If we can decrease the current level I to less than e/τ_{sp} and satisfy the constant-current operation condition, where τ_{sp} is the spontaneous emission lifetime, the charging time for one electron-hole pair into a junction can become longer than the radiative recombination lifetime. In such a case, coexistence of continuous uniform charging into the junction and discrete radiative recombination of an electron-hole pair will achieve the junction voltage oscillation and single photon emission at a frequency of $f = I/e$ (*43*). This is an optical analog of Coulomb blockade, or single-electron (electron-pair) tunneling oscillation in an ultrasmall capacitance tunnel junction (*29*). It is expected to open up a new field of combined single electronics and single photonics.

REFERENCES AND NOTES

1. H. Haken, *Light and Matter*, vol. 25 of *Handbuch der Physik* (Springer-Verlag, Berlin, 1970).
2. M. Sargent III, M. O. Scully, W. E. Lamb, Jr., *Laser Physics* (Addison-Wesley, Reading, MA, 1974).
3. W. H. Louisell, *Quantum Statistical Properties of Radiation* (Wiley, New York, 1973).
4. R. J. Glauber, *Phys. Rev.* **131**, 2766 (1963).
5. R. Loudon, *The Quantum Theory of Light* (Clarendon, Oxford, 1973).
6. H. Haug and H. Haken, *Z. Phys.* **204**, 262 (1967).
7. Y. Yamamoto, S. Machida, O. Nilsson, *Phys. Rev. A* **34**, 4025 (1986).
8. Y. Yamamoto and S. Machida, *ibid.* **35**, 5114 (1987).
9. S. Machida, Y. Yamamoto, Y. Itaya, *Phys. Rev. Lett.* **58**, 1000 (1987).
10. S. Machida and Y. Yamamoto, *ibid.* **60**, 792 (1988).
11. W. H. Richardson and R. M. Shelby, *ibid.* **64**, 400 (1990).
12. H. Takahashi, *Adv. Commun. Syst.* **1**, 227 (1965).
13. D. Stoler, *Phys. Rev. D* **4**, 1925 (1971).
14. H. P. Yuen, *Phys. Rev. A* **13**, 2226 (1976).
15. D. F. Walls, *Nature* **306**, 141 (1983).
16. For a recent review, see the special issues on squeezed states in *J. Opt. Soc. Am. B* **4** (October 1987), D. F. Walls and R. E. Slusher, Eds., and *J. Mod. Opt.* (June 1987), R. Loudon and P. L. Knight, Eds.
17. Y. M. Golubev and I. V. Sokolov, *Soc. Phys. JETP* **60**, 234 (1984).
18. For the similarities and differences between the laser oscillator and parametric oscillator, for instance, see Y. Yamamoto and H. A. Haus, *Phys. Rev. A* **41**, 5164 (1990).
19. R. Jackiw, *J. Math. Phys. (N.Y.)* **9**, 338 (1968).
20. M. Kitagawa and Y. Yamamoto, *Phys. Rev. A* **34**, 3974 (1986).
21. M. Kitagawa, N. Imoto, Y. Yamamoto, *ibid.* **35**, 5270 (1987).
22. K. Watanabe and Y. Yamamoto, *ibid.* **38**, 3556 (1988).
23. M. C. Teich and B. E. A. Saleh, *J. Opt. Soc. Am. B* **2**, 275 (1985).
24. P. Zoller, talk presented at NATO Workshop on Quantum Measurement in Optics (January 1991, Cortina).
25. J. Bergon *et al.*, *Phys. Rev. A* **40**, 5073 (1989).
26. F. Haake, D. F. Walls, M. J. Collet, *ibid.* **39**, 3211 (1989).
27. A. van der Ziel, *Fluctuation Phenomena in Semiconductors* (Butterworth, London, 1959).
28. Y. Yamamoto, S. Machida, O. Nilsson, in *Coherence, Amplification and Quantum Effects in Semiconductor Lasers*, Y. Yamamoto, Ed. (Wiley, New York, 1991), pp. 461–537.
29. K. K. Likharev and A. B. Zorin, *J. Low Temp. Phys.* **59**, 347 (1985).
30. S. Machida and Y. Yamamoto, *Opt. Lett.* **14**, 1045 (1989).
31. W. H. Richardson, S. Machida, Y. Yamamoto, *Phys. Rev. Lett.* **66**, 2867 (1991).
32. Y. Yamamoto and H. A. Haus, unpublished results.
33. H. Namizaki, *IEEE J. Quantum Electron.* **QE-11**, 427 (1975).
34. W. H. Richardson and Y. Yamamoto, *Phys. Rev. Lett.* **66**, 1963 (1991).
35. M. Buttiker, *ibid.* **65**, 2901 (1990).
36. W. H. Richardson and Y. Yamamoto, *Phys. Rev. A* **44**, 7702 (1991).
37. For a review on quantum theory of measurements, see J. A. Wheeler and W. H. Zurek, Eds. *Quantum Theory and Measurement* (Princeton Univ. Press, Princeton, NJ, 1983).
38. C. M. Caves, *Phys. Rev. D* **23**, 1693 (1981).
39. Y. Lai, H. A. Haus, Y. Yamamoto, *Opt. Lett.* **16**, 1517 (1991).
40. L. Gillner, G. Björk, Y. Yamamoto, *Phys. Rev. A* **41**, 5053 (1990).
41. For a recent review on cavity quantum electrodynamics, see S. Haroche and D. Kleppner, *Phys. Today* **42**, 24 (January 1989).
42. Y. Yamamoto, S. Machida, G. Björk, *Phys. Rev. A* **44**, 657 (1991).
43. Y. Yamamoto and S. Tarucha, unpublished results.

