and imaging sensors. Several hundred personnel who worked in other jobs involving nuclear weapons—most with high-level intelligence clearance as part of their jobs—were on call. NEST was not deployed for two reasons. The first was that it was too big and too enthusiastic. It would have overwhelmed the wider effort and cost a huge amount of money. The other important reason was that the USA had headed the war coalition. It was up to the UN to carry out the inspections and it had the mandate to do so from the ceasefire. A large team only from the USA would not be credible.

Secret US intelligence information was manipulated to disguise its source and was then used to guide Action Team management in the inspection process. The USA set up a 'Gateway' facility in Bahrain staffed by Western professional intelligence experts from several coalition countries.[40] Inspectors flew from

[38] 'United States intelligence activities', US Presidential Order 12 333, 4 Dec. 1981, as amended.

[39] E.g. Harrer, G., *Dismantling the Iraqi Nuclear Programme: The Inspections of the International Atomic Energy Agency, 1991–1998* (Routledge: London, 2014).

[40] Krasno, J. E. and Sutterlin, J. S., *The United Nations and Iraq: Defanging the Viper* (Praeger: Westport, CT, 2003), p. 82.

their home sites to Bahrain for several days of briefing prior to entering Iraq.[41] All inspectors, both IAEA safeguards staff and the external members, received enough information to know where they fitted into the process. Some US and British inspectors were given detailed information on what to look for and where.

The USA played a heavy-handed role in managing early Iraq inspections, to the annoyance of the Action Team. Routine safeguards on nuclear materials in Iraq were not reported to the IAEA's safeguards system but were the responsibility of the Action Team. All of the Action Team's findings, daily reports, photographs and so on were documented and sent to UNSCOM in New York and routinely distributed to the five permanent members of the Security Council (the P5). This guaranteed that a repository of inspection findings was safely preserved outside Vienna.

Investigation of the Iraqi gas centrifuge enrichment programme was a task of the teams investigating undeclared activity unrelated to nuclear materials accountability. The centrifuge programme had been closely monitored by Western intelligence for years. It was no secret and was frequently discussed in the European press. It was a prime target for discovery and destruction. One of the more important goals was discovery of the European companies and individuals that had contributed to the Iraqi programme. The IAEA had no centrifuge expertise on staff, and so virtually all the centrifuge inspectors were from outside the IAEA.[42] Undeclared centrifuge machines in Iraq were not on the IAEA radar before the 1990–91 Gulf War. The most important inspectors were from the United Kingdom and its two Urenco partners, Germany and the Netherlands, as well as several inspectors from the US DOE. They had been following Iraqi centrifuge procurements for several years. In the field they were not searching for general information; they were searching for the exact serial numbers of manufacturing machines and stocks of materials known to have been delivered to Iraq.

Inspectors were debriefed at the Gateway on their return to Bahrain from Iraq. A rough estimate of the effort involved in inspections is about 3000 person days in the field in the years 1991–95. This does not include a large logistical support element from UNSCOM that provided vehicles, radios, supplemental food, medics and housing arrangements. The UNSCOM support mission in Baghdad eventually numbered dozens of people who supported the Action Team and other UNSCOM teams dealing with ballistic missiles and chemical and biological weapons.

Some special skills are often needed. In many cases, inspectors found activities outside their scope of expertise. An example was the huge Badush Dam under construction near Mosul. Many plausible rumours suggested that this dam was a cover for nuclear construction nearby. Since dam construction was outside the skills of the Action Team, a consultant from the US Bureau of Reclamation joined an inspection and was able to analyse the construction site. He found nothing suspicious about the project. On another occasion, French military divers were added to an inspection team. They searched in the Tigris River for suspected water-

[41] Barton, R., *The Weapons Detective: The Inside Story of Australia's Top Weapons Inspector* (Black Inc.: Collingwood, Victoria, 2006).

[42] Harrer (note 40).

intake systems for cooling an alleged nuclear reactor hidden beneath a housing complex. Nothing was found, but it illustrates the kinds of skill that may become necessary.

Iraq was under Gulf War-related sanctions for 12 years until after the 2003 invasion. During this time Iraq paid UNSCOM and the Action Team for the inspections. This was done by allowing Iraq to sell oil and placing the proceeds in a UN-administered fund, the so-called 'Oil for Food' programme.

Languages, documents and technical tools

Iraq produced several versions of its Full Final and Complete Declaration (FFCD) as late as 2003. It ran to hundreds of pages and was eventually judged to be largely complete after intensive inspections and verification. The detailed versions of the FFCD were not made public by the Action Team. Several sections were considered to be proliferation sensitive, so the entire report was never released beyond the P5. A US Army team, the Foreign Military Studies Office (FMSO), based at Fort Leavenworth, Kansas, was tasked with analysing and releasing documents captured after the 2003 invasion of Iraq. These included tens of thousands of pages, known as the Operation Iraqi Freedom Documents. In 2003 the FMSO released unredacted portions of the FFCD draft of 3 February 1996.[43] The breach was noted by the INVO, and the USA was requested to remove the document from its website because it contained nuclear proliferation-sensitive information on bomb design.[44] It is not clear how many parties viewed or copied the document.

In September 1991 the Action Team acquired thousands of pages of Iraqi nuclear documents in a highly confrontational pair of raids on office buildings known from US intelligence. Nominally conducted by the Action Team, these raids were led by US inspectors and consisted of about 90 per cent US inspectors. Many of the team members were Arabic linguists, including the few IAEA safeguards team members. Knowledge of Arabic was extremely important in choosing which documents to seize and remove from the country. Examining intelligence and choosing buildings to search for documents is not a normal IAEA skill.

The inspections took place before dawn and were highly confrontational and dangerous. Inspectors had to work quickly to sort out which of thousands of pages were worth seizing. Iraq refused to let inspectors keep the documents they seized at the first site. The next day the team raided another building, seized more documents and refused to surrender them. This led to a stand-off for several days until the Iraqis allowed the team to leave with the documents it had found. This is known as the 'parking lot incident'.[45]

Two key progress reports of the weapon programme were found and quickly secreted out of the country. They were in Arabic but were identified by a searcher. They explicitly described the nuclear weapon programme and much supporting

[43] Draft FFCD, Version 3 D1, 3 Feb. 1996.

[44] Broad, B., 'US web archive is said to reveal a nuclear primer', *New York Times*, 3 Nov. 2006.

[45] Meisler, S., 'U.N. concedes inspectors relayed Iraqi nuclear data to Washington', *Los Angeles Times*, 1 Oct. 1991.

information. They were carefully translated in Vienna and were key to the rest of the inspections for years. Fortunately, much other key evidence was in English or a few other Western languages; this was particularly true for evidence related to trafficking with foreign suppliers—the international purchasing network operated in English. Several tens of thousands of pages of telexes, company brochures, tenders and purchase orders were highly productive for finding trafficking routes. Action Team discoveries of trafficking routes were vital for improvement of export controls after the Gulf War.[46]

Another large batch of documents, largely in Arabic, became available in 1995 when Saddam Hussein's son-in-law defected to Jordan. Hussein Kamel was the military leader of the former nuclear weapon programme and had a reputation for being a powerful and unforgiving leader.[47] Upon his defection, Iraq's National Monitoring Directorate (NMD) decided that releasing many previously withheld documents was now acceptable. These were turned over voluntarily to the Action Team for exploitation. The NMD was a bureaucracy created in 1994 solely to deal with UNSCOM as inspections became more and more routine and structured.

For example, electronic documents found in document seizures were on media as ancient as 8-inch Wang word processor floppy disks. The Action Team had no easy access to the content of these disks because no reader was readily available. The NMD was contracted to download the electronic files and translate them for the IAEA. They proved to be uninteresting administrative material.

Another huge cache of Iraqi data became available in early 2003 as the result of targeted inspections of Iraqi trading companies (see appendix A). Interestingly, UNMOVIC missile, biological and chemical entities declined to take part in this trading house exploitation. The documents clarified phony Western intelligence claims that Iraq had a nuclear weapon programme in 2003, but they were not adequate to prevent the march towards the invasion of Iraq.

