The United States and the Soviet Union are presently negotitating reductions in their nuclear arsenals. These negotiations are influenced by many factors, technological and political, and there are opportunities to debate new proposals for arms control. In this Forum, Mark et al. *argue for a mutual halt in the production of the hydrogen isotope tritium, which is an essential component of fission and thermonuclear weapons, to force substantial reductions in the nuclear arsenals. Sutcliffe responds that a cutoff of nuclear materials production carries a number of risks that need further study before such proposals can be considered by the negotiators.*

The Tritium Factor as a Forcing Function in Nuclear Arms Reduction Talks

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Both the United States and the Soviet Union depend on tritium to boost the yield of their fission weapons and the fission triggers of their thermonuclear warheads. Tritium represents the key to the compact and efficient designs of modern nuclear weapons. Because tritium decays rapidly, declining by half in 12.3 years, tritium charges in nuclear weapons become depleted and must be replaced with fresh charges regularly. Without regular production of new tritium, the large stocks of tritium needed by the United States and the Soviet Union to maintain their nuclear weapons would be depleted at a rate of about 5.5% yearly. Thus, the radioactive decay of tritium—the "Tritium Factor," as we refer to it—provides a potentially powerful means for reducing nulcear arms.

Tritium is unique among nuclear weapon materials in its potential to drive nuclear arms reductions if both sides agreed to a halt in its production. Plutonium, unlike tritium, lasts for thousands of years, and both sides already have enough plutonium to maintain their existing stockpiles of weapons, and even to modernize them (*1*).

The 5.5% annual decay of tritium could serve as a "forcing function" to produce steady, verifiable reductions in the superpowers' nuclear arsenals. Such reductions would result in a comprehensive 50% cut in warheads by about 12 years after an agreement—the year 2001, if the cutoff were to begin now. Thus, the Tritium Factor could be applied to achieving reductions beyond even those now contemplated in the ongoing Strategic Arms Reduction Talks (START) (Fig. 1). At the time a START agreement is concluded, a mutual suspension of new tritium production could be announced in conjunction with it as a confidence-building measure, representing a shared commitment to keep reductions in nuclear armaments

(Continued on page 1167)

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Limits on Nuclear Materials for Arms Reduction: Complexities and Uncertainties

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Because tritium in nuclear weapons must be replenished periodically, it has been proposed that the United States and the Soviet Union reduce their stockpiles of nuclear weapons by limiting or halting the production of this material.

Although such limits might be desirable in the future, any proposal to limit nuclear materials as a means of arms control is premature. Rather, one should first establish the value of production or stockpile limits vis-à-vis other approaches. It is not appropriate to look at some of the potential benefits of a halt in nuclear materials production without analyzing the associated risks. For example, asymmetries in nuclear materials production capabilities, design practices, and delivery system capabilities could lead to disparate impacts on the U.S. and Soviet stockpiles, possibly leaving the United States in a vulnerable position. Proposing nuclear materials limits is fraught with great uncertainties about the comparability of effects on the two stockpiles and verification issues because of the unknowns about the Soviet stockpile and production capabilities. Further, the impact on direct arms control negotiations, which focus on delivery systems, could be deleterious. Finally, the question of whether conventional arms reductions should precede further nuclear arms reductions bears on the proper timing for a proposal to limit nuclear materials.

A halt in tritium production would not necessarily lead to a reduced stockpile of nuclear weapons in the future. A limited supply of tritium could lead to a shell game tactic of maintaining the full capability of some systems while not retiring the other less effective or useless systems. Nuclear warheads can be designed that do not depend on tritium. The early nuclear weapons did not use tritium. As a result of the inevitable research efforts, new technology might circumvent or reduce the need for tritium in efficient modern warheads.

A bilateral agreement, by itself, to prohibit the production of tritium would not be sufficient. Multinational agreements and

(Continued on page 1169)

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(Mark, *continued from page 1166*)

going at a steady pace.

There are a number of compelling reasons for bringing the Tritium Factor into the nuclear arms reduction process at this time:

1) The Tritium Factor provides the only external means to "force" both sides, given the vicissitudes of negotiations, to make steady progress toward sharp reductions in their arsenals.