44. Support for W.H.R. on part of the work was provided by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Iraq and the Future of Nuclear Nonproliferation: The Roles of Inspections and Treaties

JOSEPH F. PILAT

In the aftermath of the Gulf War, revelations about Iraq's extensive program to develop nuclear weapons challenge the future of the international nuclear nonproliferation regime. Until inspections sanctioned by the U.N. Security Council began, Iraq's violations of its obligations under the Treaty on the Nonproliferation of Nuclear Weapons and its related safeguards agreement with the International Atomic Energy Agency went undetected. The ultimate impact of Iraq's behavior on the regime cannot yet be determined, but there is now an opportunity to improve safeguards and other aspects of the regime, including strengthening export controls and proliferation intelligence collection and sharing and the development of appropriate response capabilities.

SINCE ITS ENTRY INTO FORCE IN 1970, THE TREATY ON THE Nonproliferation of Nuclear Weapons (NPT) has been the centerpiece of the international nuclear nonproliferation regime. With more than 140 parties, it is the most widely adhered to arms control treaty in history. As recently as the Fourth Review Conference of NPT Parties (Geneva, 1990), there was a consensus on the value of the treaty, although there was no formal declaration of that consensus. Now, what was long assumed to be of enduring value has come under question because of the pursuit by Iraq, an NPT party, of an ambitious nuclear weapon program.

Before assessing the regime implications of recent developments in Iraq, it is useful to review provisions of the NPT. The main objective of the treaty is to prevent the spread of nuclear weapons to

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states that do not possess them. The first three articles of the treaty are designed to realize this objective. Under Article I, each nuclear-weapon state (NWS) party agrees not to transfer, directly or indirectly, nuclear weapons or other nuclear explosive devices or the control over such weapons or explosive devices, and not to assist, encourage, or induce any nonnuclear-weapon state (NNWS) to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or the control over such weapons or explosive devices. Each NNWS party to the NPT agrees, in Article II, not to receive the transfer or direct or indirect control of nuclear weapons or other nuclear explosive devices, not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, and not to seek or receive any assistance in their manufacture. Article III provides for each NNWS to accept international safeguards, which are to be applied by the International Atomic Energy Agency (IAEA) to all source or special fissionable material in all peaceful nuclear activities within the state's territory, under its jurisdiction, or carried out under its control anywhere, for the purpose of verifying treaty obligations, with a view to preventing the diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices (*1*).

In the public debate that has occurred since the revelations about Iraq's program in the aftermath of the Gulf War, many have asserted that the old nonproliferation order, largely defined by the NPT, has been shown to be ineffective and therefore no longer credible—if, indeed, following this logic, it ever was credible. In the view of one critic (*2*):

> The allied raids on Iraq's nuclear facilities and infrastructure not only set back the Iraqi program but destroyed once and for all the fiction created in the public mind over many years by artful propaganda and obscuration that the safeguards regime and current international export controls provide an effective barrier to proliferation. It is to be regretted that this message about the regime's weakness, delivered by the Israelis in 1981, was buried at that time by an avalanche of criticism of Israel by the nations now in the Desert Storm coalition. . . . The NPT regime itself provides no early red flag indicating that one of its members has begun marching down the road toward weapon production, even if no treaty violations have yet occurred.

On the other hand, there is the view that the NPT is becoming stronger after the Gulf War. According to one nonproliferation expert (*3*):

> The Gulf War and its aftermath have . . . been instrumental in radically changing and expanding the scope of the nuclear nonproliferation regime, which is becoming more rigorous and intrusive, with a central role being played by the coercive diplomacy of the five existing nuclear-weapon states. The spotlight is now on strengthening methods of denying technologies and materials to potential proliferators, on agreeing to more intrusive IAEA safeguards mechanisms, and on emphasizing the priority now placed by members of the Group of Seven and others on nonproliferation. In the background is the threat of decisive action by U.N. Security Council members against an alleged proliferator.

