The United States Nuclear Weapons Program

The Role of the Reliable Replacement Warhead

ADVANCING SCIENCE, SERVING SOCIETY

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Nuclear Weapons Complex
Assessment Committee

AAAS
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American Association for the Advancement of Science
Center for Science, Technology and Security Policy
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Background and Charter

The American Association for the Advancement of Science (AAAS), through its Nuclear Weapons Complex Assessment Committee, chartered a study in May 2006 to examine the possible role the Reliable Replacement Warhead (RRW) might play in the future of the U.S. nuclear weapons program. The study was motivated by concerns expressed by the Department of Energy's National Nuclear Security Administration (DOE/NNSA) and the nuclear weapons Laboratories that the current Stockpile Stewardship Program (SSP) might be inadequate to maintain the nuclear stockpile in the long term, and that the RRW approach could be the best way to resolve those concerns. These views were similar to those in the Secretary of Energy Advisory Board Report of July 2005, "Recommendations for the Nuclear Weapons Complex of the Future."

The basic terms of reference for the panel's study were to assess the degree to which the implementation of the RRW concept would alleviate possible risks in the existing SSP. Those risks range from issues with particular weapons systems and the manufacturing complex to more generic concerns about long-term sustainability.

The DOE/NNSA and the Laboratories' specific concerns are as follows: (1) confidence in the long-term reliability of the weapons may be difficult to maintain without testing because of aging and changes introduced by refurbishment; (2) the safety and security of the weapons may not be adequate to meet future standards; (3) maintaining existing weapons may be more expensive and difficult than manufacturing new ones; and (4) the capability to design and produce new weapons may have eroded.

The RRW has been proposed to mitigate these concerns. The intent is to design weapons with larger performance margins, advanced safety and security features, and easier and less costly maintenance, and in so doing, reestablish design and production capabilities. The weapons would not provide new military capability or meet new missions, and the expectation is that these "more reliable" warheads would allow the Department of Defense (DOD) to reduce its inactive reserve, which is kept in part to hedge against future technical uncertainties.

These concerns and claims are what the panel was asked to evaluate.

To carry out the work, the AAAS assembled a panel of individuals with broad backgrounds in diverse aspects of the nuclear weapons area. The panel included people who had managed much of the nuclear weapons complex; former staff from the nuclear weapons Laboratories, including three former Laboratory directors; academics in relevant technical disciplines who are frequent members of nuclear review committees; and others with expertise in such fields as nonproliferation and arms control. The panel was supported by staff from both the AAAS and the American Physical Society.

The panel formally met three times, twice in Washington, D.C., and once in Livermore, California, to hear presentations from staff of the DOE/NNSA; the Lawrence Livermore, Los Alamos, and Sandia National Laboratories; the DOD; Congress; and others with special expertise in such areas as arms control. The sessions were unclassified with the exception of one afternoon in Livermore, and the focus was on the RRW as an approach; there was no attempt to evaluate the details of the nuclear designs proposed for the first RRW.

One difficulty presented throughout the process was that the RRW program is at an initial stage, and as a result, its risks were not well defined and virtually no details were available about its costs, scope, or schedule. Thus, in weighing the risks of proceeding with an RWW relative to the risks of continuing on a non-RRW path, the panel members simply used their individual knowledge and experience to make those assessments, realizing that a comprehensive determination would depend on having more information in the future.

This report begins with the panel's main conclusions, which pull together many of the specific assessments in the body of the report. A summary follows, highlighting the principal points discussed in the body of the report. Two panel members elected to add brief personal commentaries, which are provided at the end of the report. Biographies of the panel members, meeting agenda details, and footnotes are included in the appendixes.

Nuclear Weapons Complex Assessment Committee

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Benn Tannenbaum, American Association for the Advancement of Science

Conclusions

Stockpile stewardship has satisfactorily maintained U.S. nuclear weapons for nearly 15 years without nuclear testing. Sustaining this record will require a continuation of the commitment to the scientific facilities and staff at the National Laboratories and modernization of the production complex (whether or not the stockpile includes Reliable Replacement Warheads [RRWs] in addition to legacy weapons that have undergone life extension programs [LEPs]).

Data on aging are obtained through surveillance of the stockpile and from laboratory studies, such as the recent work on plutonium. The appearance of age-related defects in the surveillance data on older systems has led some observers to postulate that a "frequent repair" period may be approaching in the future, but it has not yet been seen. Although the progress in both experiments and computational modeling in the Stockpile Stewardship Program (SSP) has been extensive, it is not yet sufficiently mature to predict future aging of the stockpile. The study of aging will remain largely empirical.

The recent study on plutonium aging indicates that plutonium pits may last considerably longer than could be inferred from previous data. The lifetimes of pits may be limited by chemical processes, such as corrosion of pit materials. Although these findings imply a longer useful lifetime of pits and warheads, at some point, the United States would have to build or rebuild warheads and produce certifiable pits if it is to maintain a reliable nuclear arsenal.

The independent designs for the first RRW could lead to a final design that is certifiable without a nuclear test. The design for the first proposed RRW is being completed and the selection of Lawrence Livermore as the lead laboratory for that process was announced on March 2, 2007. Both the certification of that design and the method of certification, however, still need to go through a rigorous implementation and demonstration process.

Although the first RRW could act as a catalyst for modernizing the complex, the process would present significant challenges. The first RRW is scheduled to be produced in 2012 at existing facilities that are expected to operate at a much higher level than they have demonstrated in recent years (especially the pit production facility at Los Alamos).

The refurbishment of the production complex requires a formal environmental impact process (per the National Environmental Policy Act), and that process has just begun. The riskiest period for the complex will be during the next two or more decades when the following activities will all be taking place at many sites: construction, ongoing surveillance, maintenance, LEPs, and potentially building RRWs. Although an RRW-based stockpile might make this process easier in terms of the final complex, it could make the transition more difficult because of the increased workload associated with building the new weapons and fixing their possible birth defects.

The costs associated with continuing refurbishment almost certainly will add to the Department of Energy's National Nuclear Security Administration's (DOE/NNSA) budget in the short term, unless the LEPs are significantly curtailed or other reprioritization takes place. The long-term savings envisioned for an RRW-based complex will depend on stockpile size and diversity, the operational environment, and the demonstrated efficiency of the new complex. Among these factors a major reduction in operational costs has the greatest potential for savings, but the track record is not encouraging in that regard.

Pursuing the initial phases of this path could be a prudent hedge against the uncertainties of an all-legacy future and an opportunity that might result in the creation of a better long-term posture.

The full engagement of the DOD is necessary to set the conditions under which an RRW can be introduced into the arsenal. This is particularly important for an RRW that does not provide a new military capability or respond to a mission need. Both the Nuclear Weapons Council and the Joint Requirements Oversight Council have endorsed the RRW concept as an essential first step. The technical standards, budgeting, and field-testing must now become an early and coordinated part of a joint planning process with the DOE/NNSA as it pursues its Complex 2030 vision.

Because of the above considerations, it is clear that the success of the proposed RRW program strongly depends on the engineering and project management skills of the DOE/NNSA in concert with the DOD. Most of the anticipated benefits of the program would occur in the long term through a more effective production complex and more easily maintained weapons with enhanced safety and security features. In the absence of detailed plans on scope, schedule, and costs, however, it is not possible to make judgments on the trade-offs in the weapons and the complex among stockpiles with varying mixes of legacy and LEP weapons and RRWs. Such assessments can be made only when stockpile requirements have been set and cost and schedule predictions have been made in response to those requirements.

If the RRW and Complex 2030 programs are pursued along their proposed paths, they will have a number of international impacts, including concerns regarding nonproliferation and arms control. Many of those concerns center on compatibility with the Treaty on the Nonproliferation of Nuclear Weapons (NPT) and issues such as whether the RRW is a new weapon. To respond, the United States should carry out a comprehensive assessment of those impacts and make a systematic effort to ensure that foreign perceptions of the programs are consistent with U.S. intent and its broad national security goals, including nonproliferation. Engaging the other major nuclear weapons states and states that depend on the United States for nuclear deterrence in those discussions would add credibility and value to the assessment.

Stockpile stewardship has succeeded politically because of the dual commitment to a sound nuclear weapons program and to one that proceeds without nuclear testing. Congress has provided initial legislation defining the framework for a potential RRW program. There are no presidential or cabinet-level statements from the administration that clearly lay out the role of nuclear weapons in the post–Cold War, post-9/11 world that make the case for and define future stockpile needs and that argue the case for the RRW. Based on experience, there cannot be a major transformation of the sort envisioned by the Complex 2030 and RRW programs without greater White House leadership to produce substantial bipartisan support. Because the transformation of the nuclear weapons complex is expected to take 25 years (i.e., several administrations and a dozen Congresses), a successful program will almost certainly require an approach that balances weapons program goals with those of nonproliferation and arms control.

Thus, there are risks in either long-term outcome—a stockpile that would be composed of all or mostly RRWs, or one that would be composed of all or mostly legacy warheads—and it is difficult today to weigh the pros and cons. There are some risks in even starting down a path toward a stockpile that has some (or many) RRWs. Pursuing the initial phases of this path could be a prudent hedge against the uncertainties of an all-legacy future and an opportunity that might result in the creation of a better long-term posture. It will be crucial to continually reevaluate the risks, costs, and benefits of these alternative futures—and to adapt accordingly.

Summary

A fundamental question must be answered in developing a long-range plan for the nation's nuclear weapons complex. That is, what is the long-term stockpile required by the Department of Defense (DOD) and how should the Department of Energy (DOE) size the capability of its complex to meet those requirements? This issue has not been directly addressed by the executive branch since the end of the Cold War, and many recent studies (e.g., by the Defense Science Board) have highlighted the "need for a national consensus on the nature of the need for and the role of nuclear weapons." The panel does not try to answer that question here, but instead uses the Moscow Treaty (an operationally deployed arsenal of 1,700 to 2,200 warheads) and the DOE's current planning guidelines (a manufacturing capability for a little more than 100 warheads per year) as its baseline numbers. Other important nonproliferation and arms control issues affect the Reliable Replacement Warhead (RRW) decision, but they are beyond the scope of the present paper, including what is a "new" weapon; what is the impact of adding "untested" weapons to the stockpile; and what effect does the RRW plan have on the Treaty on the Nonproliferation of Nuclear Weapons (NPT), Iran, North Korea, and other issues? The panel tries to frame the international and national policy issues associated with the program but does not address the specifics in any detail.

The panel's approach was to focus on the basic terms of reference: "To assess the degree to which implementation of the Reliable Replacement Warhead concept would alleviate possible risks in the existing stockpile stewardship program."

The Stockpile Stewardship Program

Since its inception in the early 1990s, the Stockpile Stewardship Program (SSP) has satisfactorily met its two major challenges: (1) sustaining the legacy stockpile from the Cold War era, and (2) doing so without nuclear testing. It has created state-of-the-art technical tools to surveil and assess the nuclear weapons in the stockpile, and it has used these to provide annual certifications of those weapons since 1996. It has been less effective in reestablishing the production complex necessary to refurbish the legacy weapons, although it has carried out successful life extension programs (LEPs) for some weapons systems and others are in process or scheduled for the coming decades. The panel strongly supports continued investment in the scientific facilities and staff. This investment is essential to maintain the capability to assess and certify weapons without nuclear testing. A higher near-term priority for the program, however, is to develop a responsive production complex (i.e., one that can dismantle, refurbish, or build replacement weapons in a timely and affordable manner). This is true whether LEPs, RRWs, or some combination provides the basis for the future stockpile.