There was a bright spot in the handling of documentation. The Action Team collected thousands of pages of information in total. There were about 15 000 photographs of inspections, 50 000 telexes, Arabic-language documents and correspondence. The last leader of the Action Team made a concerted effort to digitize and document as much as possible. A number of databases were created to group information together with links between them. The system was not perfect, but it represented the best that could be done in the early 2000s on a limited budget. The computer files and thousands of paper documents were carefully preserved and are accessible today.[48] Notably, the files largely consist of raw historical data and few assessments. The assessment is left to researchers, a positive outcome for what has become a historical subject.

High-resolution commercial satellite imagery was not available at the time of the Iraq Action Team inspections in the early 1990s. Some low-resolution Landsat images were purchased for orientation. Occasionally, the USA would show high-

[46] Albright, D. and Hinderstein, C., 'Creation of Leybold's internal compliance system', Institute for Science and International Security, 30 Mar. 2002.

[47] Williams, D., 'Iraqi defectors killed on return to Baghdad', *Washington Post*, 24 Feb. 1996.

[48] Harrer (note 40).

resolution classified imagery to inspectors, but not to retain. The USA made line drawings and maps from classified satellite imagery and gave them to UNSCOM and the Action Team. The site-numbering system on the US drawings was an arbitrary US choice. Inspectors were prohibited from showing the line drawings to the Iraqis, but that rule was violated immediately, including in the first Action Team report to the Security Council.[49] The INVO developed some cutting-edge techniques using satellite images from bands other than visual (see appendix B).

The Iraqis wisely adopted the US numbering system. In their responses to questions they would refer to 'building X' based on the inspectors' US-supplied maps. This was a huge advantage to Iraq. When documents based on the true Iraqi numbering system became available, the Iraqis refused to provide a cross-reference between the numbering systems. A great deal of effort was spent trying to reconcile the two systems, often unsuccessfully.

UNSCOM made an agreement with the USA to fly a U-2 observation aircraft over Iraqi targets. In what was known as Operation Olive Branch, the aeroplane was painted in UN markings and took high-resolution photographs of sites.[50] UNSCOM in New York retained the sole right to task the aircraft flights and the Action Team had to route requests through New York. The U-2 photographs were provided to the Action Team on the condition that they not be duplicated, were limited to 'need-to-know' team members and were retained in an Action Team safe. They were labelled 'Secret: Releasable UNSCOM/IAEA'—technically US documents but ceded to the IAEA. The USA made no distinction between full-time IAEA employees working on material safeguards and external experts from national nuclear programmes working on weapon and intelligence issues.

Action Team inspectors used UN vehicles for transport. Initially, no driving licence was required, but eventually a formal system was introduced by UNSCOM. Inspectors drove themselves to sites and did not have to declare where they were going in advance. This provided a small element of surprise. Sometimes they chose circuitous routes to mask the final destination. They were trailed by Iraqi government vehicles, so their direction was always under observation and reported via radio.

Transport in and out of the country was in military aircraft arranged by UNSCOM. A few early inspections entered Iraq on leased commercial aircraft. The use of German military helicopters for internal transport was a major issue between UNSCOM and the Iraqi government. It took several years to reach a mutually agreed solution allowing German pilots in German helicopters with an Iraqi observation pilot. Flight plans had to be filed in advance, so there was no chance of a surprise inspection. Initially, Iraq would not allow aerial photography during helicopter flights. This prohibition was relaxed in time when it became clear that such photography was more useful than invasive.

[49] United Nations, Security Council, 'Consolidated report on the first two IAEA inspections under Security Council Resolution 687 (1991) of Iraqi nuclear capabilities', S/22788, 15 July 1991.

[50] Richard, M., 'Beyond Iraq: The new challenges to the nuclear non proliferation regime', IAEA -CN148/19, International Safeguards Symposium on Addressing Verification Challenges, IAEA, 16–20 Oct. 2006.

Environmental sampling was used extensively in Iraq. Although it has been used since the early years of nuclear intelligence, the sampling and measurement techniques were rapidly growing more sensitive.[51] Several environmental samples provided false positive data. These results were used to incorrectly accuse Iraq of activities that were actually the result of cross-contamination of samples at the IAEA. A positive outcome of these false readings was the later development of a rigorous programme in the IAEA Department of Safeguards to guard against cross-contamination.[52]

Environmental sampling should not be confused with bulk sampling. Bulk samples taken from declared batches of nuclear materials are routinely used to confirm the chemical composition of materials and properties such as isotopic content. Bulk sampling of Iraqi nuclear materials was a powerful tool used to good effect. The IAEA implemented an extensive waterway-sampling programme developed by the US Savannah River National Laboratory.[53] This programme produced useful negative results demonstrating that Iraq was not running a clandestine plutonium-production programme. Environmental sampling provided little additional value in inspection activities.

Cooperative attitude

In short, Iraq was highly uncooperative, largely from 1991 to 1995. It complied with basic matters like allowing UN aeroplanes to land in Iraq under agreed air traffic rules; it agreed to recommend hotels; it gave inspectors limited immunity; but it refused at every step to give complete and truthful answers to most technical questions.

Iraq inadvertently declared the identity of one centrifuge facility (al Furat) previously unknown to Western intelligence. Every other interaction was provocative and confrontational. The IAEA raids on document repositories did nothing to allay these issues.

Hussein Kamel, the president's son-in-law who defected in 1995, was in a powerful position, including personally managing the centrifuge programme. He had taken over a lagging weaponization effort largely ignored by the Iraqi Atomic Energy Commission (IAEC) that was obsessed with the electromagnetic isotope separation (EMIS) programme. Kamel had probably truly been responsible for much of the obstruction of inspectors. There was a brief thawing of relationships when Kamel was blamed for everything that had gone wrong. This was an improvement in the relationship, although there were still many friction points.[54]

Kamel was interviewed by UNSCOM and a representative of the Action Team upon his defection to Jordan in 1995. In the interview UNSCOM brought a contract interpreter to the meeting. As soon as Kamel saw the interpreter he told

[51] Lowenhaupt, H. S., 'Mission to Birch Woods via Seven Tents and New Siberia', *CIA Studies in Intelligence*, vol. 12, no. 4 (fall 1986).

[52] Fedchenko and Kelley (note 22), p. 234.

[53] Fedchenko and Kelley (note 22), pp. 236–39.

[54] Williams (note 48).

UNSCOM to get him out of the room because 'He works for me!' The implication was that the translator may have been working for both sides and was not to be trusted. Unfortunately, the UN system has few ways of vetting new employees or maintaining a security knowledge of them.

This was a period of several years from 1995 to 1998 when Iraq and the Action Team became allies. The Iraqi government established the NMD in 1994 to interact with UNSCOM and the Action Team, and they settled into a comfortable relationship. Each side owed its existence to the other. Minor moves forward allowed each side to show progress while guaranteeing a long relationship and jobs for both organizations. The NMD also suited the USA. It gave the Action Team—over which the USA exerted a high degree of control—a pre-approved channel for communications and cooperation with Iraq without going through the Iraqi Ministry of Foreign Affairs or the bureaucratic IAEA system.

This cooperation ended in 1998 when a series of ineffective US bombings convinced Iraq that it was better off throwing the inspectors of UNSCOM and the Action Team out of the country. The Action Team monitored Iraq from outside the country by remote means until 2002, from 1999 as part of UNMOVIC, the successor organization to UNSCOM. This was mostly accomplished with open-source information from media and commercial satellite imagery. Member states provided almost no information during this period. Interest had shifted away from Iraq on the presumption that a decade of inspections had completely eliminated the nuclear programme. This pro forma monitoring resolved few issues.

Unfortunately for Iraq, the US administration of President George W. Bush implicated Iraq in al-Qaeda's attacks on the United States of 11 September 2001. Inspections resumed briefly in 2002 and ended in March 2003 with the invasion of Iraq. This was justified on the basis of a resumption of the Iraqi nuclear programme. No evidence of a renewed nuclear programme was found. On the contrary, it was clear that nothing of significance had been renewed or started during the three-year absence of the Action Team. Much information that was provided to the UN by some of its member states in 2002 was largely based on 10-year-old suspicions long since dealt with in 1991 and later. The conclusion of the Action Team was that no one had been assigned to work on Iraq in the US Central Intelligence Agency (CIA) after 1998; that the experienced hands had departed; that old information was being recycled by an inexperienced US team; and that no one cared what the Action Team was doing as long as it justified sanctions.

Post-denuclearization activities

Aggressive and confrontational activities lasted from 1991 until around 1995. By the end of 1992 most nuclear facilities had been destroyed and highly enriched materials accounted for, destroyed or removed.[55]

[55] Ekéus, R., 'The Iraq Action Team: A model for monitoring and verification of WMD non-proliferation', 26 Sep. 2012.