Are we, then, witnessing in Iraq the death of the old nonproliferation order and the dawn of a Brave New World of nonproliferation and arms control? Final assessments are premature because implementation is ongoing and, if the past is prologue, is likely to be challenged by Iraq at every step. Moreover, we do not yet have a full understanding of the Iraqi program because of the destruction wreaked by wartime bombing and Iraqi efforts to conceal surviving capabilities since the cease-fire. Nonetheless, certain points can be made. We have learned that Iraq had embarked on several paths in pursuit of weapon-usable materials, including gas centrifuge and electromagnetic isotope separation technologies for enriching uranium to enable its use in weapons, along with a parallel program to develop the other components required for a nuclear weapon, involving high-explosive detonation tests and research and development on nuclear initiators. We learned that Iraq's program was dependent on the utilization of new and old technologies, some of which were not under existing export controls and others of which were pursued through clandestine procurements that contravened existing supplier conventions. We learned about the vastness of the Iraqi industrial infrastructure devoted to nuclear-weapon development and may presume that large amounts of oil revenues must have been devoted to these programs.

Iraq finally admitted that it was engaged in nuclear-weapon research and development, although Iraqi President Saddam Hussein had long claimed that the Iraqi nuclear program was for peaceful purposes only (*4*). The secrecy surrounding the program and its enormous cost had always made this claim incredible, but it had been put forward even after a "smoking gun" of a nuclear-weapon development program was discovered. The "Al-Athir Plant Progress Report for the period 1 January 1990 to 31 May 1991," (*5*) annexed to the preliminary report of the inspection in Iraq in September 1991, as well as other documents uncovered by the inspection team, led to the IAEA to conclude that (*6*):

> The Government of Iraq had a program for developing an implosion-type nuclear weapon, and it [the inspection team] found documents linking this program code-named "Petrochemical Three" (PC-3) to Iraq's Ministry of Industry and Military Industrialization, the Iraqi Atomic Energy Commission (IAEC) and Iraq's Ministry of Defense. Documents were found showing that the nuclear weapons program was supported by broad-based international procurement efforts. Contrary to Iraq's claims of having only a peaceful nuclear program, the team found documents showing that Iraq had been working on the revision of a nuclear weapons design and one linking the IAEC to work on a surface-to-surface missile project—presumably the intended delivery system for their nuclear weapon.

Although these revelations are startling, our surprise over the scope and extent of the Iraqi nuclear-weapon program is almost certain to increase when the contents of the confiscated Iraqi program documents are fully understood.

These revelations concerning the scope and successes of Iraq's nuclear program are startling. And it is apparently damning for the international nonproliferation regime that none of the paths pursued by Iraq to develop nuclear weapons would have been detectable by IAEA inspectors, even though they were violations of the NPT and Iraq's safeguards agreement with the IAEA pursuant to the NPT. Nevertheless, whether the NPT regime will be irreparably harmed remains to be seen.

Enter the Security Council

Efforts to unearth and to eliminate the Iraqi nuclear-weapon program are now being pursued under the auspices of U.N. Security Council Resolutions 687, 707, and 715. Resolution 687, passed on 3 April 1991, established a formal cease-fire between Iraq and the military coalition that contested Iraq under U.N. auspices, and covered such issues as the international boundary between Iraq and Kuwait, establishment of a U.N. observer force, compensation, sanctions, and the elimination of nuclear systems and other weapons of mass destruction. On nuclear proliferation, the resolution required Iraq to (*6*):

1) Unconditionally agree not to acquire or develop nuclear weapons or nuclear-weapon–usable material or any subsystems or components nor to acquire any research, development, support, or manufacturing facilities related to nuclear weapons.

2) Submit to the U.N. Secretary General and the IAEA Director General a declaration of the locations, amounts, and types of all such material, items, and facilities.

3) Place all nuclear-weapon–usable material under the exclusive control of the IAEA, for custody and removal (with assistance and cooperation from the U.N. Special Commission).

4) And accept on-site inspection and the destruction, removal, or rendering harmless of all such materials, items, and facilities, and a plan for future ongoing monitoring and verification of compliance with the undertakings.

Driven by flagrant Iraqi noncompliance with Resolution 687, U.N. Security Council Resolution 707 was passed 15 August. It recognized and condemned Iraqi violations of the NPT, its IAEA safeguards agreement, and Resolution 687, and it demanded that Iraq among other things (7):

1) Provide full, final, and complete disclosure, as required by Resolution 687, of all aspects of its programs to develop weapons of mass destruction and of all holdings of such weapons, their components, and production facilities and locations, as well as all other nuclear programs, including any which it claims are for purposes not related to nuclear-weapon–usable material, without further delay.

2) Allow the U.N. Special Commission, the IAEA, and their inspection teams immediate, unconditional, and unrestricted access to any and all areas, facilities, equipment, records, and means of transportation, which they wish to inspect.

3) Cease immediately any attempt to conceal or any movement or destruction of any material or equipment relating to its nuclear programs or material or equipment relating to its other nuclear activities without notification to and the previous consent of the Special Commission.

4) Make available immediately to the Special Commission, the IAEA, and their inspection teams any items to which they were previously denied access.