Unlike the production complex issue, about which there is a reasonable degree of certainty and consensus, there is less agreement about long-term confidence in weapon performance. Data on aging are obtained through surveillance of the stockpile and from laboratory studies, such as the recent work on plutonium. The appearance of age-related defects in the surveillance data on older systems has led some observers to postulate that a "frequent repair" period may be approaching in the future, but it has not yet been seen. Although the progress in both experiments and computational modeling in the SSP has been extensive, it is not yet sufficiently mature to predict future aging of the stockpile. The study of aging will remain largely empirical.

The recent study on plutonium aging indicates that plutonium pits may last considerably longer than could be inferred from previous data. The lifetimes of pits may be limited by chemical processes, such as corrosion of pit materials. Although these findings imply a longer useful lifetime of pits and warheads, if the United States is to maintain a reliable nuclear arsenal, at some point it would have to build or rebuild warheads and produce certifiable pits.

Furthermore, as one looks to the long term, it is possible that changes introduced by aging or multiple repair cycles will gradually undermine confidence in the performance of the weapons in the absence of nuclear testing. Conversely, continued progress in the understanding of weapons through the stewardship program may offset this concern. Maintaining a high-quality technical staff, which is at the heart of confidence, will be equally daunting under all circumstances. Special efforts will be required to ensure competence in weapons activities that reflect state-of-the-art science, technology, and manufacturing.

The Reliable Replacement Warhead Program

The RRW concept has been introduced as a means to alleviate several perceived difficulties with the current SSP and LEP, which relate to the characteristics of some of the current weapons and the production complex. The first difficulty is that many warhead systems have relatively tight performance margins, so that aging or other problems mean more maintenance activities, which can be costly. In addition, incomplete understanding of all the relevant phenomena in nuclear weapon performance introduces uncertainty in assessing the impact of changes that occur during such repairs. Second, the manufacturing facilities needed for some of the systems have become technologically obsolete and environmentally difficult. Third, there is a general goal to enhance the safety and security (collectively called "surety") in the weapons systems for their intrinsic value as well as to reduce operational costs.

The proposed RRW program aims to respond to these concerns by designing replacement weapons that relax the high yield-to-weight constraint that dominated the Cold War stockpile, so that it can meet these reliability, maintenance, and surety objectives. More generally, it provides a hedge against perceived uncertainties in long-term sustainability of the legacy/LEP stockpile. In doing so, the program provides the basis for a modern production complex that can build and refurbish weapons with greater reliability and in a more efficient, less costly, and environmentally improved fashion.

The panel urges a design approach to RRWs that emphasizes test pedigree and performance margin with other features being incorporated within that framework. This should lead to greater confidence in early replacement weapons, as well as enable the customers and Laboratories to more thoroughly explore the trade-offs among performance, reliability, surety, and manufacturability features in later designs.

The panel advocates independent reviews through the use of intensive red teams that go beyond the traditional peer-review activities among current Laboratory designers. In the absence of nuclear testing, every effort should be made to detect difficulties and flaws with new designs to avoid the delusion of "greater confidence as one gets further away from having tested that confidence." The panel recommends that red-team reviews be applied to the non-nuclear areas such as components, production processes, and integration with the delivery vehicle to guard against surprise and reduce birth defects.

The first proposed RRW (called RRW-1) has been under competitive design by the Lawrence Livermore and Los Alamos National Laboratories (each teamed with the Sandia National Laboratory). On March 2, 2007, Lawrence Livermore was selected as the lead laboratory for the process and will now have responsibility for preparing the final design (with support from Los Alamos). RRW-1 is being designed to replace some of the W76 warheads carried on Trident missiles, and, if authorized, the first units are scheduled for production in 2012. Significantly, this warhead would have to be produced essentially with the existing production complex to meet this early date.

The panel finds that the independent designs for RRW-1 prepared by the Laboratories could lead to a final design that is certifiable without a nuclear test. Both the certification method and the certification itself, however, must still go through a rigorous implementation and demonstration process. The panel cautions that the design in and of itself may not lead to many of the conjectured benefits of the RRW program.

In addition, although RRW-1 could be a useful catalyst for "transforming the complex," it would also present the production complex with considerable challenges. For example, the pit production capability at Los Alamos would have to move from the demonstration stage to assembly line operation, and the throughput at Pantex would have to accommodate the production of RRWs as well as its ongoing dismantlement, surveillance, and LEP activities. RRW-1 would be the test-bed for the DOE/NNSA's ability to carry out a complex program on budget and on schedule. If RRW-1 is pursued, the panel recommends that it adopt conservative and realistic goals and that it let the execution of the project establish credibility and provide data for more innovation in possible later phases of the RRW program. The panel has concerns that DOE/NNSA and the Laboratories face the risk of overselling the benefits of RRW-1 when many of the RRW program goals may be achieved only after years of experience and demonstrated accomplishment.

Complex 2030

In the fall of 2006, in concert with its effort to begin preparation of a Supplemental Programmatic Environmental Impact Statement, the DOE/NNSA publicly released its thoughts on strategies and planning scenarios for the future of the nuclear weapons complex. This plan is known as Complex 2030, and the RRW is an integral part of the strategy. A focus of the strategy is on Special Nuclear Materials (SNM) and the objective is to consolidate SNM at a much smaller number of sites than at present. Other goals include a general reduction in the size and environmental impact of the manufacturing and testing activities. The actual stockpile can be determined only by the DOD, but for planning purposes, the Treaty of Moscow puts the stockpile at 1,700 to 2,200 operationally deployed strategic weapons, although it is silent on the question of reserve warheads.

When all factors are included, the DOE/NNSA's current estimate is that the complex will be sized to refurbish or build in excess of 100 weapons per year (and indeed the Notice of Intent [NOI] indicates a production capability of 125 pits per year). These quantities are in excess of what operating practices have demonstrated in the last few years at the major nodes in the complex, such as Y-12, Pantex, and TA-55. Legacy weapon maintenance and LEPs, as well as potential RRWs, must be simultaneously incorporated for many years in a comprehensive plan. The initial steps in this regard are laid out in the recent Complex 2030 Transformation Plan.

...the highest priority in managing the current production complex is to increase the weapon throughput at Pantex, which must handle dismantlement, surveillance, and LEPs. The most important element for the future complex is a plutonium strategy, especially if RRWs are to form the basis for much of the future stockpile.

The panel believes that the highest priority in managing the *current* production complex is to increase the weapon throughput at Pantex, which must handle dismantlement, surveillance, and LEPs. The most important element for the *future* complex is a plutonium strategy, especially if RRWs are to form the basis for much of the future stockpile.

No published numbers are available for the predicted cost, scope, and schedule of work at the production complex through 2030. Simple estimates indicate that a considerable investment will be required to develop a responsive complex, and further expenses would be associated with the production of RRWs (and fixing their possible birth defects). There is limited financial flexibility under the current scenario of a constant NNSA budget. Even with a reduction in the LEPs (as occurred with the cancellation of the W80 LEP) significant new funds or major reprioritization may be needed. DOE/NNSA indicates it expects to recover some of these costs through operational savings in an RRW-based complex, but these savings are unlikely to occur before the 2030 period (if then).

The panel strongly recommends that a cost, schedule, and scoping plan be developed in parallel with the National Environmental Policy Act documentation required for Complex 2030. It further urges that third-party vetting of the cost plans, either by outside groups or by a process such as the Lehman reviews carried out by the DOE Office of Science, be used to validate the results. It is particularly important to review the plan as a whole, because problems at one site can gridlock the entire system. It will be difficult to manage the renovation of individual sites, but even harder to manage the interfaces when both rebuilding and nuclear weapons work are taking place simultaneously.

The Department of Defense

Three different parts of the DOD are involved in nuclear weapons: the Navy and Air Force that procure and deploy them; Strategic Command, which would employ them; and the Office of the Secretary of Defense (OSD), which sets policy and overall guidance. The DOE/NNSA effort is wholly dependent on the stockpile requirements set by the DOD in response to national policy—for example, the sizing of the production complex is set by those requirements. The DOD must ensure that new warheads undergo a rigorous regimen of flight and other operational tests.

The RRW is a particularly unusual situation in that it does not respond to a new military capability or mission need, but relaxes the yield- to-weight requirement and emphasizes other features, such as long-term reliability, surety features, and ease of maintenance and manufacture. The panel believes that if RRWs are to become significant elements of the stockpile, the DOD needs to be clear about which weapon characteristics are most important; lay out in advance the long-term stockpile size and diversity so that the DOE can size the complex; and engage at all levels in the planning, budgeting, and testing process from the beginning of the program.

Policy, Congress, and the Administration(s)

If the RRW and Complex 2030 programs are pursued along their proposed paths, they will have a number of international impacts, including concerns regarding nonproliferation and arms control. In particular, some countries could view the RRW as contrary to both the spirit and letter of the NPT unless explicit and credible efforts to counter such assertions are made. To mitigate those concerns, the United States should carry out a comprehensive assessment of U.S. nuclear weapons policy and the international impact of that policy, and make a systematic effort to ensure that this policy is consistent with national security goals, including nonproliferation. Engaging the other major nuclear weapons states and states that depend on the United States for nuclear deterrence in those discussions would add credibility and value to the assessment.

Congress has supported the initial steps toward an RRW program, but it has also laid out seven criteria that impose tight controls on any such program. On December 1, 2006, the Nuclear Weapons Council endorsed the RRW approach, and on February 20, 2007 the Joint Requirements Oversight Council endorsed the decision to proceed with the RRW concept. Since the Nuclear Posture Review of 2001, which redefined the strategic Triad (offense, defense, and infrastructure), there have been no presidential or cabinet-level administration statements dealing with nuclear weapons. In particular, there have been no policy statements that articulate the role of nuclear weapons in a post–Cold War and post-9/11 world and lay out the stockpile needs for the future.

The SSP has enjoyed relatively good bipartisan support, which has provided facilities and resources that enable it to do its two jobs: (1) sustain the nuclear deterrent capability and (2) do so without nuclear testing. This has allowed it to be relatively neutral in terms of its nonproliferation and arms control policy impacts. The panel believes that such a balanced approach is crucial if an RRW-based future is to succeed.

The panel observes that there have been several plans to redo the nuclear weapons complex over the years and none have reached fruition, in part because of their scope and the long timescale involved. The panel believes that any plan for the nuclear weapons enterprise must have a clear rationale and bipartisan basis if it is to be sustained over 25 years (i.e., through several administrations and a dozen Congresses). In the absence of this rationale and support, and perhaps even with it, the plan must build in decision points and alternatives so that the needs of future nuclear weapons programs and policies can be met.

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Introduction

Soon after the end of the Cold War, the Stockpile Stewardship Program (SSP) was developed to maintain the safety and reliability of U.S. nuclear weapons without the need for nuclear testing. With the SSP in the middle of its second decade, its successes, difficulties, and future path have been or are being examined by many groups. These include its proprietor, the Department of Energy's National Nuclear Security Administration (DOE/NNSA); the authorizing and appropriating committees of Congress; and its direct customer, the Department of Defense (DOD), specifically the Office of the Secretary of Defense (OSD), Strategic Command (STRATCOM), and the Navy and the Air Force. It also includes a number of outside reviews, such as those completed or being carried out by the Secretary of Energy Advisory Board (SEAB) Task Force, the Government Accountability Office (GAO), the Congressional Research Service (CRS), the Threat Reduction Advisory Committee (TRAC), JASON (scientific advisors to the DOD), and the Strategic Advisory Group/Stockpile Assessment Team (SAG/SAT), as well as this report sponsored by the American Association for the Advancement of Science (AAAS).[i] Each evaluation asks some form or subset of the following question: Is the SSP providing a safe, credible, and reliable stockpile of nuclear weapons that is affordable and sustainable?