The defection of Hussein Kamel was followed by more transparency on the part of Iraq. Nonetheless, Iraq frequently refused to answer questions: it often noted that, since the Action Team had already destroyed something, it should have known what it was destroying.

In 1994 the Action Team shifted to a permanent presence in Iraq known as ongoing monitoring and verification (OMV).[56] The Action Team carried out about 1500 visits and interviews during this period until 1998. This was under the authority of the Security Council, not the IAEA's normally mandated safeguards obligations. Since the Security Council gave the Action Team powers to examine all capabilities that had been used to develop weapons in the past and might be diverted in the future, the Action Team conducted most of its post-1994 inspections in non-nuclear facilities such as machine tool factories and chemical plants. For example, the Action Team maintained a database of machine tools all over Iraq. The machine tools were visited frequently and their serial numbers recorded. They were then assessed to make sure that they were not part of a nuclear weapon programme. This was a logical outcome of the normal IAEA culture: make a list of declared materials and objects and then reverify the list on a regular basis.

Inspections ceased in 1998 and were restarted again for a few months in late 2002 and early 2003. The invasion of Iraq ended the IAEA's Security Council mandate. Iraq eventually returned to normal safeguards inspections by the IAEA of an essentially non-existent nuclear programme. One of the few surprises in the 2010s was when Mosul was recaptured from control by the Islamic State group in 2014. Some kilograms of previously undeclared uranium compounds were found.[57] This material was apparently unknown to the IAEA Department of Safeguards as of 2012, when the IAEA had given Iraq its broader conclusion that there were no undeclared nuclear materials in Iraq. Curiously, Iraq reported this find to the secretary-general of the UN and not to the director general of the IAEA.[58] The justification was that it was a report to the secretary-general under the 1980 Convention on the Physical Protection of Nuclear Materials (CPPNM), ignoring its safeguards obligations—a pointed snub of the IAEA.[59]

[56] Berlin Information-center for Transatlantic Security (BITS), 'IAEA's mandate in Iraq', 2 July 2002.

[57] Borger, J., 'The Mosul mystery: The missing uranium and where it came from', *The Guardian*, 13 July 2014.

[58] Kelley, B., 'The strange case of Iraq's missing uranium', *Jane's Defence Weekly*, 11 July 2014.

[59] Convention on the Physical Protection of Nuclear Material (CPPNM), opened for signature 3 Mar. 1980, entered into force 8 Feb. 1987, IAEA, INFCIRC/274/Rev.1. Iraq acceded to the CPPNM on 7 July 2014, with entry into force due 30 days later. The letter to the UN secretary-general was dated 8 July. United Nations, Security Council, Letter dated 8 July 2014 from the permanent representative of Iraq to the United Nations addressed to the secretary-general, S/2014/481, 8 July 2014.

4. Small-scale inspections in Libya

In 2003 it was revealed that Libya had clandestinely acquired thousands of components of gas centrifuges and was embarking on an enrichment programme to make highly enriched uranium.[60] In October 2003 the United Kingdom and others intercepted large shipments of Pakistani-designed centrifuge parts destined for Libya. While the seizure did not include weapons or weapon parts, in December 2003 Libya revealed that it had a complete set of drawings for building a nuclear device. These supposedly unsolicited drawings were a 'gift' from Pakistan to be used later should Libya embark on a weapon programme.

Libya had an INFCIRC/153-type agreement with the International Atomic Energy Agency and was clearly in breach of the agreement because of undeclared activities with nuclear materials.[61] The import of centrifuge machines for planned future breaches was a concern to the international community. The disclosure of a complete set of weapon drawing schematics and instructions was not a breach of the IAEA agreement but was an enormous concern for nuclear non-proliferation. Libya was under huge pressure because of the disclosures and had to accept intrusive inspections. It chose to open the entire set of concerns to inspection, due in part to having been found in breach and also due to great concern about the ongoing conflict in Iraq. That war was precipitated by false claims that Iraq was once again building nuclear weapons, and Libya felt that it could well be next. Libya's acceptance of inspections was a stretch of its responsibilities but was a wise voluntary move to show cooperation, remove sanctions and return to the international oil market.

Mandate

The IAEA's self-imposed mandate in Libya was clearly to investigate Libya's breach of ordinary safeguards on nuclear materials. The international implications of the gas centrifuge programme and the presence of weapon documents led Libya to agree to IAEA transparency visits at many facilities such as those for missile manufacturing, development of high explosives, industrial-scale machine tools and even chemical weapon facilities. Libya made these voluntary offers to the IAEA in the hopes of quickly showing that its fledgling nuclear weapon effort was no longer a cause for concern.

The number one priority was to take possession of the alleged weapon drawings supplied from Pakistan.[62] The Libyans provided the documents and claimed that

[60] For background see Hart, J. and Kile, S. N., 'Libya's renunciation of nuclear, biological and chemical weapons and ballistic missiles', *SIPRI Yearbook 2005: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2005).

[61] IAEA, 'The text of the agreement of 8 July 1980 between the Libyan Arab Jamahiriya and the agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons', INFCIRC/282, Oct. 1980.

[62] IAEA, Board of Governors, 'Implementation of the NPT safeguards agreement of the Socialist People's Libyan Arab Jamahiriya', Report by the Director General, GOV/2004/59, 30 Aug. 2004.

they had never looked at them or made plans based upon them. This was considered good cooperation on the part of Libya because Western intelligence did not know of the existence of the drawings until Libya declared them. The IAEA inspectors only had one day to review the drawings before they were turned over to the USA and the UK (see below).

It is also important to note that the public conclusion of the experts needed to be carefully worded. They were bound by security to neither confirm nor deny that the drawings were accurate. They couched their conclusions as follows: the drawings represent an arrangement of metal and high explosive components consistent with an implosion nuclear weapon; and the IAEA is not in a position to model the correctness of these drawings and whether they represent a working nuclear device. They did conclude that it was unfortunate that drawings and manufacturing advice that may have been useful were passed from Pakistan to Libya under questionable circumstances.

The inspectors used this review to make a road map of what equipment and facilities Libya would need to make the components in the drawings.[63] That included things like machine tools and high explosives. An inspection plan was drawn up jointly with the Libyan National Board for Scientific Research (NBSR). The weapon programme was entirely within the NBSR. Selection of facilities for visits was done in cooperation with the NBSR, which eventually complied with every request. Facilities visited included universities, missile manufacturing, high explosives and propellant plants, and scientific institutes affiliated with the NBSR.

When the IAEA asked to visit missile facilities, there was a bit of surprise and then access was granted. Agreement was accomplished verbally between inspectors and the Libyan staff assigned to facilitate requests. Both sides realized that there was potential overlap between various Libyan WMD programmes, and transparency was the fastest way to resolution.

Libya's written declaration of weapon activities was short and claimed no actual weaponization activities. This was determined to be largely true.

Selection of inspectors

The weapon inspections in Libya were far more modest than those in Iraq. An estimated 30 person days were spent in the field, divided between two inspectors. Both inspectors were trained nuclear weapon engineers, one from France and one (the present author) from the United States. Both had incidental experience with missile programmes in their home countries. The French inspector was the leader of the INVO, the renamed former Iraq Action Team. The US inspector had begun the Action Team weapon inspections in Iraq in 1991, was deputy leader of the Action Team and had done the weapon assessment in South Africa.

No IAEA member state provided any briefing on the Libyan programme to the inspectors; the inspectors were on their own. Libya gave access to about

[63] IAEA, 'IAEA inspectors in Libya making progress', Media Advisory 2004/1, 28 Jan. 2004.

20 facilities and was generally cooperative.[64] It did not escape the notice of the inspectors that nothing declared was more than about 100 km from Tripoli, but in the absence of any external sources of information that was all that could be done. Rumours of North Koreans at al-Kufrah in the far south-east of Libya did not rise to a high level of concern. Inspections of the Great Man-Made River project and missile manufacturing confirmed North Korean involvement but no connection to nuclear weapons was found.

Commercial airlines and hotels were used for logistics in Libya. All internal transport was in Libyan vehicles with Libyan government drivers. Rental vehicles were not readily available and driving conditions were chaotic. Surprise inspections are virtually impossible under these conditions. However, the IAEA and the NBSR chose inspection sites jointly, so surprise was not an issue.