2) The forcing function imposed by the Tritium Factor would influence the pace of arms reduction talks without putting undue pressure on negotiators. The two sides still would have considerable latitude in deciding which types of weapons to retire to maintain mutually stabilizing force levels.

3) A halt in new production of tritium and plutonium would allay safety concerns on both sides associated with continuing to operate their aging production reactors. In the United States, the N reactor has been shut down, and the Savannah River reactors are now required to operate at half power owing to safety problems identified by the National Academy of Sciences since the Chernobyl accident.

4) With a halt in production, plans to upgrade these reactors could be set aside. The production reactors of both sides would be placed on standby, ready to restart tritium production only if nulcear arms talks break down. The tritium recovered from retired weapons would be used to replenish the tritium supply in the remaining ones.

5) Decisions on costly plans for new production reactors could await an agreement on the level to which arsenals would be drawn down, or a breakdown in the talks. There is now a proposal before Congress by the Department of Energy to build two new production reactors at a presently estimated cost of $6.8 billion, although costs may well be much higher. The DOE plans to put one or both of these new reactors into operation by 1999. Congress could defer action so long as a mutual halt in tritium production were in effect. Eventually, to maintain a minimum effective deterrent, new tritium production at some much lower level might be needed a few decades after the cutoff.

6) The complete suspension of production-reactor operations—for both tritium and plutonium—is verifiable by national technical means supplemented by on-site inspections, as needed.

Of course, there are questions that need to be examined. How can a technical measure like the Tritium Factor be expected to "force" the process of arms negotiations? How can each side be sure that a mutual cutoff of tritium production will have comparable effect on the weapons of the other side? And, how can compliance with such a cutoff be verified?

Impact on negotiations. The Tritium Factor would serve as a "clock on the table," as in a chess match. It would provide a mechanism for automatically maintaining a minimum pace of reductions. Although negotiators may not like to work against deadlines, historically, when none exist, negotiations tend to drag on interminably and to be overtaken by events.

Each side could begin cautiously because the full impact of a tritium cutoff on weapons reductions could be cushioned somewhat at the outset by the choice of weapons systems to be retired and of available options for tritium management (*2*). There would be a limit to possible reshuffling schemes, however, and eventually the decay of the tritium inventory would force a steady reduction in the number of nuclear warheads.

Weapons reductions at tritium's decay rate would be dramatic over the first dozen years—a 50% cut in the overall nuclear arsenals of the superpowers by 2001, if begun now. Of course, tritium's decay rate remains constant, but the number of warheads retired each year, as paced by the Tritium Factor, will grow progressively smaller as the number of warheads remaining in the stockpiles declines with time. After 12 years, however, sufficient confidence might be built to permit cuts at a rate greater than tritium's decay; if so, tritium's forcing function will have served nuclear arms reduction efforts well.

Some may be skeptical of the Tritium Factor approach to nuclear arms reduction, seeing this approach to be a case of "the tail wagging the dog." Certainly, nuclear materials production policy never has been used to drive nuclear arms reduction efforts. The result to date, however, has been little in the way of arms reduction, but much in the way of materials production that feeds the arms race.

What are the risks if the Tritium Factor approach fails? In the event that arms reduction negotiations break down, the United States, using the output of production reactors held on standby, could restore its tritium inventory to 90% of the initial value in 1 year after a 3-year production halt, and to 83% in 2 years after a 6-year halt (*3*). The tritium recovery capability of the Soviet Union is likely to be comparable. However, to ensure an equivalence of recovery capability, the superpowers could agree on which reactors are to be held on standby and which reactors are to be dismantled.

Comparability of effect. An important question is whether arms reductions based on a mutual halt in the production of tritium would have comparable effect on the Soviet and U.S. nuclear arsenals. Because of the Soviet advantage in missile throw weight, it is possible that the Soviets have not pushed the miniaturization of their fission triggers to the same extent as the United States. Yet, the nuclear arsenals of both sides have a strong dependence on tritium, and Soviet tritium production—like ours—is presumably scaled to meet their continuing needs. Consequently, a tritium production cutoff would affect both sides substantially enough for the Tritium Factor to be an effective approach to mutual arms reduction. At the same time, each side can rest assured that even some 37 years after a tritium cutoff (a period equal to three half-lives of tritium), enough tritium will remain for at least 1000 to 3000 warheads—a credible nulcear deterrent—*without any resumption of production*.