The preliminary answer to this query is that SSP has done a satisfactory job and may be able to support the enduring nuclear weapons stockpile for the foreseeable future. The possibility has been raised, however, that the risks in some areas may be growing and that changes are needed in the program. Generally speaking, these risks fall into three categories: technical, programmatic, and political. Technically, the major issues raised relate to the characteristics of some weapons systems and to concerns that changes caused by aging or multiple repair cycles will undermine confidence in weapon performance. Programmatically, inadequacies in the production complex translate into questions about whether the existing stockpile can be maintained safely, securely, and reliably for the long term. Political risk is driven by the observation that the projection of the current costs may lead to a need for substantial additional funding, and that the country may lose interest in supporting a program whose national security role is not well articulated and, at the same time, is becoming increasingly costly.

The NNSA's proposed solutions for addressing and mitigating these risks are as follows: (1) change the current production complex to improve manufacturing processes and operational efficiencies, and (2) pursue the Reliable Replacement Warhead (RRW) program, in which a new warhead type (and subsequent generations of different RRW types) would be manufactured to replace legacy warheads of the current stockpile. The goals of the RRW program would be to design for greater long-term reliability, for ease of manufacture, and with modern safety and security features. Thus, in the long run, its proponents assert an RRW would be a safer and more secure warhead, and potentially would lead to a reduction in funding needed to maintain the U.S. nuclear weapons stockpile. The RRW program could therefore "transform" both the stockpile and the NNSA weapon complex to make both better suited to future needs.

...many recent studies... have highlighted the "need for a national consensus on the nature of the need for and the role of nuclear weapons."

In addition to an evaluation of the RRW proposal in comparison with the present SSP, the panel was cognizant of a more fundamental question: What is the long-term stockpile required by the DOD and how should the DOE size the capability of its complex to meet those requirements? This issue has not been directly addressed by the executive branch since the end of the Cold War, and many recent studies (e.g., by the Defense Science Board) have highlighted the "need for a national consensus on the nature of the need for and the role of nuclear weapons." The panel does not try to answer that question here, but instead uses the Moscow Treaty (an operationally deployed arsenal of 1,700 to 2,200 warheads) and DOE's current planning guidelines (a manufacturing capability of a little more than 100 warheads per year) as its baseline numbers. Many nonproliferation and arms control issues are beyond the scope of the present paper, including what is a "new" weapon; what is the impact of adding "untested" weapons to the stockpile; and what effect does the RRW plan have on the Treaty on the Nonproliferation of Nuclear Weapons (NPT), Iran, North Korea, and other issues? The panel tries to frame the international and national policy issues associated with the program but does not address the specifics in any detail.

The panel took the approach of first learning about the status of the SSP and the RRW from the active participants in the program and then using its collective experience to judge the credibility and value of various options. All members of the group have been involved in the technical work, management, or review of nuclear weapons activities, most for several decades. Some are still working with the NNSA or the weapons Laboratories in consultant roles, and some are part of other review mechanisms. As a group, the panel's collective focus has been to examine the risks and benefits in the various alternative futures.

The Stockpile Stewardship Program

During the Cold War, nuclear weapons entered the stockpile through a sequence of design, test, and build; the stockpiled weapons were then periodically evaluated, altered, and eventually retired. A new warhead type was introduced into the stockpile (i.e., carried through the design, testing, and production sequence) every year or two, and there were generally several in the "pipeline" at any one time. New nuclear warheads were designed in direct response to military requirements or were driven by technological possibilities that were then adopted by the military. These new nuclear explosive designs were simulated in great detail using computers and laboratory-scale experiments and then tested in integral full-scale nuclear explosive experiments. Once a design type had been accepted by the military (typically after a competition between the two design laboratories), it was engineered for the intended application and manufactured by the production complex at which various sites made the different components that were shipped to the final assembly plants. Typically, a warhead would remain in the active stockpile for around 20 years, although some were retired much earlier and others remained well beyond that nominal figure. The weapons in stockpile were surveilled, assessed (sometimes with nuclear tests), and occasionally refurbished, but the program was dominated by the frequent introduction of new designs and the retirement of old ones.

Nuclear testing and new warhead design and production ceased altogether following the end of the Cold War (the last U.S. test was on September 23, 1992), and no new designs have been introduced into the stockpile since the W88 in 1989. A number of the manufacturing plants were closed down for economic, safety, or environmental reasons. Most notable was the closure of the Rocky Flats plant in Colorado where all modern plutonium pits were manufactured. The overall budget for the nuclear weapons program declined substantially, and only the substitution of technology transfer for weapons work and funding by other agencies and other parts of the DOE allowed the Laboratories to avoid major reductions in staff. In 1993, the Stockpile Stewardship Program (SSP) was created with a goal of maintaining the safety and reliability of the existing stockpile without the need for nuclear testing. This program became the centerpiece of the nuclear weapons program following the signing of the Comprehensive Test Ban Treaty (CTBT) in 1996. The SSP was founded on the belief that these goals could be achieved by preserving and reinvigorating the intellectual base of the Laboratories; employing an array of advanced computers, modeling approaches, and experimental techniques; and implementing a more comprehensive stockpile surveillance program.

The SSP replaced the predominant design-test-build sequence of the Cold War with a sequence focused on surveying, assessing, and refurbishing the stockpile, along with a vigorous scientific program to gain a better understanding of nuclear weapons in the absence of nuclear testing. The DOE and its predecessor agencies had always supported a formal stockpile surveillance program to examine the condition of nuclear weapons in the U.S. stockpile, but with the end of nuclear testing, new Laboratory tools were needed to support stockpile surveillance. The SSP continued the existing surveillance program by systematically inspecting samples of each of the nine kinds of warheads in the active stockpile on an annual basis, which included laboratory inspection and destructive testing of a small number of nuclear components. Any issue found during this surveillance (e.g., aging problems such as cracks or corrosion) would be assessed for its impact on safety and reliability using a new family of supercomputer codes and new laboratory facilities. Problems would be corrected by refurbishment of the warhead using the production complex. Furthermore, a schedule of systematic maintenance and upgrading would be instituted. In this Life Extension Program (LEP), each warhead type would be refurbished on a scheduled basis to ensure the long-term health of the stockpile and more cost-efficient workload balancing within the complex. The most problematic part of the surveillance and LEP was the plutonium pit, because it could not be tested to demonstrate nuclear performance.

SSP… has made significant advances in the basic science of nuclear weapons performance and the properties of nuclear explosive materials; developed and certified new processes for manufacturing plutonium pits… and established, vetted, and applied… a systematic process of assessment of the U.S. nuclear stockpile.

A major part of the SSP was an effort to better understand the science involved in nuclear explosions. The objective was to reduce uncertainties so that the level of confidence in assessment of weapon performance would be comparable with what was once achieved with a combination of computer calculations, non-nuclear experiments, and nuclear tests, but now without nuclear tests. Ultimately, this led to QMU (Quantification of Margins and Uncertainties), a systematic way of evaluating the performance margin of the nuclear warhead. As long as the margin was large compared with the technical uncertainties, there should be confidence in the nuclear performance of the warhead.

The SSP took several years to develop on both a technical and budgetary basis. By 1995, however, the nuclear weapons Laboratories had informed President Bill Clinton that it was likely they could maintain the stockpile in the SSP without nuclear testing, and he asked the Senate to approve the CTBT. In return, he agreed that a necessary condition for success was the vitality of the three weapons Laboratories, and he also put important safeguards into the language requesting Senate approval of the treaty. Although the Senate did not ratify the CTBT, there has nonetheless been a de facto ban on testing for nearly 15 years. The (increasing) SSP budgets have been funded by several Congresses and two administrations (albeit not without some difficulty), and a critical ingredient has been the relatively bipartisan support of the SSP concept.

More than a decade after its inception, the SSP has a body of substantial achievements. It has made significant advances in the basic science of nuclear weapons performance and the properties of nuclear explosive materials; developed and certified new processes for manufacturing plutonium pits (although this is just now reaching the operational phase); and established, vetted, and applied on an annual basis a systematic process of assessment of the U.S. nuclear stockpile. These achievements were possible because SSP challenged and rejuvenated the technical personnel in the Laboratories associated with the nuclear weapons program and supplied the staff with the resources and facilities needed to do their new job. In particular, SSP built the world's greatest supercomputing capability and applied it successfully to understand and mitigate stockpile issues. It has constructed, or is in the process of constructing, state-of-the-art laboratory facilities, including (1) the National Ignition Facility (NIF); (2) the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT); (3) Z, a Sandia National Laboratory machine designed to study fusion; (4) and a subcritical experiments capability at the Nevada Test Site (NTS). These facilities provide new insights into weapons science and weapon performance. It has used these new tools to resolve many issues from earlier tests and to teach a new generation of scientists about the stockpile and nuclear design. New surveillance diagnostics have been developed and used in the annual evaluation process. The LEPs for the W87 have been carried out, the program for the W76 is well under way, and others have begun or are scheduled to begin in FY2009. Most important, since 1996, the Laboratory directors and the commander of STRATCOM have had the technical and institutional tools needed to annually assess for the DOE and the DOD whether the stockpile is safe and reliable without nuclear testing.

Why, then, is there concern about the future of the SSP? There are two central issues: (1) lack of weapon production complex efficiency and capability; and (2) uncertainty about the ability to maintain confidence in weapon performance without nuclear testing, as weapons age, as multiple changes are introduced through LEP refurbishments, and as changes in assessed performance occur because of improved scientific understanding.

There is strong consensus that a major shortcoming is the lack of a responsive production complex (i.e., one that can dismantle, refurbish, or build new weapons in a timely and affordable manner). Some capabilities have been restored, but the uranium work at Y-12, the weapons throughput at Pantex, and the pit production capability at Los Alamos are not yet at the desired levels. Many factors contribute to this, including aging facilities that, in many instances, are more than 50 years old; lack of resources and prioritization to invest in replacing or modernizing those facilities; and more stringent safety and security requirements that have greatly increased the cost of doing business, made efficiency more difficult to achieve, and made the operational environment a more difficult one within which to carry out work.

Unlike the production issue, about which there is a reasonable degree of certainty and consensus, there is less agreement about long-term confidence in weapon performance. A major question concerns the issue of aging and its impact on performance margins. An analogy for lifetime issues has been proposed: like any manufactured product (e.g., cars), there is a "bathtub curve" in which a number of birth defects gradually reveal themselves over the first few years of a product's life (some because of bad design, some because of imperfect production), then a relatively quiescent period when the gadget is trouble free, and eventually an aging defects period in which various parts begin to wear out and need to be fixed or replaced on a frequent basis. In the nuclear weapons world, observations of defects of any kind are referred to as findings (among which there are *significant* findings), and a chart of these over the years is a good indicator of the progress of warheads through their life cycle. These findings through 1995 are documented in a Sandia report, and recently, this report was partially updated. No sharp "frequent repair" upturn has been seen in the data in these reports, although there have been age-related findings, particularly in the older systems, which have led to speculation that the onset of the postulated increase curve could occur in the not-too-distant future.

In general, most of these age-related findings are due to the more numerous non-nuclear parts of the warhead system. These parts are relatively easily tested and fixed in the sense that they do not require nuclear testing. But some significant findings involving nuclear and non-nuclear parts are potentially more serious, because they raise questions about whether the findings can be assessed without nuclear testing and because remediation may require cycling through the full production complex with all the concerns described above. For example, recent plutonium aging data show that the properties of plutonium metal change very slowly because of radioactive decay with minimum plutonium lifetimes approaching a century.[ii] Consequently, chemical processes (e.g., corrosion of pit materials) rather than radioactive properties will determine the lifetime of pits in most systems. In any case, pits probably will need to be replaced at some point, and it is unclear whether the projected capability will be adequate. Changes have been observed in other parts of the physics package that may eventually require repair. Furthermore, as one looks to the future, it is possible that, even with a functioning production complex, changes introduced by aging and frequent repairs will, in the absence of nuclear testing, gradually undermine confidence in the reliable performance of the weapon (although progress in the SSP could offset this trend).