Languages, documents and technical tools

There were few documents to examine in Libya. The Pakistani drawings and supporting material were virtually all in English. It was the common language for the illicit trade. One area where Libya was not forthcoming was government edicts and financial information. This was largely to shield Libyan government officials from proof of corruption. No political documents requested were ever provided. Environmental samples did not detect any unknown activity in Libya.

In early 2003 an IAEA inspector (the present author) was asked to examine satellite imagery of Tajoura Nuclear Research Centre near Tripoli on the basis that 'something was up' that might entail having to go to Libya. Although some weapon money was sent to Tajoura for infrastructure improvement, nothing to do with the centrifuge and weapon programmes was there—it was all at sites yet to be discovered.

Documentation of the Libya experience was similar to South Africa. The IAEA kept the weapon inspections internal and largely undocumented, probably irretrievable today.[65]

Cooperative attitude

Libyan authorities were initially cooperative with the nuclear inspectors from the IAEA. Libya's society was very hierarchical: important decisions were made at the top; mid-level bureaucrats could not make on-the-spot decisions for access to sites. Nevertheless, decisions were usually considered overnight and virtually always communicated within a day. Almost all requests were agreed except for access to documents. This seemed largely to be because documents could provide evidence of corruption that could be used to harm key people.

Because the inspectors had little background on Libya, they worked cooperatively with the NBSR. A key element of any nuclear weapon is high-

[64] IAEA, Board of Governors, 'Implementation of the NPT safeguards agreement of the Socialist People's Libyan Arab Jamahiriya', Report by the Director General, GOV/2004/33, 28 May 2004.

[65] Summary information is available in IAEA, GOV/2004/33 (note 65).

explosive or other energetic material. The inspectors had no information concerning such capabilities in Libya and asked the NBSR to provide access to any and all 'energetic materials' facilities. In the absence of collateral information, the inspectors accepted that Libya provided rather good access to the most relevant high-explosive manufacturing site as well as several solid-propellant production and testing grounds that could have value to a nuclear weapon programme just beginning to learn how to handle and test explosives. There was even a visit to an Iranian-built liquid propellant plant for Scud missiles, which was not very relevant to nuclear weapons but indicated cooperation on the part of the NBSR to be complete. No evidence has been found to indicate that the NBSR tried to hide any capability.

Meetings with missile programme personnel were useful for many reasons. One outcome was to observe that the senior managers of the missile and nuclear programmes knew each other reasonably well. Indeed, there was distinct acrimony between the two sides. The root of the problem appeared to be competition for funding: the missile personal saw funding of a nuclear programme as unnecessary. Some of the NBSR nuclear programme hosts actually left the inspectors' meetings with missile personnel, apparently unwelcome.

Libyan cooperation stopped quickly when the USA and the UK agreed that great progress had been made in resolving WMD issues.[66] Sanctions were lifted, oil sales resumed and Libya saw little reason to be transparent anymore. Its goals had been achieved.

Post-denuclearization activities

In terms of disarmament, there was nothing to remove from Libya's 'weapon programme' other than the drawings of an alleged explosive device. The IAEA was firmly opposed to taking physical possession of the drawings because it had no security procedures to protect them. Instead, it was agreed in advance that these drawings would go to the secure repositories of the UK and the USA, although they remain IAEA property.[67] Under US law, nuclear weapon design information is 'born classified' and must be handled in special security and classification channels. The US mission to the IAEA was not certified to handle nuclear weapon design information, so the materials had to be sent to the custody of the DOE in the USA.[68] The UK had a similar problem.

In terms of nuclear fuel cycle facilities and nuclear materials, there was little to monitor in Libya following the few months of denuclearization. The USA removed all elements of the gas centrifuge programme. This included specialized machine tools that Libya had bought to make more centrifuges on the advice of the Khan Network (the Pakistani nuclear proliferation network that had also supplied Iran

[66] Nephew, R., *Libya: Sanctions Removal Done Right?—A Review of the Libyan Sanctions Experience, 1980–2006* (Center on Global Energy Policy: New York, Mar. 2018).

[67] These instructions to give the documents to the USA were given to the 2 inspectors in the presence of John Bolton in the US ambassador's office in Vienna.

[68] News24, 'Libyan nuke drawings "Chinese"', 16 Feb. 2004.

and North Korea). A cylinder of uranium hexafluoride produced in North Korea containing uranium from Pakistan was also removed. Research reactor fuel was repatriated to its original source, Russia.

Some important dual-use capabilities in Libyan missile factories were identified, in particular certain vacuum induction furnaces and their power supplies. Vacuum induction furnaces are critical for melting weapon quantities of uranium. These furnaces were not being used to melt and cast uranium, but they could be diverted, re-engineered or partially dismantled to do two separate tasks and then reassembled. The furnaces were one of the few important dual-use capabilities for nuclear weapon development found in the Libyan industrial system. The missile facilities were briefly listed as facilities capable of being restarted in the Libyan nuclear programme and so were subject to inspection. They were almost immediately removed from the list of on-going normal safeguards inspections because they did not process nuclear materials. Knowledge of a key capability was unilaterally surrendered by the IAEA Department of Safeguards when it had an unimpeded opportunity to broaden its understanding of the whole WMD programme in a state. This could be characterized as a 'state-level approach' to understanding proliferation. A ballistic missile facility with specialized manufacturing capabilities that could be used to build nuclear weapons should be of high importance and not ignored. Facilities that are not defined as 'nuclear facilities' can contribute materially to a nuclear weapons programme.

5. Lessons learned

In all three of the cases, the International Atomic Energy Agency successfully resolved the issues at hand and returned the countries to ordinary IAEA safeguards. All three countries signed and brought into force an additional protocol to their INFCIRC/153 safeguards agreement.[69] As of 2018 the IAEA had drawn a 'broader conclusion' that there were no undeclared materials or facilities in Libya or South Africa and no diversions of materials from peaceful activities in Iraq.[70] Clearly, the IAEA's goals of resolving issues and returning states to normal verification activities were being met.

None of the three cases will be replicated exactly in the future. But each case offers lessons about the verification of nuclear disarmament that can, and should, be learned. In future instances of nuclear disarmament verification, aspects such as the design of the mandate, the selection of inspectors and the logistical set-up must be grounded on the experiences—both positive and negative—in South Africa, Iraq and Libya.

Mandate

The IAEA is not free to choose inspections or transparency visits on a whim. There needs to be a mandate from the United Nations Security Council, or an invitation from a member state to come and resolve a political question. The mandate usually involves serious accusations of the presence of undeclared nuclear materials or undeclared nuclear facilities defined in international agreements.

The important lesson learned from the IAEA experience in South Africa is that the transparency visit format has proven to be a useful tool, and will be for future verification. Transparency visits are used to resolve issues that may or may not involve suspected safeguards violations. While South Africa did not want its transparency visits to be private—its goal was to have the IAEA release a public assessment that all weapon activities had been transparently revealed and verifiably terminated—future transparency visits could be more private. They are an ideal mechanism for a state and the IAEA to meet privately to discuss concerns and possibly visit facilities. These facilities may not be actually involved in activities covered by safeguards. For example, a state could permit the IAEA to visit a military base or university where there is no declared nuclear facility when the state knows the concern can be resolved cooperatively.

When this is done in an apolitical way, resolution can be rapid. This avoids overreaction, especially when other states have an incentive to inflate issues to be

[69] IAEA, INFCIRC/394/Add.1 (note 28); IAEA, 'Protocol additional to the agreement between the Socialist People's Libyan Arab Jamahiriya and the International Atomic Energy Agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons', INFCIRC/282/Add.1, 16 Feb. 2007; and IAEA, 'Protocol additional to the agreement between the Republic of Iraq and the International Atomic Energy Agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons', INFCIRC/172/Add.2, 26 Feb. 2010.

[70] IAEA, 'Safeguards statement for 2018', June 2019.

larger than they are. For example, the present author was one of two inspectors sent to Syria on a low-key transparency visit in February 2004 to resolve a US accusation that the IAEA was assisting Syria in nuclear facility development. Syria provided an invitation in response to IAEA questions, and the situation was cooperatively investigated and resolved. The United States did not repeat the accusation.