5) Allow the Special Commission, the IAEA, and their inspection teams to conduct both fixed wing and helicopter flights throughout Iraq for all relevant purposes, including inspection, surveillance, aerial surveys, transportation, and logistics, without interference of any kind and on such terms and conditions as may be determined by the Special Commission, and to make full use of their own aircraft and such airfields in Iraq as they may determine are most appropriate for the work of the commission.

6) Halt all nuclear activities of any kind, except for use of isotopes for medical, agricultural, or industrial purposes, until the Security Council determines that Iraq is in full compliance with this resolution and paragraphs 12 and 13 of Resolution 687 (1991), and the IAEA determines that Iraq is in full compliance with its safeguards agreement with that agency.

7) And comply fully and without delay with all its international obligations, including those set out in the present resolution, in Resolution 687, in the NPT, and in its safeguards agreement with the IAEA.

On 11 October 1991, the Security Council passed Resolution 715, which in essence approves the implementation of plans for the intrusive, long-term monitoring of Iraq set forward by the IAEA. In addition, it states, among other things, that the Security Council (*8*):

1) Demands that Iraq meet unconditionally all its obligations under the plans approved by the present resolution and cooperate fully with the Special Commission and the IAEA Director General in carrying out the plans.

2) Requests the Committee established under Resolution 661 (1990), the Special Commission, and the IAEA Director General to develop a mechanism for monitoring any future sales or supplies by other countries to Iraq of items relevant to the implementation of Resolution 687 and other resolutions.

3) Requests the Secretary General and the IAEA Director General to submit to the Security Council reports on the implementation of the plans approved by the present resolution, when requested by the Security Council and in any event at least every 6 months.

Resolution 707 has intriguing features, such as its sanctioning of aerial inspection and its Draconian restrictions on the Iraqi nuclear program; and the approval in Resolution 715 of intrusive monitoring of Iraq's nuclear activities as well as of nuclear exports to Iraq could have dramatic consequences in the long term (*9*). It is, however, Resolution 687 that has the most immediate, far-reaching, and important implications for nonproliferation. It is unprecedented; it marks the first time the Security Council has invoked its authority under Chapter VII of the U.N. Charter to eliminate an aggressor state's nuclear capability along with other weapons of mass destruction. Passage would have been impossible without the changes in the Soviet Union and the interests of the Chinese in breaking their isolation in the aftermath of the Tiananmen Square crackdown. But it was Iraq's flagrant aggression, its humiliating loss in the Gulf War, and its fervent pursuit of weapons of mass destruction that were crucial in creating the conditions for the international response.

When the question of whether Resolution 687 will serve as a precedent for future nonproliferation efforts is addressed, it is necessary to recognize that the response to Iraq's proliferation activities by the U.N. Security Council is in many respects unique. International consensus for action against Iraq was not based on nonproliferation concerns either originally or primarily—it was rather the Iraqi aggression against Kuwait that drove the international reaction. And Resolution 687, though it has key nonproliferation aspects, was not exclusively a nonproliferation document. That fact was evidenced recently when a consensus failed to emerge for the use of military action when Iraq was not forthcoming with the mandated notification of the nuclear facilities and materials in its possession pursuant to Resolution 687. The United States, in July and again in September 1991, was poised to use military force against Iraq. After Iraq's release of the nuclear inspection team, which had been barricaded in a parking lot in Baghdad, this threat faded. However, concerns about continued Iraqi refusal fully to comply with the Security Council's resolutions have led to recent calls for a military response, and this prospect cannot be ruled out. Even if military action is widely supported and undertaken, the Iraqi challenge to U.N. authority rather than nonproliferation will be the more important and likely rationale for the response.

It is not yet the case that events in Iraq demonstrate a dramatic new consensus on nonproliferation. Heightened interest in nonproliferation has been developing gradually, as evidenced by the positive discussions of the treaty at the 1990 NPT Review Conference. But this interest is not as sweeping as many are now suggesting. And the prospects for U.N. action against other proliferators, unless they are defeated in war or are pariah states, seem uncertain at present. In part because states may imagine themselves as its future objects, "coercive disarmament" as the implementation of Resolution 687 can be described, is unlikely to be viewed as a precedent.

Indeed, rather than strengthening the nonproliferation regime, the experience of Iraq might wholly destroy the international consensus that relied in part on the perceived effectiveness of the regime. It can no longer be stated that there have been no material breaches of the NPT's fundamental obligations or of IAEA safeguards agreements. Iraq's pursuit of nuclear weapons was a violation of its NPT and IAEA safeguards obligations. The letter of 7 July 1991, from the Iraqi Minister of Foreign Affairs to the U.N. Secretary General, clearly showed that Iraq's notification of its nuclear capabilities pursuant to Resolution 687 in letters of 16 and 26 April 1991 were incomplete and designed to conceal substantial activities, both of which were viewed by the U.N. Security Council as material breaches of Iraq's obligations under Resolution 687 (*10*). On 15 July 1991, the Special Commission and the IAEA provided information to the U.N. Security Council showing Iraq in flagrant violation of Resolution 687 (*11*).