> ***There are two [concerns]: (1) lack of weapon production complex efficiency and capability; and (2) uncertainty about the ability to maintain confidence in weapon performance….***

Finally, there is the matter of the overall makeup and deterrent characteristics of the stockpile. Currently, there are nine systems in the combined deployed and reserve stockpile: two submarine launched ballistic missile (SLBMs) (the W76 and the W88); three intercontinental ballistic missiles (ICBMs) (the W62, which is scheduled for retirement, the W78, and the W87); two aircraft-delivered bombs (various versions of the B61 and the B83); and two cruise missiles (the W80 and the reserve-only W84). Built up during the Cold War, this strategic stockpile was primarily designed to maximize the yield-to-weight ratio in the warheads and to act as a deterrent to the former Soviet Union. Although the actual numbers of nuclear weapons and delivery systems have been greatly reduced since the end of the Cold War, the deterrent character of the stockpile remains similar to that during the Cold War. It may become less clear how this stockpile relates to U.S. preeminent security objectives in the post-9/11 era, especially given the successful development of non-nuclear precision strike weapons. Accordingly, some military planners want to develop nuclear warhead options (e.g., lower-yield weapons) that could play a more active role in national security discussions, although Congress has opposed consideration of "new missions" for the stockpile. A critical question, then, that has not yet been addressed by Congress, NNSA, DOD, or any other group remains. This is, what is the long-term stockpile required by the DOD and how should the DOE size the capability of its complex to match those requirements? Indeed, this question reinforces STRATCOM Commander General James Cartwright's call for a national "debate on the role of nuclear weapons within the context of the current global environment ... [to] build a long term nuclear investment plan suited to national security goals."[iii]

A critical question, then... [is] what is the long term stockpile required by the DOD and how should the DOE size the capability of its complex to match those requirements?

The Reliable Replacement Warhead Program

The Reliable Replacement Warhead (RRW) concept has been proposed as a means of alleviating many of the perceived risks associated with the SSP (or perhaps as a hedge against them). As generally envisioned, the RRW approach would (1) reduce emphasis on the yield-to-weight criterion used during the Cold War to obtain adequate yield to weight and thus provide enhanced performance margins of the nuclear part of the warhead; (2) allow for more reproducible and easier manufacturing using less toxic materials and more modern processes; (3) result in improved safety and security; and (4) provide greater flexibility in design to meet future needs. If these goals were all met, the product is conjectured to be a warhead system with comparable military effectiveness and higher long-term reliability relative to its legacy predecessor and a modernized and consolidated production complex with fewer sites. Additionally, the product would have reduced processing and transportation costs because of changes in safety and security practices enabled by the new surety features.

Each of these attributes is enabled by a set of technological advances. The most important change is the relaxation of the yield-to-weight criterion that dominated Cold War design. Once that extra freedom provided by relaxed criteria is available to the designer, it can be used for higher performance margins, surety features, different materials, or ease of maintenance and manufacture. Because all of these features can be simultaneously optimized, a major decision for any new design will be which of them to emphasize. The rich nuclear test history (more than 1,000 tests) will provide opportunities to use a tested component (e.g., the primary) as part of the "new" design and thus ensure that the nuclear performance features are bounded by successful past nuclear tests. And, the tools and understanding developed in the SSP provide an additional basis for confidence in the credibility of the design.

The RRW concept was first articulated in its present form a few years ago by the Laboratories. After considerable discussion, in 2005, the Nuclear Weapon Council authorized a joint DOD/DOE study of specific RRW designs, and established an RRW Project Officers Group (POG) to advance this idea. Central to the study was a design competition between a New Mexico team (Los Alamos and Sandia Albuquerque) and a California team (Lawrence Livermore and Sandia California) to produce an RRW design for a warhead that could fit in three different missile reentry bodies and that met the other general requirements described above.

This competition resulted in two such designs with some variants in the details. On March 2, 2007, Lawrence Livermore was selected as the lead laboratory for the process, and it now has responsibility for preparing the final design (with support from Los Alamos). Simultaneously, studies will be undertaken to develop the program definition and cost estimates for the project. Preparations would then ensue to enter full-scale engineering design of the new warhead with a scheduled initial operational capability date of 2012.

So far, the design has been for a particular warhead, called the RRW-1, and is intended to replace some of the W76s. Many of the posited advantages of the RRW approach could accrue as more types of RRWs might be added to the stockpile in coming years and perhaps decades, replacing legacy weapons and curtailing the need for continuing LEPs. It could well be that a mix of RRWs and legacy weapons would provide the lowest risk and most cost-effective future stockpile. But plans for possible future stockpiles using various mixes and evolutions of RRW and legacy weapons have not yet been completed. Thus, in parallel with decisions and progress on RRW-1, the DOD would develop a stockpile plan for the coming decades, and the DOE would prepare a plan to replace its current Program of Record with one that gradually replaces the LEPs on existing systems by involving RRWs of various kinds. This program would entail the development and public airing of a Supplement to the 1996 Stockpile Stewardship and Management Programmatic Environmental Impact Statement (PEIS) that described all the changes and future configuration for each of its sites. Concurrently, but not as a National Environmental Policy Act (NEPA) requirement, the DOE would develop a budget to reflect both the investments and operating costs expected at each of the laboratory sites in New Mexico and California and the appropriate production sites.

Finally, the administration will need to incorporate these plans (and costs) in its annual budget submission to Congress. To date, Congress has offered cautious support for the RRW concept, and legislation has set stringent conditions for the program to satisfy. In addition to the properties described above, the legislation specifically requires that the RRW be designed and built to reduce the likelihood of nuclear testing (compared with the existing stockpile), lead to a smaller stockpile, fulfill only current mission requirements, contain improved surety attributes, and save money, at least on a life-cycle basis.[iv]

The Panel's Analysis

The panel held three meetings. The first and third meetings were held at the American Association for the Advancement of Science in Washington, D.C., on May 31–June 1, 2006, and October 24–25, 2006. The second meeting was held at the Lawrence Livermore National Laboratory in California on August 10–11, 2006. Participants heard briefings by a number of NNSA officials, design team leaders and members, other speakers from the three nuclear Laboratories, individuals with special nuclear expertise, people with long histories in the arms control field, officials from the DOD, and staff from Congress. Other primary sources included the SEAB report issued in October 2005, the GAO report released in April 2006, the Defense Sciences Board (DSB) study on Nuclear Capabilities, reports from the CRS, and the testimony of NNSA officials, especially that of the deputy administrator for defense programs, on April 5, 2006.[v] Several of the panel's members served on the DSB, others are and will be part of a planned JASON (scientific advisors to the DOD) review, some are on the University of California National Security Panel, and others serve on the TRAC (the advisory committee for the Office of the Under Secretary of Defense for Acquisition and Technology [OSD/AT&L]), and the STRATCOM SAG/SAT. The presentations were unclassified except for one classified session, which was held at Livermore to probe more deeply into some of the design and testing issues.

The basic terms of reference for the panel's study were to assess the degree to which the implementation of the RRW concept would alleviate possible risks in the SSP. A difficulty throughout the process was that the RRW program was in an early stage, which meant that its risks were not well defined and virtually no details were yet available about its costs, schedules, and scope. Thus, in weighing the risks of proceeding with an RRW program relative to the risks of continuing on a non-RRW path, the panel members relied on their individual knowledge and experience to make those assessments, realizing that a comprehensive determination would depend on having much more information in the future.

The RRW-1 Design

The Laboratories invested substantial technical and management effort in preparing their RRW-1 designs and that was apparent in their briefings to the panel. Each team made use of the SSP tools developed over the past decade as well as archival knowledge of testing history. Both teams were cognizant of the legislative requirements, including the use of materials that may be restricted for environmental or safety reasons in future manufacturing processes. The panel did not examine the technical details of the designs in depth, as JASON, the SAG/SAT, and perhaps others will review them as the designs reach their later stages. The panel is concerned, however, that the teams were overly ambitious in their goal of "transforming the complex" at the expense of conservatism in design to ensure that RRW-1 can be certified and produced. Because continuing certification will inevitably be a worry in the long term (when no living memory of the test era is available), the panel believes that the earliest RRW concepts should put a transparent and strong emphasis on nuclear test pedigree and margin to alleviate any worries about excessive reliance on computer modeling. The more solidly the RRW-1 design is grounded in test history, and the larger its predicted margin, the more likely it will be that it can be deployed without testing.

...even with an RRW program, much of the legacy stockpile most likely will have to be sustained for decades.

Those features must be balanced against the other potential benefits offered by the RRW-1 designs. The DOD will have one set of priorities, stakeholders interested primarily in modernizing the complex will focus on that objective, and others may wish to emphasize surety features. How these criteria are weighted will depend on the needs of the time and will depend on what is technically possible.

The panel believes that an independent review of the final design is a necessary and critical contribution to confidence in the process (in addition to the Laboratories red-teaming each other). One possibility is to use formal outside groups, such as JASON or the SAG/SAT, to perform such an assessment. Another approach is to use a mix of retired weapon designers, new weapons scientists at the Laboratories, and other Laboratory experts not involved in the design to carry out the evaluation. This offers the additional benefits of automatically incorporating nuclear test knowledge as well as educating and training new staff—and it may be one of the best ways to uncover the "unknown unknowns" that are always worrisome in a new design.

A continuing concern was that the design teams risk overselling the program by attempting to invoke a long list of promised benefits that might accrue to the overall program and complex, beyond those of the specific RRW-1 design, including cost savings, reduced likelihood of testing, more responsive infrastructure, ease of certification, greater confidence in reliability, reduction in the size of the stockpile, and increased safety. Although each of these is part of the overall RRW concept and these claimed benefits are desirable, the extent to which they might accrue over the long term is uncertain without detailed plans and comparisons, and without continuing experience derived from specific applications. Substantial caution is appropriate because some of these potential benefits are beyond the control of the Laboratories, for many there is little historical precedent, and they may not emerge as quickly or completely as advertised. Most important, even with an RRW program, much of the legacy stockpile most likely will have to be sustained for decades.

▸ FINDING: **The independent designs for RRW-1 prepared by the Laboratories could lead to a final selected design that is certifiable without a nuclear test. Both the certification method and the certification itself, however, must still go through a rigorous implementation and demonstration process. In addition, we have serious concerns that the design in and of itself may not lead to all of the claimed benefits of the RRW program.**

▸ RECOMMENDATION: **The Laboratories and the NNSA should take any final RRW-1 design through the same sequence that is applied to the annual stockpile certification and should incorporate other features that explicitly deal with the "nontested" nature of the proposed warhead. In addition, we strongly recommend that an independent group be established to provide a red-team evaluation of any new designs and that this critical review process be broader and more intensive than the traditional inter-Laboratory peer review.**

▸ RECOMMENDATION: **The NNSA and the Laboratories should avoid claiming longer-term benefits of RRW-1 (and RRW, in general) to the overall stockpile and to the complex as feasible until the analysis and work to justify those conclusions has been carried out and independently reviewed.**

The Production Complex

Before commenting on individual elements of the complex, a simple analysis helps size the problem. Consider a hypothetical stockpile of 2,500 weapons (counting both deployed and reserve weapons) and assume a functional lifetime of 25 to 50 years per warhead. After that time, the warhead either has to undergo life extension or replacement by a new warhead. For a stockpile composed of both legacy weapons and RRWs, this means producing 50 to 100 sets of warhead components per year, on average, even if no significant birth defects, early aging defects, or common-mode failures occur. Given the unknowns about weapon aging, and possible DOD preference for a higher peak replacement capability as a condition of going to a much smaller stockpile, it is estimated that the NNSA will target LEP and RRW production rates in excess of 100 weapons per year (and, indeed, the 2030 Complex described in the NNSA Notice of Intent indicates a production capability of 125 pits per year).