The first lesson from Iraq is that there are practical limitations to a mandate of 'anywhere, anytime' inspections. Politicians can easily write blanket authorities. Inspectors need to use judgement, reserve and a holistic view of all the data before creating incidents. Significant discretion and common sense are required before inspectors begin breaking into mosques, temples or churches. One example teaching this lesson was presented to the Action Team in 1992: human sources reported that highly enriched uranium had been produced in Iraq and was buried in graveyards. The information was weak: it did not fit with a technical assessment that Iraq had never mastered the technology to indigenously produce HEU; and all HEU from external sources was verified as being secure. Digging up unspecified graveyards for doubtful purposes would have caused a huge uproar and understandable confrontations with an upset Iraqi public. But it fitted with the agenda of some parties to keep looking for mythical WMD long after reasonable scientific conclusions had been drawn.

Information such as the false information about graveyards surfaced on several occasions. It would be leaked to the press and then cited by opponents of UNSCOM inspections to try to discredit the teams' willingness to be aggressive and complete. It was also cited as evidence that not all claims—from any source, no matter how vague and insubstantial—had been pursued and vetted; sanctions on Iraq were therefore forced to continue. As late as 2003 the USA constantly pressured the Action Team to publicly state that there were 'unsettled issues' so that inspections needed to be continued indefinitely. The issues chosen were minor and unlikely to ever be resolved, making the indefinite extension of the inspection mandate possible.

Another example relates to the fact that, throughout the 1990s, there were persistent reports pressuring UNSCOM to find alleged factories producing WMD hidden under President Saddam Hussein's palaces. These reports were regularly leaked to make UNSCOM look weak and unwilling to follow-up on 'intelligence', no matter how ridiculous. Carefully arranged inspections by UNSCOM in 1998 revealed no such thing.[71] The post-2003 military occupiers found Saddam's palaces to be comfortable headquarters buildings. Despite thousands of troops being housed in the palaces, to date no WMD factory has been discovered there.

The second lesson from Iraq is that an organization created for a single specific job with clearly defined mandate and deadlines can be effective. There was a critical difference between UNSCOM's approach to its other WMD missions and the approach of the IAEA, its nuclear action arm. UNSCOM was created to do one

[71] United Nations, Security Council, 'Memorandum of Understanding between the United Nations and the Republic of Iraq', 23 Feb. 1998, S/1998/166, 27 Feb. 1998.

job. It delegated that job to many well-qualified people who were recruited for their appropriate skills and geographical balance. UNSCOM had no precedents to guide (or restrict) its inspections. Its leaders and management knew that they had a single assignment with a logical end point. It was a learning-while-marching experience.

In contrast, the IAEA had several decades of experience in some portions of its task. That experience limited curiosity and innovation. Portions of the IAEA's activity were hampered by tradition and guidelines that were effective for part of the task and unprepared for others. The IAEA also had to deal with the fact that it would have to work with the Iraqis after the Security Council mandate was fulfilled: its NPT safeguards mission was valid for the foreseeable future after the UNSCOM mission was completed. A future requirement for cooperation often tempered aggressiveness, unlike UNSCOM.

Finally, Iraq showed the need for inspectors with courage. International inspectors do not carry arms for self-defence. They cannot demand entry to facilities that are guarded by armed guards. Iraqi guards fired shots in the air on at least one occasion, but some courageous inspectors prevailed in their work.

An important lesson from Libya was how the IAEA's focus on nuclear materials can miss crucial evidence of nuclear proliferation activities. The mandate in Libya was driven by information supplied by the United Kingdom and the United States regarding shipments of large quantities of parts to assemble gas centrifuges, designed in Pakistan and largely manufactured in Malaysia. There were also machine tools and bespoke electronics supplied by certain Western countries for the sole purpose of equipping a gas centrifuge plant. Some small nuclear materials accountancy issues were also suspected. A key discovery was the finding that a high-technology company in Malaysia, Scomi Precision Engineering, was manufacturing metal components for gas centrifuges.[72] This was completely missed by the IAEA safeguards system because no nuclear materials were involved—the IAEA's safeguards interests in Malaysia did not cover manufacturing information. Malaysia had no known 'nuclear programme' and was not of any safeguards interest. Malaysian customs authorities had no training or experience with nuclear components, and could not recognize nuclear components made of ordinary materials such as aluminium or steel. Parts were exported as ordinary machine parts on false export documents. The safeguards and export systems were not designed to detect these activities and they did not. This reinforces the fact that the IAEA's limited nuclear material accounting system was never designed to be a broad mandate to catch all aspects of nuclear proliferation.

The case of Libya also shows that it is extremely useful to consider nuclear weapon proliferation in the context of missiles designed to carry them and the overlap with other WMD activities such as chemical weapons. Specialized manufacturing and research activities essential to nuclear weapon development may be found in other factories and laboratories. The fact that these capabilities are not in legally defined 'nuclear facilities' should not exempt them from investigation

[72] Hardy, A., 'Scomi sullied by Libyan nuclear scandal', *Energy News Bulletin*, 11 Feb. 2004.

and monitoring. The definition of 'nuclear facility' is appropriate for safeguards under the NPT. It is inadequate for assessing a nuclear programme that includes, for example, high-explosive testing activity.

Selection of inspectors

The selection of inspectors is critical to inspection success. They need to be well trained in a variety of physical professions and to complement others in the inspection team to ensure broad recognition of observations. The sensitivity of some nuclear technology requires that they are judged by the inspectorate and member states to have security vetting of some agreed sort.

A lesson learned in South Africa is that future disarmament verification may require a standby cadre of inspectors cleared for access to nuclear weapon information. Obviously, for reasons of compliance with the NPT, such inspectors will have to be recruited from the P5—the five states that hold nuclear weapons legally under the treaty.

Experience from Iraq showed that a military-scale effort to denuclearize an uncooperative country can require hundreds of people and a large logistics chain. The Action Team on its own might have been able to resolve issues related to the verification of old nuclear materials known to be in Iraq. It is unlikely that it would have discovered the tonnes of material secretly accumulated by Iraq.[73] It is almost certain that the Action Team alone would not have discovered the uranium-enrichment facilities on its own.[74] Satellite imagery and US experts in EMIS were the key to even starting discovery.[75] Finally, knowledge of the weapon programme was completely absent at the IAEA headquarters in Vienna and needed to be completely supplied by foreign experts. Examples in Iraq and Libya show that IAEA safeguards on nuclear materials are not sufficient to detect clandestine nuclear proliferation. IAEA staff specializing in nuclear material auditing are not primed to detect nuclear weapon manufacturing and other specialized nuclear support activity.

It is also important that inspection teams include experts with knowledge peripheral to the main subject at hand. For example, in Iraq it was essential to have a dam expert when trying to evaluate rumours about a dam used as a construction site to hide a reactor, and military divers combed the opaque river floor looking for cooling systems.

A lesson from Libya, similar to the lessons from South Africa and Iraq, is that it is necessary to have trained and security vetted experts prepared and procedures predefined to deal with nuclear weapon information. The discovery of alleged nuclear weapon documents in a country known to have an interest in nuclear weapon proliferation was an unpleasant discovery. Security dictated that only

[73] United Nations, Security Council, 'Plan for the destruction, removal and rendering harmless of the items specified in paragraph 12 of Security Council resolution 687 (1991)', S/22615, 17 May 1991; and United Nations, S/22788 (note 50).

[74] Fedchenko and Kelley (note 22), pp. 231–32.

[75] Thorne (note 36).

personnel vetted by their home countries to handle nuclear weapon designs were allowed to access sensitive details.

Languages, documents and technical tools

Inspection teams will certainly involve many nationalities but possibly little overlap with the culture and languages being inspected. Care needs to be taken to ensure reliable communications between teams and the inspected party. Team members need to be familiar with inspection tools provided by organizations like the Action Team of the IAEA and tools brought from member states to enhance capabilities.

It is also worth noting that many familiar analysis tools in extensive use today were not available for inspections and visits in South Africa and Iraq. It is hard to remember that in the early 1990s the predecessors of tools such as Google and Google Earth were in their infancy and not widely used or available. Obviously, the world of open-source tools has burgeoned since the inspections discussed here and will be extensively used in the future. Teams were issued with portable GPS units for navigation that were the size of a waffle iron and, with big batteries, weighed several kilograms. When UNSCOM teams were known to be in the field, the USA's GPS satellite constellation was set to a higher precision.