Of course, the weapons laboratories on each side could work on new designs requiring less tritium or not relying on boosting at all (*4*). The design and production of these weapons may take some years, however; and because of their greater weight and size (owing to the need for using fissile material to achieve the same effect), such

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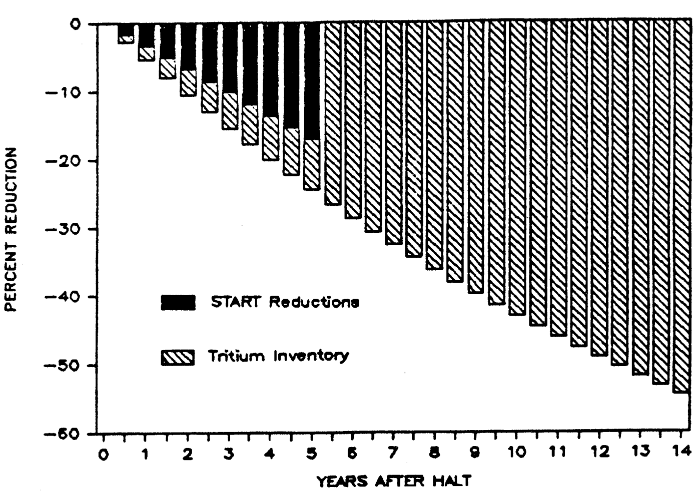

Fig. 1. The percent reduction in a superpower's inventory of tritium for nuclear weapons as a result of radioactive decay following a halt in tritium production. The reduction in the tritium inventory would force a like reduction in the stockpile of nuclear warheads. Under the proposed START agreement, the reduction of 4000 strategic warheads (17% of the U.S. nuclear stockpile) over even the 5-year period proposed by the Soviet Union would not quite match tritium's decay.

(**Mark**, *continued from page 1167*)

weapons may require new delivery systems. New designs to replace present triggers of thermonuclear weapons would require tests of the complete weapon to confirm the effect of the trigger on the second stage, and new delivery systems also would require testing. Such tests would be subject to detection. A ban on nuclear testing would be desirable, as would a ban on reuse of fissile material from nuclear warheads that would be dismantled by mutual agreement, although these bans would not be essential to implementation of the Tritium Factor.

Verification issues. It should be emphasized first that verification of weapons reductions, whether driven by the Tritium Factor or not, would be by confirmation of destruction of retired weapons. The principal verification problems in this case are the same as those currently being dealt with in connection with implementation of the Intermediate Nuclear Forces (INF) and negotiation of the START treaties. Such verification will require on-site inspection.

The nonoperation of dedicated production reactors can be verified by satellite surveillance in the thermal infrared wavelength region because these reactors are major infrared heat sources when operating. Any undeclared source of thermal radiation could be challenged as a potential clandestine facility and made subject to on-site inspection.

At operating power and dual-purpose reactors, inspectors under international or bilateral auspices would be able to detect dedicated tritium production by utilizing devices for nondestructive irradiation of fresh reactor fuel, targets, and control rods. Such devices could use a beam of neutrons to detect the presence of lithium-6 targets used for tritium production (*5*). In addition, activities in separation plants to recover tritium from irradiated targets would be detected by the monitoring of emissions at the stacks of these plants.

Under conditions in which the destruction of nuclear weapons at agreed rates was being verified, and checked against the number of weapons remaining in the nuclear stockpiles, any secret stockpile of tritium would be of little significance. Any such secret inventory would be decaying while these procedures applied. This factor, along with the absence of new delivery systems that would be required for deployment of additional warheads built from a clandestine supply of tritium, would make any attempt to store or acquire a secret stockpile of tritium unappealing (*6*).

In addition to the superpowers, the other nuclear weapon states (France, Britain, and China) produce tritium for weapons, and there is some commercial capacity (principally Canada, but also France) for recovering tritium from the moderator of heavy-water reactors. However, supplies of tritium from such sources are on a smaller scale than the current requirements of the superpowers, and most of the military tritium production in other nuclear weapons states will be fully committed to meet their own needs, which in any event are on a relatively small scale (*7*).