If the existing stockpile were to be reduced to the 2,500-unit level in 25 years, Pantex assembly and disassembly capacity would have to be much greater than the 100 LEP or RRW weapons per year it currently handles. This additional capacity will be needed to handle the backlog and dismantling of excess weapons that would be required to get down to the targeted 2,500 weapon-stockpile level and to meet the annual surveillance requirements. Pantex assembly and disassembly capacity would have to average at least a few hundred weapons per year throughout the 25-year period. For an all-RRW stockpile, this corresponds to an even greater workload because every new warhead will be accompanied by a dismantlement. In short, the steady-state throughput capability in the complex needs to be on the order of a couple of hundred units per year for stockpiles on the order of 2,500 weapons. A key point is that, even with an RRW program, the legacy stockpile will most likely have to be sustained for decades.

These quantities are in excess of what operating practices have demonstrated in the last few years at the major nodes in the complex, including Y-12, Pantex, and TA-55. Regardless of whether the stockpile is the current legacy-based one with scheduled LEPs, an all-RRW stockpile in some distant future, or something in between, a credible plan is needed to create a responsive infrastructure that can meet the minimum numbers given above. A potential additional complication is that the RRWs may also experience "birth defects" in design, manufacturing, and so on, thus adding *their* repair to the workload on the complex. This could be especially important in the case of non-nuclear components that are almost certain to be redone with modern, but new, mechanical and electrical components.

The panel heard no quantitative analysis that enhanced surety features in the RRW designs would be sufficient to substantially reduce the current reliance on guns, guards, and gates for the security that governs the work in most parts of the complex and that drives costs up and throughput down. Equally demanding is the development of a plan that can incorporate both RRWs and legacy systems over the next 25 years, while simultaneously achieving the modernization of the manufacturing processes. This is particularly stressing for plutonium pit manufacturing because the current Los Alamos production capacity is significantly lower than the required 100 units per year and the expected lead time for any new pit production facility is 15 to 20 years.

- **FINDING: The existing complex has not been meeting current weapon requirements, and it is unlikely to have the necessary capacity to execute the Complex 2030[vi] vision without substantial changes in NNSA investment strategy and operating practices. The two most critical path items in the complex are changes at Pantex to accommodate the weapons throughput necessary for a reasonable range of stockpile options and the development of a plutonium strategy that can produce pits in reasonable quantities on a timely basis. These items are needed whether or not an RRW is an integral part of the plan because a responsive production complex is also needed for an LEP-based stockpile. The RRW approach could be an enabling factor in helping to resolve some of these issues, but it would also create challenges because of the higher production rates during the transition period when both LEPS and RRWs have to be processed. Most important, the first RRW would be built essentially with the existing production complex.**

- **RECOMMENDATION: The development of an acceptable plutonium strategy should be the highest priority in planning the future production complex, especially if the RRW concept is to be the basis for much of the stockpile. And, although RRW pits may turn out easier to build than legacy pits, the capability and capacity to produce legacy pits cannot be ignored. The highest priority in managing the current production complex is to increase the weapon throughput capability at Pantex. An RRW might make things a bit easier, but a large number of legacy weapons will still need LEPs, dismantlement, and surveillance before an all-RRW stockpile could be achieved. Potential safety and security benefits of RRW will need to be vetted through the**

DOE/NNSA internal and external regulators, but potential savings are likely to be overwhelmed by the need to deal with the legacy stockpile through the year 2030.

Pits

As indicated above, plutonium pit manufacturing represents one of the key challenges of the SSP. The ability to remanufacture new plutonium pits or extend the lifetimes of existing pits is crucial to defining the requirements for the future production complex. Life extension of plutonium pits depends on plutonium aging and on the aging of other pit materials. Plutonium can age by mechanisms similar to other metals—that is, by surface corrosion or by metallurgical changes. In addition, plutonium is susceptible to self-irradiation damage because of its alpha decay.

One of the most important contributions of science-based stockpile stewardship over the past decade has been a greatly increased understanding of the effects of self-irradiation damage on the structure and properties of plutonium alloys. The modeling efforts at the Lawrence Livermore and Los Alamos Laboratories have improved theoretical understanding immensely. Experimental studies with naturally aged material and on materials in which aging effects are accelerated by the addition of Pu-238 have greatly enhanced basic understanding of aging effects in plutonium. A recent review by JASON of an evaluation of plutonium pit lifetimes by the Laboratories, and accepted by the DOE/NNSA, concludes, "The assessment demonstrates that there is no degradation in performance of primaries of stockpile systems due to plutonium aging that would be cause for near-term concern regarding their safety and reliability. Most primary types have credible minimum lifetimes in excess of 100 years as regards aging of plutonium; those with assessed minimum lifetimes of 100 years or less have clear mitigation paths that are proposed and/or being implemented."

Concerns have been raised by one panel member (Hecker)[vii] that the plutonium lifetime assessment is too optimistic in some cases because of insufficient data on the engineering performance of aged plutonium and lingering questions about its dynamic performance, along with the effectiveness of mitigation strategies for all cases. In addition, pit lifetimes may also be limited by chemical processes, such as corrosion of various pit materials, including plutonium.

The second path to deal with an aging stockpile is to remanufacture. Although the blueprints of existing system are readily available, it is only recently that certified pits could again be produced in the United States because of the closure of the plutonium production facility at Rocky Flats in June 1989. The pit production capabilities have been painstakingly reestablished at TA-55 during the past 10 years. For a variety of reasons, the production equipment has changed, although previous production experience was tapped into while reestablishing production. One frequently cited concern is that pits are produced at Los Alamos by a cast process instead of the wrought process that had been used at Rocky Flats. There is, however, an accepted test pedigree for cast pits. The decision to use the casting process was made for two reasons: (1) the expense and difficulty of installing the necessary equipment for wrought processing at TA-55 and (2) the wrought process was difficult to reproduce. Designers concluded, however, that a sufficient test pedigree for cast pits existed to allow the certification. Other process changes implemented at Los Alamos were rigorously examined and judged acceptable. Extensive laboratory and subcritical tests were conducted to justify certification.

Although the RRW offers potential advantages in terms of pit robustness and manufacturability, it does not by itself address a major concern about plutonium manufacturing. Over the past 15 years, continually increasing regulatory restrictions, compounded by operational measures to adhere to those regulations adopted by the NNSA and the Laboratories, have increased the challenges of sustaining activities at the plutonium facilities and have resulted in an increase in the cost of operations. Concerns have been expressed that these operating challenges make it difficult to attract and retain top-quality scientists, engineers, and technicians to the plutonium facilities.

Finally, there are several areas of plutonium research and engineering practice that could become part of the future plutonium strategy. Pit reuse, for example, could be a potential option for RRWs and, if adopted, could lower the requirements for a pit manufacturing facility. It has also been noted[viii] that the historical alloy used in pits was not optimized for stability, but rather for yield-to-weight requirements. This has led to concern about the stability of the plutonium phases retained by alloying plutonium with gallium. The expressed concern is that these concentrations are close to an "engineering cliff" in the stability of some pit designs. Thus, alternative alloy compositions that enhance stability could now be considered consistent with the relaxed yield-to-weight requirements of an RRW design.

- **FINDING: Plutonium pit production and lifetime extension both pose some of the most serious challenges to stockpile stewardship, with or without an RRW. Remanufacturing and certification of current pits in new production facilities is challenging because of the changes in the regulatory environment for plutonium operations. Results to date on plutonium aging are encouraging and offer the possibility that expanding the capability to remanufacture pit types does not require an expedited process, but rather one that can be planned and implemented on the same timescale as the overall upgrades of the production complex.**

- **RECOMMENDATION: A continuing, focused program to study plutonium aging for the various pit types is imperative. Such studies should include both naturally aged plutonium pits and accelerated aging plutonium samples. It will be particularly important to conduct studies on the chemical and engineering processes that are now also among the limiting factors that determine pit lifetimes. All pit lifetime extensions should be taken through a certification methodology as rigorous as that employed for remanufactured or new pits. And, with or without the RRW program, it is critical for the DOE/NNSA to ensure that the productivity and operability of the nation's plutonium facilities are in line with U.S. national security needs.**

Confidence

The issue of confidence is at the heart of any major decisions with regard to the nuclear weapons stockpile. Before the endorsement of the SSP, a confidence conference was held in 1995 at STRATCOM to debate the matter with all members of the nuclear weapons community. The decision to proceed with SSP without testing was tense and complex. More than a decade later, the efforts expended in the Laboratories and in parts of the complex have provided a substantial measure of confidence in the safety and reliability of weapons, although there has been no nuclear testing. This increased confidence has been due, in part, to the much greater understanding of stockpile science acquired in this last decade and, in part, to the work of the surveillance and refurbishment programs.

These latter activities have been reflected in the thoroughness and rigor that has accompanied the annual certification process carried out by the Laboratories and STRATCOM. Each system is examined in detail, each finding assessed, and multiple levels of review are carried out. As noted earlier, however, the panel believes that confidence would be further enhanced by establishing an independent red-team process that goes beyond the intra- and inter-Laboratory review activities. This will be even more important if RRWs are introduced into a stockpile for which the same level of test history is not necessarily present and the use of a nuclear test is not available to resolve an unexpected finding.

A continuing, focused program to study plutonium aging for the various pit types is imperative.

Even with these measures, some have concerns that the long-term maintenance of the legacy stockpile still has substantial uncertainties because of aging or multiple refurbishments. From that perspective, the development of the RRW option could serve as an effective hedge against those uncertainties. On the other hand, if the RRW process is repeated multiple times into the future, similar issues about those new designs will occur. There is no perfect recipe for "manufacturing confidence" and a future approach that provides a mixed approach may well represent the best of various alternatives.

A continuing confidence issue will be the quality of the people doing the work. New technical staff have been recruited to the program and trained on the new tools and have been educated in the history of the weapons and the overall program. Although life extension is not equivalent to executing a new design, it nonetheless employs many of the same tools, processes, and disciplines. New designs and designers will need the same immersion in nuclear weapons testing history to ensure they do not stray too far from past testing history. Maintaining staff composed of first-class technical people over a space of decades will always be a challenge whether the stockpile consists of legacy weapons or RRWs, and there are no simple recipes to ensure enthusiasm and high quality over the long term. Full engagement with stewardship tools for diverse scientific purposes will be equally important as life extension and new design as mechanisms to ensure the vitality of staff.

- **FINDING: The legacy systems and their LEPs have helped to maintain confidence in the stockpile by reducing changes to their tested configurations; eliminating defects from the systems; establishing and vetting assessment, certification, and LEP procedures; and developing and certifying key remanufacturing procedures.**

- **RECOMMENDATION: RRWs should be encouraged to follow a similar route of excellent test pedigree while using the new tools of SSP to achieve higher margins and other desirable features. As in a previous recommendation, we urge the establishment of an independent red-team review to provide an additional layer of confidence, especially if RRWs are introduced into the stockpile. In addition, the results detailing the rate, type, and number of significant findings must be updated and released, and, where possible, age-related effects should be noted.**[ix]

- **FINDING: Confidence in the weapons depends on the capabilities of the scientists and their direct involvement with surveillance, refurbishment, and design activities. In a non-nuclear testing world, special efforts need to be made to ensure that nuclear weapons expertise is maintained and that both scientific and weapons skills can be exercised and demonstrated.**

- **RECOMMENDATION: Special efforts will be needed to ensure that the future generations of nuclear weapons workers have both the historical knowledge and current state-of-the-art technical understanding to establish maximum confidence in their product.**

Costs

There are no budgetary estimates, yet, for the transformation plan for NNSA. The SEAB task force did a rough approximation of long-term costs for three different program options, but not at a level of detail that can be treated as a serious estimate. In part, this is because the overall plan requires a number of major new investments (such as the pit production facility) and activities (such as conjectured surety savings at some sites) whose budgets have to be vetted by an extensive professional process. Even more important, however, is the development and promulgation of the national requirements that will dictate the stockpile size and diversity (as explicitly pointed out in the GAO report). How many warheads of what kind will be needed when, and how much of a reserve capacity and surge capability will be needed to sustain deterrence? The analysis needed should be done jointly by the DOD and DOE, although the overall requirements are ultimately set at the national level. The RRW concept adds a potentially useful dimension, but the ability to reduce total stockpile numbers may not occur until the RRW process has been demonstrated. In turn, this process may not be authorized until the DOD can accept lower levels. Furthermore, the RRW program would likely lead to reductions in the hedge (i.e., the inactive reserve) but would not necessarily contribute to a reduction in the deployed arsenal.