At a meeting of the IAEA's Board of Governors in July 1991, IAEA Director General Hans Blix told the board that Iraq was not in compliance with its safeguards agreement with the agency because it had not placed the materials, facilities, and installations related to its enrichment programs under safeguards. A resolution of the board at the July meeting reflected the conclusion that Iraq breached its safeguards commitments and its NPT commitments. The IAEA's 35th General Conference, on 19 September 1991, strongly condemned Iraq's noncompliance with its nuclear nonproliferation obligations, including its safeguards agreement with the agency (*12*). And, in the preliminary report of the September 1991 inspection, it was stated:

The documents found by the team clearly demonstrate that the government of Iraq is in violation of Security Council resolutions 687 and 707. This is underscored by the fact that Iraq detained the inspectors and confiscated documents, which had been legitimately collected. Specifically, the following

may be noted: Iraq had—despite its statements to the contrary—a complex, comprehensive nuclear weapons development program characterized by parallel approaches to fissile material production and by theoretical and experimental design work. Iraq still has substantial facilities, which were part of the clandestine program and which have not been declared. Iraq has removed significant documentary material and equipment from identified nuclear program sites—including some documentary material removed shortly before the arrival of the team (*13*).

Looking to the future of the regime, we see that not only have limitations, or "loopholes," been demonstrated in safeguards, but other limitations of the regime may have been widely recognized by would-be proliferators as well. We can, for example, expect that a lesson drawn by potential proliferators, or "bomb lobbies" within proliferant countries, is that utilizing old technologies, which are uncontrolled and effectively uncontrollable, can have important advantages. Most proliferators have chosen newer technologies for good reasons. Iraq's efforts were exceptional but may be emulated in the future. Although the erosion of the regime is possible, it is by no means inevitable. It may be true, however, that the international nonproliferation regime has been irrevocably changed by the implementation of Resolution 687, even if it does not become a direct precedent for future nonproliferation measures.

Nonproliferation Regime Failures?

On examining the Iraqi nuclear activities that have come to light, and recognizing that activities that had been going on for years came as a surprise, it would appear that intelligence shortcomings as well as nonproliferation regime limitations contributed to the current situation. With respect to intelligence, it is argued that a refocusing of vast assets from the waning Soviet threat to emerging regional proliferation threats can rectify this grave error. This should be beneficial, but it will not provide complete solutions to a complex set of issues. Some prescriptions for the nonproliferation regime, on the other hand, have suggested the need to tear it down and to rebuild it from its foundations. Such views are neither useful nor realistic. Nothing concrete is being put forward to replace the old regime; nothing appears on the horizon that could replace a structure that has evolved over four decades. The regime needs not to be reformulated but to be carefully reviewed and, where possible, improved. Why is this so?

That violations occurred is, as indicated, no longer in question. But the mere fact of the violations, however grievous, does not mean that the treaty is dead or that safeguards are meaningless. It is true that the NPT has no verification provisions for some of its fundamental treaty obligations. IAEA safeguards under the treaty are not designed to verify all aspects of the fundamental pledge of NNWS parties not to acquire in any way nuclear weapons. Rather, safeguards are only designed to detect one step on one of the paths to nuclear weapons—the diversion of nuclear material from declared peaceful nuclear activities to nuclear weapons or other nuclear explosive devices. IAEA safeguards under the treaty are primarily systems of material accountancy, designed to verify statements by an NPT party regarding the presence, amounts, and use of nuclear material on its territory. They depend greatly on the declarations, and the national systems of accounting and control, of the states being inspected. Safeguards are not intended to prevent diversions but only to provide assurance that diversions of significant quantities of material from declared peaceful activities have not occurred. However, states are obligated to place all peaceful nuclear activities under safeguards (*14*). This, in principle, allows the IAEA to verify that states are in compliance with their safeguards undertakings (but not all of their NPT undertakings) and enables states to demonstrate their compliance with those safeguards undertakings.

The relation between the NPT and IAEA safeguards, and the fact that the IAEA has neither enforcement powers nor the ability to apply sanctions (other than reporting noncompliance to the Security Council and withholding technical assistance), limit the regime's verification role. Indeed, the entire regime is designed not for verification but rather, through its provisions for inspections, for confidence-building and demonstrating compliance. In this light, Iraq's dedicated clandestine pursuit of enrichment technologies would not have been subject to safeguards unless Iraq so notified the agency, which we may safely assume was not about to happen. The reprocessing of plutonium taken from the operating research reactors was, in principle, subject to safeguards, but the activity was at such a low level that it fell into a *de minimus* category for purposes of inspection (and would have taken many years or even decades to reach significant weapon quantities if pursued at the ongoing level). Iraq's behavior, then, clearly demonstrated that the regime has had certain limitations built into it that must be recognized and understood before sensible policy decisions can be made.