As to the possible commercial sources, there would be the need for international safeguards barring military use. Civilian power and large research reactors would have to be made subject to International Atomic Energy Agency (IAEA) safeguards or bilateral arrangements (or both) to ascertain that tritium is not being produced in fuel rods, control rods, or blankets or being diverted for weapons purposes from the heavy-water moderator of CANDU-type reactors. It would be difficult to trace gram quantities of tritium, but safeguarding of the kilogram quantities of significance to a large nuclear weapons program should not be a problem (*8*).

Conclusion. An agreed mutual halt in tritium production would confirm the intent of the superpowers to reduce their arsenals significantly. Use of the Tritium Factor to achieve deep cuts at a steady pace would be responsive to people's hopes for an end to the nuclear arms race. It would remove the need to operate aging production reactors or to build costly new ones, either of which would merely continue the arms race. Finally, it would provide meaningful support for an appeal by the superpowers that all nations avoid nuclear materials production programs that contribute to nuclear proliferation and associated risks of nuclear terrorism (*9*).

REFERENCES AND NOTES

1. Energy Secretary James Herrington recently told a congressional committee, "We're awash in plutonium. We have more than we need." Testimony before the House Appropriations Subcommittee on Interior, 23 February 1988. Hearing of the Subcommittee on Interior and Related Agencies of the House Committee on Appropriations for FY 1989, Part VII.
2. For example, a surplus of tritium could be created for a period by initially retiring those weapons that contain the largest tritium charges. Also, tritium reservoirs of weapons could be recycled more frequently and filled with a somewhat smaller quantity of tritium than is currently the practice without sacrificing weapon effectiveness.
3. Here it is assumed that the annual rate of tritium production after restart is 10% of the prestart inventory. For the United States, a realistic situation would be an initial tritium inventory of 100 kilograms (an average of about 4 grams of tritium per warhead) with the three operable production reactors at Savannah River resuming operations at half-power and producing a total of 10 kilograms of tritium annually. See T. B. Cochran, W. M. Arkin, R. S. Norris, M. M. Hoenig, *Nuclear Weapons Databook* (Ballinger, Cambridge, MA, 1987), vol. II, pp. 62–75.
4. Isotopes other than tritium, such as helium-3, have been considered for boosting, but use of these is considered not to be within reach of present weapons technology.
5. A random sampling system could easily be developed to provide sufficient assurance of detection. Inspectors would also be able to sample air and water, but verification by this means may prove to be impractical because of the difficulty in distinguishing between dedicated tritium production and other modes of reactor operation. In particular, at heavy water moderated power reactors (for example, CANDU-type), it would be virtually impossible to detect tritium production in targets against the background of tritiated water vapor normally released from the moderator.
6. It should be noted that even with a secret stockpile of tritium, either side would be in an advantageous position to readily terminate or "break out" of a tritium-cutoff agreement only if it also managed, without being detected, to build or maintain a large secret store of warheads utilizing tritium and of the needed delivery systems—a most unlikely event. A secret tritium stockpile could be applied to building a large number of new tritium warheads, but this would take a period of time and create a "national crisis" situation sufficient to permit the other side to take extraordinary steps to respond in kind.
7. This situation could change if fusion reactors, which would utilize and produce kilogram quantities of tritium, became a reality. However, the lead time for commercial development of fusion reactors is suficiently long to allow the superpowers and the IAEA to develop safeguards and inspection measures sufficient to prevent diversions of tritium from civilian fusion activities to weapons programs.
8. The. United States needs to produce about 5 kilograms of tritium annually to maintain its inventory.
9. See P. Leventhal and Y. Alexander, Eds., *Preventing Nuclear Terrorism*, The Report and Papers of the International Task Force on Prevention of Nuclear Terrorism (Lexington Books, Lexington, MA, 1987), pp. 45–49; Frank von Hippel, in *Nuclear War, Nuclear Proliferation, and Their Consequences*, Sadruddin Aga Khan, Ed. (Clarendon Press, Oxford, 1985), pp. 65, 66, and 74.