What can be said, however, is that there is limited flexibility in the way the NNSA and Congress manage the budget. The ability to proceed with RRW-1 (and future RRWs) depends on the knowledge gained and tested in the SSP, so to significantly curtail future SSP expenditures could undermine one of the basic needs of the RRW program. Safety and security savings that might come with RRW would only accrue gradually and would not be fully realized until major consolidations in the complex have completely taken place (if then). Modernization of existing sites and clean up of former sites will entail significant new expenditures, even if the eventual operating costs may decrease. Because of the promulgation of operational and regulatory requirements, the effective budget for doing programmatic work (technical and production activities) is a much smaller fraction of the total budget than it was in earlier eras.

Consequently, in addition to the possibility of new funding, the most likely source of funds for RRW work would be the funding for LEP activities and perhaps reprioritization in other areas. The cancellation of the W80 LEP has already provided initial funding for the RRW program (which is around $25 million for 2007 and is several times that in the proposed 2008 budget). If some other LEPs can be delayed, stretched out, or cancelled because of a change in stockpile requirements, then some funds (assuming a constant purchasing power budget) could be freed up for new investments. These funds, however, are in the few hundred million dollars per year range as long as the LEPs are maintained on any schedule resembling the current one. It is then a matter of whether these "savings" would be used for RRWs, other weapons priorities, or new facilities.

An unspoken issue in much of the costing and scheduling process is the credibility of the DOE/NNSA in planning and carrying out large-scale projects. As pointed out by virtually everyone (the GAO report documents this), the agency's track record is not good. To be sure, many of the "bad" examples represent one-of-a-kind, state-of-the-art facilities that were practically forced to assume conventional construction levels of contingency to obtain approval. These conditions, however, may well hold for the proposed RRW program and the plan to transform the complex. The growth in costs because of enhanced security and safety requirements and more recently because of private sector management of some sites is almost never factored into the "constant budget" equation that has governed the NNSA's recent financial planning.

- **FINDING: The DOE/NNSA budget is strongly dependent on the DOD stockpile requirements and no complete cost estimates can be made until any changes in the existing requirements are known. There is limited flexibility under a scenario of constant NNSA budgeting. Even with a reduction in the LEPs, significant new funds or major reprioritization will be needed to produce a responsive production complex or to produce RRWs. The introduction of RRWs is unlikely to lead to operational savings until most of those investments have been made and amortized. Consequently, an RRW program would likely add to costs in the near term, and it is not yet possible to determine when (and whether) the RRW could lead to savings in the long term.**

- **RECOMMENDATION: The NNSA should build in mechanisms to provide independent vetting of its cost estimates. This could be an outside group of industrial experts, an in-house group (such as the Lehman teams used effectively by the DOE Office of Science), or a combination of both. Its major projects, such as the pit production facility, should be frequently reviewed at the secretarial officer level to help reestablish financial and management credibility.**

Planning

To carry out a transformation to Complex 2030 requires a comprehensive planning effort on the part of both the DOE and the DOD. As noted above, the NNSA cannot properly size the complex until new national stockpile requirements are spelled out. To achieve the Complex 2030 vision, the NNSA must prepare detailed NEPA documentation that describes their plans and environmental impacts. These impacts, in turn, must be presented to all of the relevant local communities and discussed at public hearings. Experience indicates that this process can require years even after the initial documents are drafted.

An important non-NEPA factor for the Record of Decision (ROD) on the Supplement to the Stockpile Steward Management (SSM) PEIS is the concomitant availability of credible cost estimates for the proposed complex. Failure to achieve success on a major node (e.g., the pit production facility) can essentially gridlock the entire schedule. Stated slightly differently, the complex must be rebuilt and refurbished while it is carrying out all the necessary stockpile work—a much harder management task than building new plants on green field sites.

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It is not clear whether the RRW program simplifies or makes it harder to get through the NEPA process. The opportunity to reduce the overall environmental impact by using less hazardous materials and less hazardous waste-generating processes can be a positive factor. The most controversial aspect of any proposed change, however, is likely to center on the plans for Special Nuclear Material (SNM), including where, how much, and when. In the next 25 years, the RRW could make this more challenging because it could require more pit production than may be needed for the repair of the legacy stockpile and perhaps because of workload and scheduling complexities.

- **FINDING: Successful completion of the NEPA process is on the critical path to achieving the responsive infrastructure envisioned for Complex 2030. The role of the RRW can only be effectively incorporated subsequent to the specification of stockpile requirements and can be an enabling as well as a complicating factor.**

- **RECOMMENDATION: The development of NEPA documentation should be one of the highest near-term NNSA priorities. The role of the RRW should not be overstated because many of the changes would be sought even in a business-as-usual scenario (i.e., LEPs).**

▸ **RECOMMENDATION: Costing and scheduling plans are central to the credibility of the NEPA process and should be presented in parallel with the environmental impact statements. Special attention should be given to the systems aspect because stockpile work and site-to-site interactions will be present throughout the refurbishment process.**

DOD Role

There are three different parts of the DOD involved in nuclear weapons: the Navy and Air Force, which procure and deploy them; STRATCOM, which is the Combatant Command that would employ them, including planning and targeting; and the OSD, which sets policy and overall guidelines. A special feature of the relationship is that the customer does not have responsibility for warhead costs, meaning that its needs do not always mesh with the budget available to its DOE/NNSA supplier.

As indicated, the DOE/NNSA effort depends on the stockpile requirements set by the DOD in response to national policy. How many warheads are needed in the long term, and how many different kinds (and how many of each kind) are needed? Is it possible to give up a large part of the reserve capability on the premise that a revitalized production complex can quickly build large numbers of new warheads if a crisis occurs? Where is the confidence line between “well-tested” legacy warheads that may have an accumulating number of LEP-induced changes and RRWs that have an as-yet-to-be-determined virtual test pedigree as well as a likely set of birth defects? How will DOD set the standards, and how will it determine the budgets to bring RRWs into the stockpile?

The proposed RRW program presents a particularly unusual situation in that it does not respond to a new mission need, and in fact, represents a relaxation in its yield-to-weight specifications. In return, the program holds out the possibility of enhanced safety and security and sustained reliability with lower maintenance costs. It also presumes that the composite of these characteristics will lead to greater confidence in the quality of the RRW than a legacy warhead, but that statement can only be assessed on a case-by-case basis.

The RRW concept has been endorsed by the NWC (the Nuclear Weapons Council) on December 1, 2006 and through the JROC (the Joint Requirements Oversight Council of the DOD) on February 20, 2007. The JROC has formally designated the U.S. Navy as the lead component of the DOD for the development and fielding of the RRW-1, which would replace a portion of the existing SLBM warheads.

What the RRW program, in general, and the RRW-1, in particular, both require is that the DOD fully engages with the NNSA to do all of the flight-testing and other work necessary to integrate the new warhead into its delivery systems. No matter how careful the NNSA system is in trying to match the mechanical properties of the existing warheads, only flight-testing can verify that fact and test other aspects of the RRW in an operational-like environment. This is neither a trivial nor an inexpensive obligation for the DOD, and it needs to appear in its planning and budgeting process on the same timescale as the NNSA plan.

▸ **FINDING: The full engagement of the DOD is necessary to set the conditions under which an RRW can be effectively introduced into the arsenal. The technical standards, budgeting, and field-testing must all become part of a combined planning process with the DOE/NNSA—neither party can wait for the other to see “how it turns out” before committing resources and institutional will. The NWC process to incorporate the proposed RRW-1 in the arsenal has made a start in this direction, but the “bugs” in its system are still being worked out. Early indications, however, are that the FY2008 budget proposal for the DOD includes the funding necessary to begin work for the RRW-1.**

▸ **RECOMMENDATION: The DOD and DOE/NNSA use the RRW-1 as a prototype to establish the procedures for warhead replacement in the absence of changing mission needs. Although formally the same as the historical process, which has been dormant for nearly 20 years, sufficient differences indicate that the DOD and DOE/NNSA protocols and interface should be refurbished.**

Policy Context

The Nuclear Posture Review of 2001, especially through its promulgation of the strategic Triad of offense, defense, and infrastructure, laid the foundation for a twenty-first-century strategic posture. As pointed out in many reports (e.g., the DSB study on Nuclear Capabilities and the Defense Threat Reduction Agency [DTRA]-sponsored report on Foreign Perspectives), there has been little subsequent discussion of the elements of that Triad and virtually no high-level articulation of U.S. nuclear policy. In the absence of a clear nuclear posture, many interpretations are possible, and the lack of a national understanding and consensus on the role of U.S. nuclear weapons puts any new approach at considerable political risk at home and abroad. For example, an RRW plan that emphasizes the goal of sustaining the deterrent without nuclear testing could be perceived quite differently from one that focuses on future flexibility to develop and deploy nuclear weapons for new military missions.

Whether or not the RRW program were to proceed, there is still a growing view that the broad goals of U.S. nuclear policy need to be addressed. Many concerns about the sustainability of the SSP and the LEP have been raised, and various studies have raised a number of questions about both the size and character of the stockpile. And, in a recent *Wall Street Journal* article, Schultz, Perry, Kissinger, and Nunn argued that a reaffirmation of the U.S. commitment to Article VI of the NPT should provide the basis for future nuclear weapons actions. It is hard to imagine broad RRW and Complex 2030 decisions being made "under the radar" in light of all this activity independent of the details of these discussions.

As indicated earlier, this study did not explore the details of treaty matters, including what is a "new" weapon; what is the impact of adding "untested" weapons to the stockpile; and what effect does the RRW plan have on the NPT, Iran, North Korea, the CTBT debate, and other issues? The panel did, however, try to identify some of the larger issues and these are described below.

International Perspective

The recent DTRA-sponsored report summarizes current foreign views on U.S. nuclear weapons policy. It states that there is a widespread perception that the United States is placing heightened emphasis on nuclear weapons as part of its overall defense strategy, intentionally or unintentionally lowering the threshold of nuclear weapons use. This, in turn, leads to concerns among friends and allies about the possible adverse nonproliferation impacts of U.S. nuclear policy and posture. In particular, unless explicit and credible efforts to counter those assumptions are made, some countries could view an RRW program as contrary to both the spirit and letter of the NPT. Rightly or wrongly, current U.S. policy may be viewed through the lens of the recent debates on low-yield weapons and bunker busters, so that programmatic discussions within the United States will be significantly affected by international policy questions. Stated another way, the RRW program will inevitably be seen as an integral part of U.S. national security policy and its goals will be debated within that framework, not as an isolated technical matter.

Framing the RRW Policy Role

The negative impact of an RRW program on these policy issues could be reduced by clarifying that an RRW is not intended to be a "new type" of nuclear weapon or to provide "new" nuclear weapons capabilities or missions. As long as RRWs are at most one-for-one replacements for existing nuclear weapons, with the same limitations and capabilities, and in that sense not very different from an LEP upgrade to an existing nuclear weapon, it can be argued that the RRW plan does not reflect a new nuclear policy. Ignoring ideological and semantic difficulties, one can ask how a warhead designed to do the same mission with the same general characteristics should introduce any important differences of "newness" from its predecessor. If the RRW program in conforming to the legislation further enables a reduced stockpile size and is clearly identified as not leading to "new" weapons, then it could be perceived as an arms control benefit rather than as an unsettling development. Of course, stockpile size is not verifiable under present restrictions, so new measures of transparency would be needed to communicate such information in a credible manner.