The experience in South Africa, confirmed in Libya, showed that future disarmament-verification inspections will have to have a system—developed in advance—for documenting events and preserving knowledge. Similar to the field of crime scene management, where the job of one of the three persons working at a crime scene is to observe and document everything, future disarmament-verification inspections should include personnel and procedures dedicated specifically to preservation of information. Forensics institutions around the world consider it mandatory to preserve the information about the cases they worked on for decades afterwards. An organization conducting disarmament verification should also have a similar system. A robust system of documenting the verification activities, as well as of preserving that documentation, is required for future disarmament-verification schemes. If lessons are not documented and passed-on to the next inspectors, they may as well not even exist.

It is also important to analyse information and not just collect it. Hundreds of observations were made in the course of the inspections in South Africa but never summarized (e.g. as a training aid). Just a high-level summary report for politicians is not an adequate result of the investment of hundreds of hours of expert time. Iraq also showed that inspection does not end in the field. Analysis is vital to planning more inspections and for reaching final conclusions. The amount of effort consumed in analysis and translation can be much larger that the inspections themselves.

The US administration in 1991 placed great trust in UNSCOM and the Action Team and provided them with accurate and highly valuable information to guide inspections. In 1995 the present author had returned to Los Alamos National Laboratory and was a programme manager for some nuclear intelligence activities.

He tried to interest sponsoring agencies in Washington, DC, in documenting the former Iraqi nuclear programme. There was no interest in such a task on the basis that the Iraqi programme was deemed to be dead and analysts were moving on to new proliferation concerns. By 2002 the Bush administration was not a proponent of international cooperation. It provided little data to the Action Team and much of it was 10 years old and had been resolved a decade earlier. New US analysts on the Iraq problem started essentially from scratch in 2002 and often recycled old intelligence from the 1980s. Only one government other than the USA provided material intelligence support to the Action Team in 2002.

Iraq also showed that an aggressive denuclearization effort looking for carefully hidden capabilities will need a large logistical tail. In a case where missiles will be of equal interest, the UNSCOM arrangement of coordinating teams will be necessary. When it came to taking environmental samples in Iraq, the first inspectors to do so had no training—including the present author—and took many soil samples especially around hydrodynamic explosive testing sites. These samples were useless. Natural soil contains significant amounts of uranium, making it extremely difficult to find suspicious uranium particles in soil, even human-modified ones. Other enrichments of uranium may stand out and other radionuclides such as plutonium are relatively easy to detect. Samples should be taken in locations where the majority of the sample is not soil. The IAEA later developed an excellent sampling protocol after experiences with cross contamination. This professional collection process is a model for all environmental sampling in future disarmament-verification scenarios.

A final lesson, from Libya, illustrates the importance of looking for nuclear activities at places outside the state's atomic energy organization, such as at Tajoura. The well-known Pelindaba Centre in South Africa was not the key site of the weapon programme.[76] There have been examples in Libya, but also Taiwan and Egypt, where important activities were not at a known nuclear research centre. In Iraq there were essentially two separate programmes competing with each other and leaving conflicting clues.

Cooperative attitude

Cooperation from the inspected state is vital. The extent of cooperation varied in the cases discussed here. It can also be seen in the IAEA's two experiences with special inspections: in 1992 Romania declared its transgressions and invited the IAEA to investigate; in 1993 North Korea denied the IAEA request.

The cooperative nature of the arrangement between the IAEA and the South African government and the generally accommodating attitude towards inspections played an important role in concluding verification efforts, even under restrictions agreed by both parties.

Iraq began its interactions with the Action Team in a highly confrontational way. This evolved to cooperation from 1995 to 1998. In 2002 Iraq again allowed

[76] Kelley (note 14).

inspections and the NMD worked tirelessly to assist the Action Team in its mission. Iraq's position was clear: there was no nuclear weapon programme, there were no nuclear weapons, all that had been destroyed remained destroyed, and personnel associated with the old programme had dispersed. Indeed, the Iraqis were highly cooperative in 2002–2003 since their only hope to avoid a war was to cooperate fully with the INVO and UNMOVIC. The lesson here is that those who shout the loudest are often those who were not there but who have the access to media that a careful and confidential inspection process does not have.

UNSCOM and the Action Team were found to have been compromised by insiders who gave away sensitive information. This happened on more than one occasion, such as the Arabic interpreter incident. Some inspectors showed classified documents to the Iraqis in an effort to 'move things along more quickly'. Lack of vetting and security clearances is a weakness of the UN system.

The Libyan experience demonstrated that reluctance to cooperate with an inspection effort might not be caused by an intent to obstruct it. It might have a completely unrelated nature—such as attempts to conceal evidence of corruption. Libya also showed how domestic rivalry—in this case, between the missile and nuclear programmes—can helped to map out largely separate programmes. Inspection of WMD programmes overall led to knowledge of the scope of the Libyan effort.

Many media reports point to the end of Libya's nuclear weapon programme and the death of the Libyan leader Muammar Gaddafi as proof that cooperating with inspectors does not work. The finding in Libya—that Libya did not have a nuclear weapon programme, only a cache of documents and no system for exploiting them—again highlights the danger that those who were not present often have the loudest voice. The lack of a clear final public report on the entire Libyan affair also contributed to speculation.

Post-denuclearization activities

Inspections are not finished when teams finally leave the field. Lessons learned need to be documented and relations need to be returned to normal. The IAEA largely closed files, sometimes haphazardly but finally, and returned to normal safeguards with all three countries. UNMOVIC's job ended with the US-led invasion of Iraq, and it was dissolved after documenting its findings. Many principal members of UNSCOM have published lengthy memoires and have remained active in the media.

Even given the cooperative attitude and voluntary nature of the arrangements between the IAEA and South Africa, it took almost two decades to advance formal verification activities to the point when a broader conclusion could be made. It should be expected that verification of disarmament in countries with larger fuel cycles and longer histories of nuclear weapon development will take a significant time, possibly also measured in decades.

Attempting to quantify a decades-long programme using sources as diverse as handwritten logs and missing documents is also challenging. This lesson

is particularly pertinent for disarmament verification of the kind that could be expected in North Korea or, even more so, under the terms of the TPNW.

Iraq was anxious to cooperate with UNMOVIC and the Action Team in 2002. It was clear that the USA was determined to go to war. Iraq asserted aggressively that it had no nuclear weapon programme and worked to demonstrate that. There has been a mischaracterization in the media and academia since 2003 that Saddam Hussein was deliberatively ambiguous about WMD in the hopes that the uncertainty about his defensive capability might protect him from war. This mischaracterization is disingenuous in some cases and apparently designed to create doubts about the UNMOVIC inspections. The Iraqi government through the NMD made it abundantly clear that all nuclear activity had stopped after 1991 and offered all assistance to INVO to prove this. The Iraq Survey Group, a major US intelligence effort in Iraq after the 2003 invasion, confirmed virtually all of the Action Team's findings that there was no nuclear programme of any kind in Iraq in 2002–2003.[77]

A similar scenario may occur again in future inspections on behalf of parties trying to destroy confidence in denuclearization: the best method to maintain overt or even covert nuclear weapons is to undermine confidence in inspectors.

[77] Duelfer, C., *Comprehensive Report of the Special Advisor to the DCI on Iraq's WMD* (US Government Printing Office: Washington, DC, 30 Sep. 2004).

6. Conclusions: Six lessons of the past for future disarmament

The International Atomic Energy Agency has participated in countless resolutions of nuclear material issues, but it has rarely had to deal with weapon-related issues. It has participated in the denuclearization of three states that had advanced nuclear weapon ambitions. The three cases discussed here directly involved serious weapon issues and the lessons learned are certainly relevant and instructive for future disarmament.

Policymakers frequently refer to these experiences and ask how they can be models for future denuclearization. North Korea is the obvious immediate concern followed by elimination of weapons under the Treaty on the Prohibition of Nuclear Weapons. None of the previous inspections will be the exact model for a possible denuclearization in either of these two prospective cases.

The most important guide will be the legal mandate. In Iraq, UNSCOM and the Action Team had virtually free rein to go anywhere, anytime. This was because Iraq had been defeated in a war. In South Africa the government gave the IAEA broad powers but on a cooperative and quiet basis. Libya gave up its programme to remove sanctions and a perceived threat of war with the United States. It agreed to penalties for nuclear material-related violations. It allowed transparency visits to non-nuclear facilities and universities.