The Fate of the Regime

The treaty and its safeguards arrangements were then not designed to address the proliferation paths Iraq chose. Iraq, after its chastening experience in 1981, appears to have deliberately chosen to pursue its nuclear weapons ambitions clandestinely in a way that would minimize chances of detection and preemptive response, until such time as its nuclear capability could be revealed as a fait accompli. Does this itself undermine the NPT and the IAEA? The answer will depend on whether the treaty and IAEA safeguards are perceived as germane and credible over time. And this, in turn, will depend on such factors as:

1) Diplomatic leadership in support of the NPT and the IAEA, especially by the United States.
2) Efforts by the IAEA to adjust and strengthen safeguards in response to the Iraqi experience, including implementation of the agency's right to undertake "special inspections."
3) Perceptions of security (and economic) benefits of the treaty, especially by states in the Middle East and other troubled regions.

Each of these conditions appears more likely than not to be realized, at least after a fashion. The United States has continued its long-standing support for the regime, and its Enhanced Proliferation Initiative, which predates the Security Council resolutions, is carefully designed to support modest, evolutionary improvements in the nuclear and other nonproliferation regimes that now exist. The Nuclear Suppliers Group, which met in March 1991, established a working group on dual-use technologies that may be useful for the development of nuclear weapons, a nonproliferation move that had been strongly advocated by the U.S. government and has now received much greater international priority. Such an approach will be even more critical because of "lessons learned" from the Iraqi experience by proliferators. Yet, the difficulties of controlling dual-use exports, which are widely available in international commerce, should not be underestimated, especially if they are based on old technologies. This suggests that new approaches may also be desirable. Calutrons, similar to those developed by Iraq in its electromagnetic isotope separation program, produced enriched uranium used in "Little Boy," and were viewed in some quarters for a considerable period following the Manhattan Project as a likely technology for relatively unsophisticated proliferants. However, in recent years gas centrifuge technology has been regarded with some justification as a greater proliferation concern. Indeed, we learned about Iraq's interest in centrifuges before Desert Storm, and before learning of Iraq's interest in calutrons. Al-

though calutron technology is probably not controllable, we cannot afford to regard it as an unlikely path to enrichment. We will need to monitor indicators of electromagnetic separation programs (for example, massive electricity use) and share information and intelligence on possible users.

As for the IAEA, it appears committed to improving safeguards as a result of the experience in Iraq. Indeed, the commitment to strengthening safeguards is a long-standing one. The experience in Iraq may have served to mobilize the political support that the IAEA needs to accomplish this goal. In a statement to the IAEA General Conference in September 1991, the agency's Director General addressed the issue of whether major changes were needed to strengthen safeguards. In his view, developments in Iraq after the Gulf War demonstrated both challenges to safeguards and the ability of the agency to meet those challenges. He concluded that, if three major conditions were fulfilled, the IAEA would have a high degree of assurance that it could detect clandestine nuclear activities. The three conditions were that the agency be provided access to information on sites that may require inspection; that the agency have short-notice access to any such sites as an unequivocal right; and that the agency have such access to, and support from, the Security Council as is necessary to perform the inspections (*15*).

The requirements put forward by Director General Blix are not unreasonable, and he is already attempting to realize them, but he is unlikely to receive from IAEA member states all that he would like. With respect to his first requirement, there will, of course, be limits to the willingness and ability of states to provide the IAEA with intelligence, and difficulties and expenses associated with interpreting that information, but interested states will probably be more willing than they were previously to provide information to the agency about possible clandestine programs. The second requirement can readily be fulfilled through implementation of procedures for special inspection rights, a rarely used right akin to "challenge inspections" in the argot of arms control. Special inspections have never been conducted at an undeclared site. However, as U.S.–Soviet bilateral arms control has demonstrated, the exercise of challenge inspections (especially at undeclared or suspect sites) will require the difficult development of detailed procedures to make them in any sense effective—for example, defining access, timelines, and whether or not there are to be rights of delay or refusal. For the IAEA to conduct such inspections, a fundamental new dimension in the manner the agency interacts with its member states will be involved. Historically, IAEA inspections have been conducted on a cooperative basis; however, a viable and credible special inspection regime cannot rely solely on cooperation of the host country. Special inspections must allow for the possibility of noncooperation or even outright interference. This necessary shift will have implications not only for the operations, but for the very nature of the agency. Ultimately, success will depend on the political will of the agency's member states.

Access to the Security Council is critical. Assured of support, inspectors in Iraq braved bullets and barricades. Yet, in future cases involving transgressions of nonproliferation undertakings, such support may not come at all, and it is certainly unlikely to be forthcoming in the manner in which Director General Blix requests. Only on an ad hoc, case-by-case basis can we expect the Security Council to support the agency in enforcing nonproliferation accords, and in most cases we can expect such an action to occur after the fact. Meeting the second requirement and searching for means to partially meet, as appropriate and possible, his first and third requirements, should be sufficient to remedy the regime's glaring shortcomings. It may be the most practical option and should not be rejected in the interest of developing some more perfect alternative.