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Conversely, if an important goal of the RRW and Complex 2030 programs is to enable new capabilities and new missions, then that view needs to be introduced and engaged with U.S. allies and Congress so that the policy implications are clearly understood by all parties. For example, the possibility of a much smaller but more diverse stockpile (perhaps some of it in a "ready-to-be-built" mode) could represent an outcome of an RRW capability that would introduce additional dimensions into the traditional nuclear weapons debates.

Furthermore, one could view the RRW as a new capability in and of itself, which could be perceived as adding a strategic advantage beyond Cold War norms. The ability to develop modern nuclear weapons without testing (if proven feasible) would represent something new even if the country did not use it to produce “new” weapons, thus adding another issue to arms control discussions.

All these points suggest the importance of characterizing any RRW decision in clear and unambiguous terms, setting forth what is being proposed and what is not. At present, the panel has no such clarity.

Congressional View

Congress has supported the initial steps toward an RRW program. In 2005, it laid out seven overarching criteria for the program (see appendix D, endnote iv) and put tight controls on what the RRW program could and could not do. Roughly speaking, the legislation requires that the RRW program lead to warheads with greater reliability and surety; reduce the likelihood of a need for nuclear testing; facilitate a reduction in the size of the stockpile; and be supported by a more effective and less costly production complex. The appropriations for the initial phases of the RRW program have provided start-up funds and their committees have generally accepted the objectives of the authorizing language.

Programmatic actions to date have been consistent with the criteria, although milestones or benchmarks are generally notional rather than specific. Ultimately, the DOE/NNSA and the DOD need to spell out for Congress (and the executive branch) the metrics by which they would measure how well they are meeting the stated goals.

More recently, some congressional leaders have called for more explicit connections of the RRW program with policy objectives. For example, some members of Congress would seek support for advances in arms control, such as passage of the CTBT. Others have raised issues about the costs involved in Complex 2030 and whether the overall program can meet the “less costly” criterion in the legislation. There has also been criticism of the NNSA’s rejection of some of the stronger consolidation recommendations for the production complex that were contained in the SEAB report. A more comprehensive listing of these views is contained in the most recent report from the CRS.

It is unclear whether work on the RRW-1 through its final warhead design and engineering studies and on the Supplement to the PEIS for Complex 2030 will be completed in time for a production request in the FY2009 budget (the last to be submitted by this administration). Those actions would require an aggressive schedule and little opportunity for the independent reviews of technical and programmatic matters that have been discussed in this report.

Executive Branch Role

To date, the RRW and Complex 2030 have been developed by the Laboratories and the NNSA, conceptually supported by the DOD through the NWC and the JROC and legislatively spearheaded by the Congress that defined the policy framework. As discussed, there has been no presidential or cabinet-level statement from the administration that clearly lays out the role of nuclear weapons in the post–Cold War, post-9/11 world, that makes the case for and defines future stockpile needs, *and that argues the case for the RRW.* [x, xi] In the panel’s experience, there cannot be a major transformation of the sort envisioned by the RRW program and Complex 2030 without White House leadership to produce substantial bipartisan support over a period of 25 years (i.e., through several administrations and a dozen Congresses). If for no other reason than the control of the Office of Management and Budget over the budget process, there must be active engagement by the administration(s) if significant new investments or changes in policy and strategy are needed for the success of an enterprise. Perhaps more to the point, nuclear weapons are ultimately an instrument of policy and strategy rather than of war fighting, and only with the leadership of the president can there be major changes in that instrument. Only a president and a well thought-out diplomatic strategy can put this in terms likely to be constructively understood by the international community.

- FINDING: **U.S. nuclear policy will matter to both the proposed plans for RRW and Complex 2030, and there are substantial short- and long-term pragmatic and political risks in proceeding without a clear set of objectives. If an extension of the SSP goal is the primary aim, it should be so stated and clarified as necessary. The technical bargain that produced the stewardship plan has largely been fulfilled, although the political process has not led to formal ratification of a CTBT.**

- RECOMMENDATION: **To conform to existing policy, the proposed RRW approach needs to transparently pursue and emphasize those features (such as reliability and reduced risk of testing) that extend the stewardship goals of U.S. nuclear policy. Any change in that approach needs to be widely debated to produce a national consensus on the future role of nuclear weapons.**

- **FINDING:** If the RRW and Complex 2030 programs are pursued along their proposed paths, they will have a number of international impacts, including concerns regarding nonproliferation and arms control. It will require a thorough and systematic effort to ensure that the foreign perceptions of the programs are consistent with U.S. intent and national security goals.

- **RECOMMENDATION:** The United States should carry out a systematic and comprehensive assessment of the international implications of the proposed RRW and Complex 2030 programs and incorporate its findings as part of the presentation of its plans. Although this may not be able to be completed in time for the current RRW-1 decision, it is essential to the longer-term program. Special efforts to include the other major nuclear weapons states and states that depend on the United States for nuclear deterrence would add credibility and value to the assessment.

- **FINDING:** It will be difficult to complete and review the design work on RRW-1 and Complex 2030 within the lifetime of the current administration's window for requesting authorization and a budget to begin production of RRW-1.

- **RECOMMENDATION:** We urge the DOE/NNSA and the DOD to carry through with independent review mechanisms of design, certification, costs, schedules, and protocols such as those discussed in this report. Even if this introduces delays into the process, it will provide the necessary foundation for decisions by future administrations and Congresses that would have to provide the major financial and political impetus for the program.

- **FINDING:** Congress has been strongly engaged in the defining legislation for the proposed RRW program and has set clear goals the program must satisfy. In the final analysis, however, we believe that only presidential leadership can create the bipartisan program necessary to transform the nuclear weapons complex on a path that may take well over two decades.

- **RECOMMENDATION:** The White House, the DOD and DOE/NNSA, and Congress need to develop a policy and plan that can develop the basis for bipartisan support for the future nuclear weapons program (e.g., the proposed RRW and Complex 2030 plans) if it is to be supported across the change in administration that will occur in 2009 (and in many future such transitions).

Personal Comment of Charles B. Curtis

The report is a faithful exposition of the panel's deliberations and findings. As a matter of policy, however, I would like it recorded that I recommend against further steps down the RRW path at this time. Under current circumstances, a decision to proceed with an RRW program will likely be misunderstood by our allies, misinterpreted by the international community, and exploited by our adversaries, seriously complicating our nonproliferation objectives. We have time to get the RRW and Complex 2030 questions right. But to do so, we must first clearly and unambiguously articulate the role and purposes of nuclear weapons; specifically identify our weapons requirements; rationalize these roles, purposes, and requirements to our nonproliferation strategies; and *then* clearly lay out what type of "responsive infrastructure" is required and how an RRW program fits in. This work has not been done.

Personal Comment of John S. Foster

Although I am in agreement with many of the specific recommendations in the report, I am disappointed that in my judgement it does not provide adequate focus on its terms of reference: to assess the degree to which RRW would alleviate risks in the SSP. Rather, it is long on risks and short on reducing risks (the value of RRW); long on raising uncertainties and short on recognition of answers to many of them already provided by Congress and DOD/NNSA officials. The report fails to recognize the urgency of initiating the RRW program to reduce risks in the stockpile by: failing to recognize the DOD requirement for diversity; failing to recognize the need to proceed with RRW-1 to provide a back-up to the Trident warhead; and providing an opportunity for retiring experts to train the next generation. Instead it conveys the impression that, despite such urgency, RRW be held hostage to the resolution of domestic and international political nuclear weapons issues, which are real, while all other nuclear powers have already initiated programs similar to RRW.

APPENDIX A: Biographies of Panel Members

C. Bruce Tarter (Chair) is director emeritus of the Lawrence Livermore National Laboratory and was the eighth director to lead the Laboratory since it was founded in 1952. A theoretical physicist by training and experience, he began his career at the Laboratory in 1967. As director from 1994 to 2002, he led the Laboratory in its mission to ensure national security and apply science and technology to the important problems of our time. Dr. Tarter received a S.B. in physics from MIT and a Ph.D. from Cornell University. He is a Fellow of the American Physical Society and the American Association for the Advancement of Science, and has received the Roosevelts Gold Medal Award for Science (1998), the National Nuclear Security Administration Gold Medal (2002), and the Secretary of Energy's Gold Award (2004).

Philip Coyle is a senior advisor to the president of the World Security Institute, and to its Center for Defense Information, a Washington, D.C.–based national security study center. He is a recognized expert on U.S. and worldwide military research, development, and testing; on operational military matters; and on national security policy and defense spending. Mr. Coyle has previously served on the Defense Base Realignment and Closure Commission, as the assistant secretary of defense; as director of Operational Test and Evaluation in the Department of Defense; and as Lawrence Livermore National Laboratory associate director and deputy to the Laboratory director. During the Carter administration, Mr. Coyle served as principal deputy assistant secretary for Defense Programs in the Department of Energy. In this capacity, he had oversight responsibility for the nuclear weapons testing programs of the Department. Mr. Coyle graduated from Dartmouth College with an M.S. in Mechanical Engineering and a B.A.

Charles B. Curtis served as under secretary and, later, deputy secretary of energy from February 1994 to May 1997. He was the chief operating officer of the Department of Energy and, among other duties, had direct programmatic responsibility for all department science, technology, and national security programs. Mr. Curtis was the department's designated member of the Nuclear Weapons Council throughout his tenure. Mr. Curtis is a lawyer with more than 15 years' practice experience and more than 18 years in government service. He was a founding partner of the Washington law firm Van Ness Feldman. Mr. Curtis served as chairman of the Federal Energy Regulatory Commission from 1977 to 1981 and has held positions on the staff of the U.S. House of Representatives, the U.S. Treasury Department, and the Securities and Exchange Commission. He is a current member of the Council on Foreign Relations.

Steve Fetter is dean of the School of Public Policy at the University of Maryland, where he has been a professor since 1988. Dr. Fetter serves on the Department of Energy's Nuclear Energy Research Advisory Committee, the Board of Directors of the Sustainable Energy Institute and the Arms Control Association, the University of Chicago's Advisory Committee on Nuclear Non-Proliferation, and the Board of Editors of Science and Global Security. He is a Fellow of the American Physical Society. Dr. Fetter served as special assistant to the assistant secretary of defense for International Security Policy and received the Secretary of Defense Medal for Outstanding Public Service. He received a Ph.D. in energy and resources from the University of California, Berkeley, and an S.B. in physics from MIT.

John S. Foster is chairman of the board of GKN Aerospace Transparency Systems, chairman-emeritus of Technology Strategies & Alliances, and a member of the board of Wackenhut Services Inc. He currently is co-chair of the Nuclear Strategy Forum. He was director of defense research and engineering (DDR&E) for the Department of Defense for eight years (1965–73); served on the president's Foreign Intelligence Advisory Board (1973–90); was chairman of the Defense Science Board (1990–93); and currently serves as a Senior Fellow of the DSB. Before his appointment as DDR&E, he was director of the Lawrence Livermore National Laboratory and associate director of the Lawrence Berkeley National Laboratory. Mr. Foster retired from TRW Inc. as vice president of science and technology in 1988. He continues as a consultant to Northrop Grumman Space Technology. His numerous awards include the National Academy of Engineering Founders Award, James Forrestal Award, Enrico Fermi Award, AEC Ernest Orlando Lawrence Memorial Award, and three Department of Defense Distinguished Public Service Medals.