Six lessons from the experiences of nuclear disarmament verification in South Africa, Iraq and Libya stand out. Any future disarmament-verification effort should apply these to avoid repeating the mistakes of the past and to benefit from the experience accumulated. It is important that the IAEA improve its analysis and documentation of critical events. Otherwise each new event will be approached without the experience gained in earlier inspections.

Lesson 1. Do not destroy evidence before a thorough analysis is possible

Destroying evidence too early is a problem. South Africa destroyed its weapons before the IAEA arrived. That made resolution dependent on circumstantial secondary data. In Iraq the Action Team was correctly worried that it might have to leave the country before it could render known capabilities harmless. Once items were destroyed, the remnants were released from accountability and they disappeared. In retrospect, destroyed materials rendered harmless needed to be preserved as evidence and as intelligence sources. It was extremely embarrassing when Action Team inspectors in Iraq asked questions about a building they had blown up, and the Iraqi answer was ‘you must have known if you blew it up’.

The IAEA director general was correctly concerned about the existence of nuclear weapon drawings in Libya. His initial guidance was to verifiably destroy them in Libya. But he also realized that they were important legal evidence and agreed to turn them over to a nuclear weapon state that could make valuable

assessments. There was universal agreement that the documents should not be stored in an international organization with a primitive sense of security, such as the IAEA. An obvious question is whether the documents that were removed were the only copies. That is impossible to answer. The inspectors just have to do their best.

Lesson 2. Rights granted by mandates are hard to recover if they are given away

Inspectors should not give away rights. Once they are lost, they are hard to get back. A good example is the IAEA's reluctance to use the special inspection powers granted to it by safeguards agreements.

In Libya the IAEA weapon inspectors spent as much time as possible in the Libyan missile and high-explosives facilities. There were few locations for a separate nuclear weapon programme. The missile facilities contained dual-use equipment that could have supported a nuclear weapon programme. If the IAEA had a broader perspective, it would have seen nuclear weapons and their delivery systems as connected programmes. Indeed, the rivalry between missile and nuclear programmes helped to map out the largely separate programmes Yet the missile facilities were unilaterally dropped from the inspection programme because they did not handle nuclear materials: the IAEA's core mandate. IAEA managers are trained in the narrow mandate and are reluctant to use the full power of state-level analysis. The IAEA either has to have a broader mandate or the United Nations needs an integrated inspectorate system in addition to the IAEA.

Lesson 3. Inspectors with broad industrial experience are necessary

A variety of inspector skills is important. Sometimes experienced nuclear inspectors come across technologies they have never seen. The two IAEA inspectors in Libya inspected a biological weapon plant. They were able to say it was not a nuclear facility, but they were not capable of assessing its true purpose. In a prominent case, in May 1999 and May 2000 North Korea allowed US nuclear specialists to inspect an extensive underground complex that the USA suspected was an underground nuclear reactor.[78] They concluded that it was not a nuclear reactor. A team with a greater breadth of experience might have determined what it actually was.

In a corollary, some of the best information for analysing the Iraqi programme came from reports by the safety department of the Iraqi nuclear programme. Safety personnel had general knowledge of the scope of the entire programme. For example, their reports of providing firefighting capability to all of the sites of the programme was key in mapping the extent of the programme.

[78] Nuclear Threat Initiative (NTI), 'Geumchang-ri underground facility', 30 Sep. 2011.

In 2002 the Action Team needed potential inspectors for the resumption of inspection in Iraq. The Germany mission to the IAEA was asked to offer positions to 'physicists' in Germany who might be interested in inspections in Iraq. The majority of respondents were young and educated in esoteric high-energy physics with no experience in weapons programmes of any kind or engineering. The call for candidates had obviously gone to a narrow group of people who matched what the government thought was needed. The request for support from Germany was poorly phrased, inappropriate and poorly handled by the German side.

Lesson 4. Security culture needs improvement to a high standard of classified work

Sensitive information in the hands of the inspectors needs to be protected. Inspectors in Iraq showed sensitive line drawings and maps to the Iraqis. The Iraqis used this to their advantage to sow confusion between the US and Iraqi numbering systems. Some UNSCOM inspectors even showed secret aerial images to the Iraqis in the interests of expediency. This was a sign of a poor security culture. Inspectors in Iraq carried handheld radios for safety and coordination. Mobile phones were not widely available and may be a new security problem.

Lesson 5. Successful denuclearization may not be universally accepted

It would seem reasonable to many people that materials for proliferating nuclear weapons should be removed from a defeated aspiring proliferator. This has not always been the case.

Removal of spent nuclear fuel from Iraq became a difficult political hurdle. There were many kilograms of HEU in Iraq from France and the Soviet Union. Neither country was anxious to repatriate HEU or irradiated fuel to its territory. In some cases, there were actual laws concerning accepting 'nuclear waste' from abroad. Environmental groups protested against accepting nuclear materials. Eventually, Russia agreed to accept both the Soviet- and French-origin fuel. Finally, the USA agreed to take tonnes of natural uranium and slightly enriched uranium, especially after the 2003 invasion. Some phases of denuclearization in Iraq took over a decade.[79]

The situation in Libya was similar. Gaddafi had about 100 tonnes of uranium yellowcake raw material sitting in a warehouse in Sabha, in the Sahara, about 40 km south of Tripoli.[80] It was verified by normal IAEA materials inspectors outside the scope of the extra activities on weapons and centrifuges. The IAEA worked with a buyer to remove this material to make fuel in a nuclear power state. They were unsuccessful as of the time of Gaddafi's death, in 2011. Yellowcake is a precursor material for nuclear fuel. Without major processing, it is not of any nuclear weapon threat. Nevertheless, it is a valuable starting material for nuclear

[79] Dillon, G. and Baute, J., 'An overview of the IAEA Action Team activities in Iraq', International Conference the Back-end of the Fuel Cycle: From Research to Solutions, Paris, 9–13 Sep. 2001.

[80] Spencer, R., 'Dumped in the desert . . . Gaddafi's yellowcake stockpile', *The Telegraph*, 25 Sep. 2011.

power fuel. Enriched research reactor fuel was moved from Libya to Russia in 2008. Some barriers to removing nuclear material can be a problem.

Lesson 6. Credibility relies on inspector integrity

The inspection process is often adversarial. That is the nature of the process. But it is also important to bargain in good faith, especially on the part of the inspectors. Dirty tricks and breaking regulations may be normal for the inspected, but it should not be for the inspectors.

UNSCOM in New York crossed this line when it allowed certain missile inspectors to begin using the inspections as a vehicle to implant sensing devices unrelated to the inspection mandate. This damaged UNSCOM's reputation beyond repair and caused it to be completely reorganized as UNMOVIC. This approach was different from the approach of the Action Team, which was confrontational and active when necessary.[81]

[81] A biased but revealing description of the New York UNSCOM inspectors emphasizes the differences. Public Broadcasting Service (PBS), 'Spying on Saddam: Scott Ritter interview', *Frontline*, 27 Apr. 1999.

Appendix A. Targeted inspections of trading houses: Special techniques for secure computer searches

A special case of document search became possible in 2002 and 2003 in Iraq. A United States-led invasion was clearly on the horizon and Iraq was doing everything it could to cooperate with UNMOVIC and the INVO (the renamed Action Team) in the hopes of preventing a war. One of the valuable things that Iraq agreed to was to open up records of commercial trading companies in Baghdad that were involved in military imports.

The first to comply with an INVO request was a trading company that had issued tenders for the import of certain aluminium tubes. The company opened its files completely and showed all of the tenders and all of the responses. The USA had proposed that the aluminium tubes were gas centrifuge rotor tubes. The records at the company strongly suggest that most of the US argument was bluster. For example, US cost claims for the tubes were wildly in error: the tubes being offered were cheap.[82] The specifications were exactly for Italian Medusa rocket motor casings—as used in the inventories of member states of the North Atlantic Treaty Organization (NATO)—and inappropriate for centrifuges. The Iraqi company allowed two inspectors to review the documents and take copies as needed. Their only request was to be judicious about copying because paper and toner were in short supply due to sanctions.

The INVO had independent information on other trading companies. Information leaked in US media claimed that transactions made by these companies were nuclear-related.[83] In its last inspections before the 2003 invasion, an INVO team with many forensic specialists from France and the US national laboratories carried out a multi-day series of inspections at one trading house after another. The teams were sensitive to possible Iraqi interference, so they brought their own copiers, toner, copy machines and even generators. That proved to be unnecessary: the Iraqi were caught off guard. They were accustomed to teams investigating test sites and factories. However, they recognized the point of the inspections was to absolve them of transgressions and cooperated completely.