Finally, the growing support for the regime evidenced by the deliberations at the 1990 Review Conference (despite there being no final declaration), by developments since 1990 at the IAEA, and by wide support in the United Nations for Resolutions 687, 707, and 715, indicates that the time is ripe for serious measures to strengthen the nonproliferation regime. Serious does not, however, mean overreaching. The most likely path to destroying the fragile consensus developed so far is to try to create or refashion institutions to treat parties as defeated states or pariahs. It is clear that there will be little support for measures that will ultimately threaten interests shared by the majority of states. Some of the tensions between the U.N. Special Commission and the IAEA reflect different long-term objectives associated with whether implementation of Resolution 687 is unique to Iraq or should establish long-term precedents for carrying out IAEA inspections. If the resolution is viewed as a precedent, its punitive aspects could revive old arguments against the NPT and the nonproliferation regime that evoke their discriminatory nature. This could be counterproductive. Such concerns apply not only to nonproliferation but also to broader arms control lessons.

Arms Control Lessons

There has been considerable interest in the arms control implications of the implementation of Resolution 687 in Iraq. Although it would be as premature to draw definitive conclusions from the implementation of Resolution 687 in this sphere as it would be in the nonproliferation sphere, it can be stated that the inspections to date have shown both the limits of and prospects for short-notice, suspect-site inspections.

Even after a number of intrusive nuclear inspections, in which, after some difficulties, the inspectors had carte blanche, there is a realization that we may never know exactly what level the Iraqi program achieved, and that further inspections as well as continuous monitoring for many years to come will be required for reasonable assurances about Iraq's "denuclearization." On the other hand, revelations from an early inspection, despite Iraq's interference with the inspectors' access, ultimately led to Iraq's admissions about its enrichment programs. This experience confirms what we have long known about on-site inspections and can help increase public awareness of the opportunities and risks associated with this verification measure. In this vein, the disclosures of Iraq's nuclear program should offer opportunities to strengthen the IAEA's safeguards system, especially to develop a consensus on the implementation of its rights under NPT safeguards agreements to undertake special inspections, which began to emerge even before the extent of the Iraqi nuclear program was realized.

The Iraqi experience could also help to promote certain technologies, techniques, and procedures, for example, aerial inspection, thereby establishing a strong rationale for their place in the new arms control panoply. Yet, as suggested, neither the highly intrusive inspections nor the continuous monitoring regime as applied to Iraq is likely to have a place per se in future bilateral, regional, or international accords without significant qualifications and conditions. Parties are not likely to accept instruments that treat them as "defeated powers," with all that such treatment allows in terms of access. The United States could not accept such an approach either constitutionally or as a matter of U.S. national security policy. It may be possible to strengthen future arms accords substantially, but there will always be limitations as long as the accords are based on mutual agreement among sovereign states.

Conclusions

All in all, much of the public criticism of the NPT regime since the Resolution 687 process began appears exaggerated. This criticism is

a blow, however, to those with great expectations for the prominence of exclusively multilateral approaches to nonproliferation. After all, the nuclear nonproliferation structure is, in principle and practice, the oldest and strongest of the existing nonproliferation regimes. If it fails dramatically, what hope can there be for solving missile, as well as chemical and biological weapon, proliferation concerns? However damaging a failure would be, it appears that if the regime can withstand this onslaught and continue to inspire confidence in the perception of most states (parties and nonparties), the NPT and associated IAEA safeguards can be a beacon of nuclear stability in a world in flux. With the dissolution of the Soviet Union, this role is of even greater value than if the "problems" were confined to the Third World.

Our experience with Iraq should confirm what has long been understood by policy-makers—the NPT and safeguards are not in themselves sufficient to halt proliferation. The vigilance of all concerned states is necessary to support and to supplement these institutions; unilateral or multilateral actions outside the boundaries of the regime may be required, whether economic sanctions or military responses. It will be important to maintain an appropriate stance on those institutions to avoid a cheerleading approach and to promote public discussion of what can and cannot be done in the context of the regime.

There is both a need and an opportunity for strengthening safeguards. Indeed, the disclosures of Iraq's nuclear program should spur states to strengthen the IAEA's safeguards system as a matter of some urgency. Crucial to fulfilling this objective is the implementation of the IAEA's rights under NPT safeguards agreements to conduct special inspections, a matter that has been under discussion for over a year now and is now moving forward rapidly. Director General Blix recently put forward a proposal for improved safeguards in a closed session of the Security Council and presented proposals to the IAEA's Board in December 1991. In an earlier interview, he reportedly said that he requested governments to provide information on NPT violations. If the evidence is deemed credible after screening by a special unit in the IAEA secretariat tasked with such a determination, he said he would use his special inspection authority if authorized by the agency's Board of Governors (*16*).

In addition to implementing special inspections, perhaps other capabilities for IAEA monitoring could be developed and deployed on the basis of our experience with Resolution 687, for example, the use of aerial inspections, perhaps in special inspections (despite the crisis provoked by the use of U.N. helicopters in Iraq), or the development of an international registry of transfers of nuclear and dual-use items. There is also a demonstrated need for the IAEA to act on the basis of the national intelligence of member states and the prospect that information-sharing will be possible. But there are limits to the extent and nature of the information that the agency can receive (especially without a Security Council blessing or "cover"), and there is perhaps a real danger that such sharing could be used mischievously by some states (a problem that may plague special inspections).

Although much appears possible in principle, in practice I believe that we will see special inspection rights be brought into effect, perhaps some other adjustments made to safeguards procedures, and some level of intelligence-sharing between member states and the IAEA. Not much else is likely in this sphere, and other possible steps may ultimately not be productive. Other elements of the nonproliferation regime should also be strengthened, including export controls, the collection of proliferation intelligence, and the development of response capabilities. This will likely be achieved in an evolutionary manner. In addition, because Iraq's achievements vividly demonstrate the limits of denial approaches to nonproliferation, more attention will have to be given to reducing incentives for proliferation and to "managing" or "constraining" proliferation once it has occurred.

REFERENCES AND NOTES

1. The NPT has other key objectives, which are not directly germane to the focus of the discussion in this review. In addition to nonproliferation per se, the treaty has a goal to ensure the fullest cooperation in the peaceful uses of nuclear energy, consistent with the objective of nonproliferation. Although Article III provides for strict controls over peaceful nuclear activities to ensure they are not misused for proscribed military purposes, Articles IV and V provide a framework for peaceful cooperation. All the parties to the treaty undertake, in accordance with Article IV, to facilitate the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of nuclear energy. Those parties to the treaty with an advanced nuclear capability are to cooperate in contributing to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of NNWS parties to the treaty, with due consideration for the needs of the developing areas of the world. Article V affirms the principle that potential benefits from peaceful nuclear explosions should be made available to NNWS on a nondiscriminatory basis. Another objective of the NPT is to encourage arms control efforts in the nuclear and nonnuclear arenas. Accordingly, under Article VI, each of the parties undertakes to pursue "good faith" negotiations on effective measures relating to cessation of the nuclear arms race at an early date, to nuclear disarmament, and to achieving a treaty on general and complete disarmament under strict and effective international control. And, in this vein, Article VII states that nothing in the treaty affects the right of any group of states to conclude regional treaties to ensure the total absence of nuclear weapons in their respective territories.
2. L. Weiss, *Bull. At. Sci.* **47** (no. 5) 11 (1991).
3. J. Simpson, *ibid.* (no. 8), p. 13.
4. P. Lewis, "U.N. backs plan to destroy Iraqi arms plants," *New York Times*, 24 October 1991, p. A7.
5. Annex to the *First Report on the Sixth IAEA On-Site Inspection in Iraq Under Security Council Resolution 687*, 22 to 30 September 1991.
6. *First Report on the Sixth IAEA On-Site Inspection in Iraq Under Security Council Resolution 687*, 22 to 30 September 1991, p. 1.
7. U.N. Security Council Resolution 687, S/RES/687, 3 April 1991.
8. U.N. Security Council Resolution 707, S/RES/707, 15 August 1991.
9. U.N. Security Council Resolution 715, S/RES/715, 11 October 1991.
10. A. Hussein, Minister of Foreign Affairs of the Republic of Iraq, letter to J. Pérez de Cuellar, U.N. Secretary General, 18 April, 26 April, and 7 July 1991.
11. J. Pérez de Cuellar, note (S/22788, 15 July 1991), transmitting to the U.N. Security Council a letter from the Director General of the IAEA, 12 July 1991, and the *Consolidated Report on the First Two IAEA Inspections Under Security Council Resolution 687 of Iraqi Nuclear Capabilities*, 11 July 1991.
12. "Iraq's non-compliance with its safeguards obligations," IAEA General Conference Resolution, GC (XXXV)/RES/568, September 1991. See also "Iraq's non-compliance with its safeguards obligations," IAEA Director General's Note on the *Agency's Actions Concerning Iraq in 1990–91*, IAEA GC (XXXV) INF/299, September 1991.
13. *First Report on the Sixth IAEA On-Site Inspection in Iraq Under Security Council Resolution 687*, 22 to 30 September 1991.
14. L. Scheinman, "Nuclear non-proliferation and IAEA Safeguards: The international system and the experience in Iraq," *Bull. Atlantic Council U.S.*, **2**, no. 3 (13 February 1991).
15. Statement by the IAEA Director General, Hans Blix, to the *35th Session of the General Conference of the IAEA*, Vienna, Austria, 16 September 1991, pp. 8–9.
16. P. Lewis, "Atomic agency maps plans to go after nuclear charts," *New York Times*, 11 October 1991, p. A6.

17. The author thanks S. Maaranen, K. Apt, A. Nichols, and M. Mullen from the Los Alamos National Laboratory; A. Sands and W. Domke from Lawrence Livermore National Laboratory; L. Scheinman from Cornell University; and D. Boothby from the U.N. Special Commission for comments. Any errors of fact or judgment are the author's alone. The views expressed are his own and not those of the Los Alamos National Laboratory, the Department of Energy, or any other government agency.