One of the most important activities was the review of computer records. A French-led team provided excellent guidance for how to conduct such a forensic search. Reviewing computer files in the office being inspected is a difficult task. In many cases the party being inspected will be helping the investigator work through the filing system. That gives the subject the opportunity to see how the investigator works, their main interests, search terms and methodology. Time

[82] Albright, D., 'Iraq's aluminum tubes: Separating fact from fiction', 5 Dec. 2003.

[83] ElBaradei, M., IAEA Director General, 'The status of nuclear inspections in Iraq: An update', 7 Mar. 2003.

may be limited if there are huge holdings. Interpreters will be stretched thin if there are many pages in a foreign language.

The French approach was to 'mirror' the subject's computer hard drives. This process involved copying every digital bit on the subject's machine to produce an exact copy. Iraqis resisted briefly but quickly complied. The search was to their benefit, and they knew that the records would exonerate them, not convict them. The mirrored hard drives were taken away for careful exploitation, some immediately and with much more effort over subsequent days and weeks.

The French also provided another excellent legal suggestion: they made two mirrors of each drive. One was given to the Iraqi NMD in a container under an IAEA seal. This technique, which the French use in forensic investigations, gives the accused some assurance that their data cannot be corrupted and used against them. The French team created a unique fingerprint of every bit on the hard drive using an algorithm. If a single bit of data were changed, then the fingerprint would change as well. This provided a unique assurance that data could not be changed. The copy from the Action Team and the one given to Iraq were identical. If the Iraqis suspected tampering, they could then compare their original with the IAEA copy.

The same procedure is used with environmental samples.[84] The reason for such care is legal jeopardy. In the early days of an inspection, things move quickly and documentation is often poor. In 2003 the Action Team or the INVO had been inspecting Iraq for 12 years. The process of inspecting procurement records in offices is time consuming, detailed and legalistic. On several occasions, the Action Team and UNSCOM took physical samples on sites that proved to be unreproducible or cross-contaminated.[85] This should not be the case in a process going on for years.

The trading house searches were extremely successful. They turned up many transactions that had been highlighted in the press as suspicious. In fact, none were. The press was following leaks. Transactions involving certain aluminium tubes, ring magnets and other matters were found and resolved.[86] The aluminium tubes were for rockets, not centrifuges. The ring magnets were for loudspeakers, not centrifuges. There was no nuclear-related transaction. In early March 2003, this inspection was stopped and the search teams were quickly removed from Iraq due to the immediate threat of war.

It was not the end of the story. After the war, a US Federal Bureau of Investigation (FBI) search team found a number of computer hard drives under IAEA seals at the NMD in Baghdad. They asked the IAEA what they were. The IAEA explained that they were the property of the IAEA and should be returned to Vienna. They were never returned.

[84] Rauf, T., 'Environmental sampling in Iran', Arms Control Association, 20 Aug. 2015.
[85] Fedchenko and Kelley (note 22), pp. 233–36.
[86] ElBaradei (note 84).

Appendix B. Use of thermal and hyperspectral bands of satellite imagery for non-proliferation studies in Iraq

Thermal imagery analysis

Thermal spectral information can be used to detect sources of heat such as a nuclear reactor or an industrial plant consuming high levels of electrical power. The use of thermal imagery was highlighted in 1979 when the US ambassador's aeroplane was used to spy on South African nuclear facilities.[87] The United States was able to determine when the huge Pelindaba nuclear enrichment plant was active, but it could not determine how well the plant was working.

In Iraq the Action Team adapted thermal imagery from a satellite on a trial basis and was able to assess an underground facility near Mosul in 2002.[88] This was in a period when Iraq had banned all UNMOVIC inspectors, including the Action Team. Monitoring of Iraq continued, but only indirectly through satellite imagery and open sources.

Thermal satellite imagery is often used to detect plumes of heat, especially in water bodies to detect hot water discharge. There is a pumped storage project near Mosul where off-peak electricity is used at night to take cold water from the bottom of the Saddam Dam reservoir (renamed Mosul Dam in 2003). It is pumped to the top of a hill and then allowed to run down through turbines to generate extra electricity at times of peak demand. The pumps and turbines are located deep underground in a facility first inspected by the Action Team in 1991. Human source reports in 2002 suggested the electrical generators had been removed and replaced by nuclear activities. The satellite imagery provided strong evidence that the plant was actively making electricity: the hilltop reservoir was as cold as the discharge from the dam's turbines, whereas the surface of the reservoir was hot in the summer sun. It was clearly a pumped storage operation, with no hidden nuclear activity.

Hyperspectral imagery analysis

In another case, the INVO and the Canadian Nuclear Safety Commission (CNSC) explored the use of hyperspectral imaging bands of commercial satellites.[89] All substances have spectral properties whereby they absorb and reflect different wavelengths of light. These spectra can be measured using optical spectrometers.

[87] Burns, J. F., 'South Africa ousts 3 U.S. Embassy aides, charging air spying', 13 Apr. 1979.

[88] Iraq Nuclear Verification Office, International Atomic Energy Agency and the Canadian Nuclear Safety Commission, 'Thermal Imagery Study, Saddam Dam, Pumped Storage Project, Northern Iraq', Information Date Aug. 2002, Report Date May 2003.

[89] Borstad, G. A. et al., 'Hyperspectral imagery for safeguards applications', Proceedings of the 45th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, FL, July 2004.

Each substance has a distinctive 'fingerprint' of light that can be used to identify the substance. This ordinarily happens in laboratory situations, but using spectral information from a satellite sensor is a rapidly evolving field.

The hyperspectral sensors in commercial trials in 2002 had very low spectral resolution. A ground target needed to be many metres in size to get accurate readings. The Action Team chose a practice problem in Iraq with a large ground signature. Iraq was known to have extracted significant amounts of uranium from phosphate fertilizers at the Al Qaim superphosphate fertilizer plant. This big industrial plant has a white dust plume on the ground around it that is easily visible from space. There were a number of cement plants in the desert that also had a large white pattern around them. The research problem was to see if a satellite could distinguish a cement plant from a fertilizer plant. If unknown fertilizer plants were discovered, they could be clandestine uranium sources.

This collaboration between the IAEA and the CNSC was plainly a research project. It was funded in a period when all verification in Iraq was being done from outside the country using indirect means. The results were ambiguous and it was obvious that better satellite sensors were required. Nevertheless, this was a clear indication that the Action Team was striving to find the best technologies of the day and apply them to Iraq's denuclearization.

About the author

Robert E. Kelley (United States) is a veteran of over 35 years in the US Department of Energy (DOE) nuclear weapons complex, most recently at Los Alamos National Laboratory. He worked in research and engineering before turning to information analysis in the 1980s. He managed the centrifuge and plutonium metallurgy programmes at Lawrence Livermore National Laboratory and later was director of the DOE Remote Sensing Laboratory, the main US nuclear emergency-response organization. He was also seconded by the DOE to the International Atomic Energy Agency (IAEA).

He served twice as a director of the IAEA's nuclear inspections in Iraq, in 1992–93 and again in 2001–2005, conducted transparency visits in South Africa in 1993, and was a nuclear inspector concentrating on weapon issues in Libya in 2004. In addition, he participated in transparency visits in the Democratic Republic of the Congo, Egypt, South Korea, Syria, Taiwan and Tanzania.

Verifying Nuclear Disarmament: Lessons Learned in South Africa,Iraq and Libya

Inspections in the 1990s and early 2000s in South Africa, Iraq and Libya were designed to discover the details of nuclear weapon programmes and destroy any remnants. As the global norm against nuclear weapons strengthens, the international community may once more require verification of a state's denuclearization. But success in the three earlier cases does not guarantee success in the next similar task—any future inspection mission must learn from the lessons of the past.

This report draws on the unique experience of Robert Kelley, a participant in all three past denuclearization efforts. In it, he gives an account of the unique scale and circumstances of each investigation and the different tools and approaches required. By publicly documenting and comparing obstacles and successes in the three cases for the first time, this report gives meaningful and practical insight into the difficult work of disarmament and its verification. It is an essential resource for future inspectors—and all others interested in what real disarmament looks like on the ground.