Steve Guidice served in many different leadership positions at the Department of Energy Albuquerque Operations Office (DOE/AL). He has been a weapon program manager and member of the Department of Defense/DOE Project Officer Group, the branch chief for weapon surveillance, the director of weapons quality, the director of weapon production, and the head of the Office of National Defense Programs with a $2 billion annual budget, the latter position being responsible for all the previous functions as well as nuclear explosive safety. After the end of the Cold War, Mr. Guidice was responsible for developing and managing the massive U.S. weapons dismantlement campaign as well as a plan to reconfigure the DOE Nuclear Weapons Complex that led to Secretary of Energy Record of Decisions in 1993 and 1996. After graduating college, and before his career with DOE, Mr. Guidice worked as a civilian test engineer in the U.S. Navy's nuclear weapons program.

Siegfried S. Hecker is co-director of the Stanford University Center for International Security and Cooperation, Senior Fellow of the Freeman Spogli Institute for International Studies, and professor (research) in the Department of Management Science and Engineering. He is also director emeritus at the Los Alamos National Laboratory, where he served as director from 1986–97 and was Senior Fellow until July 2005. He received his B.S., M.S., and Ph.D. degrees in metallurgy from Case Western Reserve University. His current professional interests include plutonium research, cooperative nuclear threat reduction with the Russian nuclear complex, and global nonproliferation and counterterrorism. Dr. Hecker is a member of the National Academy of Engineering and serves as a councilor, is chair of the Joint U.S./Russian Academies

Committee on Counterterrorism Challenges in Russia and the United States, and serves on the National Academy of Sciences' Committee on International Security and Cooperation Nonproliferation Panel.

Edwin E. Ives served as the deputy assistant secretary for Military Application and Stockpile Management, Defense Programs; the deputy (Weapons Stockpile Matters) to the vice president, National Security Sector, of the Sandia National Laboratories. Before his management roles, Mr. Ives was involved in the early implementation of nuclear safety features and weapon use control features common throughout the current stockpile and had weapon design responsibility on W76, W78, W80, B83, and W87, as well as on many weapons currently retired from the stockpile. Mr. Ives served for two years as director of development testing, providing testing capabilities in support of development programs. Mr. Ives also spent seven years as director of weapons development at the Sandia California site. Mr. Ives received a B.S. in electrical engineering from Auburn University and an M.S. in electrical engineering from the University of New Mexico.

Raymond Jeanloz, a professor of earth and planetary science and of astronomy at the University of California at Berkeley, conducts basic research on materials at high pressures and temperatures. He chairs the U.S. National Academy of Sciences' Committee on International Security and Arms Control, and has served as an advisor to the U.S. government in areas ranging from environmental and resource issues to national and international security. His scientific work has been recognized through a MacArthur Prize Fellowship and Fellowship in the American Academy of Arts and Sciences and by the American Association for the Advancement of Science. Dr. Jeanloz is a member of the National Academy of Sciences. He received his Ph.D. from the California Institute of Technology.

Robert W. Selden retired from the Los Alamos National Laboratory in 1993. His career in the Department of Energy National Laboratories began at the Lawrence Livermore National Laboratory in the 1960s when he was one of the two participants in the *N*th Country Experiment to design a nuclear explosive from unclassified information. Dr. Selden served as the division leader of the Los Alamos Applied Theoretical Physics Division (the organization responsible for the physics design of nuclear weapons at Los Alamos), as associate director for theoretical and computational physics, and as the first director of the Los Alamos Center for National Security Studies. Dr. Selden served as the chief scientist of the U.S. Air Force from 1988 to 1991. In addition, he is a member of the Strategic Advisory Group of the U.S. Strategic Command and is currently serving as the chairman of the group's Stockpile Assessment Team.

Michael L. Telson is the senior advisor to the University of California (UC) in its Washington Office of Federal Governmental Relations. Dr. Telson has served as chief financial officer of the Department of Energy, as a special assistant to the secretary of energy, and before that to the deputy secretary for energy, science, and budget issues. He has served as senior analyst for energy and science on the staff of the Committee on the Budget, U.S. House of Representatives, and as the staff economist of the House Ad Hoc Committee on Energy. He holds Ph.D., E.E., M.S., and B.S. degrees in electrical engineering from MIT, and an M.A. in management from the MIT Sloan School of Management.

Ellen Williams is a distinguished university professor for the Institute for Physical Science and Technology, Department of Physics, Materials Research Science and Engineering Center, at the University of Maryland. She is an experimental condensed matter physicist who works on the applications of statistical mechanics to problems of nanostructure formation, stability, and functional behavior. Her research has been recognized by the Maria Goeppert Mayer Award and the Adler Lectureship Award from the American Physical Society, and the David Turnbull Award from the Materials Research Society. Dr. Williams is a member of the American Academy of Arts and Sciences and the National Academy of Sciences. She holds a Ph.D. in physical chemistry from the California Institute of Technology.

Richard Wagner is a lab associate with the Los Alamos National Laboratory, based in Washington, D.C. He previously has served as vice president and chief scientist of Kaman Sciences Corporation and group vice president of the Kaman Corporation, has served as assistant to the secretary of defense for atomic energy, and has held a variety of managerial positions at the Lawrence Livermore National Laboratory. Dr. Wagner is a member of the U.S. Strategic Command's Strategic Advisory Group. He has twice been a member of the Defense Science Board, a founding member of the Threat Reduction Advisory Committee of the Office of the Secretary of Defense, and a member of the Defense Intelligence Agency's Advisory Board. Dr. Wagner holds B.A. from Williams College, and a Ph.D. from the University of Utah, both in physics.

Francis Slakey received his Ph.D. in physics in 1992 from the University of Illinois, Urbana-Champaign. He holds an endowed position at Georgetown University where he is the Cooper/Upjohn Professor of Science and Public Policy and the co-director of the Program on Science in the Public Interest. He has written widely on science policy issues, publishing more than 50 articles for the popular press, including the *New York Times*, *Washington Post*, and *Scientific American*. He is a Fellow of the American Physical Society, a MacArthur Scholar, and currently a Lemelson Research Associate of the Smithsonian Institution. Dr. Slakey is the associate director of public affairs for the American Physical Society.

Benn Tannenbaum received his Ph.D. in experimental particle physics from the University of New Mexico in 1997. He is currently project director of the Center for Science, Technology and Security Policy at the American Association for the Advancement of Science, focusing on connecting scientists with government on security matters. He has testified before the U.S. House of Representatives Committee on Homeland Security about radiation portal monitors. He serves on the American Physical Society's Panel on Public Affairs and on the board of directors of The Triple Helix. He served as the 2002–03 American Physical Society Congressional Science Fellow. During his Fellowship, Dr. Tannenbaum worked for Representative Edward J. Markey (D-MA) on nonproliferation issues.

APPENDIX B: Meeting Agendas

AAAS Panel on RRW: Meeting 1 Agenda

American Association for the Advancement of Science, Washington, D.C.

Day 1 (May 31, 2006)

8:30 Welcome and Introductions; *Neureiter (AAAS)*

8:45 Panel Purpose, Scope, and Timetable; *Tarter*

Session I: Perspectives on RRW Program and Stockpile Transformation

9:15 Joint DOD/NNSA Views; *Henry (DOD), Schoenbauer (DOD)*

Session II: Why RRW? (and related issues)

10:30 Implications for NNSA Stockpile Stewardship and Sustainability Modernization and Transformation of the Complex; *Harvey(NNSA), Crandall (NNSA)*

Session III: Technical Discussion from the Laboratories

11:15 Why we are concerned about long-term ability to sustain the legacy stockpile?; *Martz (LANL)*

1:00 Why do we think we can develop or field an RRW without nuclear testing?; *Terminello (LANL), Hommert (LANL)*

1:45 Why do we need a robust approach to surety?; *Walker (SNL)*

Session IV: Congressional Perspectives

2:45 Congressional Motivations and Drivers; *Creedon (SASC)*

Session V: Counterpoints and Questions

4:00 The Case for Continuation of the SSP, Alternatives to RRW; *Garwin*

5:00 Wrap Up Discussion; *Tarter*

5:30 Adjourn

Day 2 (June 1, 2006)

Executive Session

1:00 Adjourn

AAAS Panel on RRW: Meeting 2 Agenda

Lawrence Livermore National Laboratory, California

Day 1 (August 10, 2006)

8:30 Welcome and Introduction; *Tarter*

Session I: Discussion of Intermeeting Activities and Readings

8:45 Hobson Views; *Tarter*

9:00 Director's Perspective; *Miller (LLNL)*

9:45 JASON Views; *Williams, Jeanloz*

10:30 Plutonium Workshop; *Hecker*

Session II: Nonproliferation Questions

11:00 Nonproliferation Issues; *Lehman (LLNL), Nacht (University of California, Berkeley)*

Session III: NNSA/LABS (SRD)

1:00 Stockpile Stewardship Historical Record of Introducing Mods into the Stockpile (pre-1992) Without Testing; *Keller (LLNL)*

2:00 How do Stockpile Stewardship successes enable RRW and its transformation of the complex?; *O'Brien (LLNL)*

3:00 RRW Design Overview in the Context of Stockpile Margins and Constraints; *Martz (LANL)*

3:30 Plan for RRW Certification Without Testing (LANL); *McMillan (LANL)*

4:00 Plan for RRW Certification Without Testing (LLNL); *O'Brien (LLNL), Hsu (LLNL)*

4:30 Enterprise Modeling for the Complex; *Shang (LLNL)*

Day 2 (August 11, 2006)

Executive Session

1:00 Adjourn

AAAS Panel on RRW: Meeting 3 Agenda

American Association for the Advancement of Science, Washington, D.C.

Day 1 (October 24, 2006)

8:30 Welcome; *Tarter*

8:45 Complex 2030 Planning Process and Related Issues; *Allen (NNSA Weapons Program's Office of Transformation)*

9:45 Significant Findings; *White (LANL Deputy Director for National Security)*

11:00 Report on Recent Congressional Visits; *Tarter*

2:30 Report on WSI Meeting; *Coyle, Tannenbaum, et al.*

1:00 STRATCOM Perspective; *Schroeder (STRATCOM Global Strike Capabilities Division)*

Day 2 (October 25, 2006)

Executive Session

End Executive Session

11:00 Further Information from DOD; *Hannah, (Navy Strategic Systems)*

1:00 Adjourn

APPENDIX C: Abbreviations and Acronyms

AAAS	American Association for the Advancement of Science
OSD/AT&L	Office of the Under Secretary of Defense for Acquisition & Technology
CRS	Congressional Research Service
CTBT	Comprehensive Test Ban Treaty
DARHT	Dual Axis Radiographic Hydrodynamic Test Facility (LANL)
DOD	Department of Defense
DOE	Department of Energy
DSB	Defense Sciences Board
DTRA	Defense Threat Reduction Agency
GAO	Government Accountability Office
ICBM	intercontinental ballistic missile
JASON	scientific advisors to DOD
JROC	Joint Requirements Oversight Council (DOD)
LANL	Los Alamos National Laboratory
LEP	Life Extension Program
LLNL	Lawrence Livermore National Laboratory
NEPA	National Environmental Policy Act
NIF	National Ignition Facility (LLNL)
NNSA	National Nuclear Security Administration
NOI	Notice of Intent
NPT	Treaty on the Nonproliferation of Nuclear Weapons
NTS	Nevada Test Site
NWC	Nuclear Weapons Council (joint DOD/DOE)
OSD	Office of the Secretary of Defense
Pantex	nuclear weapon maintenance and disassembly plant near Amarillo, TX
PEIS	Programmatic Environmental Impact Statement
POG	Project Officers Group
QMU	Quantification of Margins and Uncertainties
ROD	Record of Decision
RRW	Reliable Replacement Warhead
SAG/SAT	Strategic Advisory Group/Stockpile Assessment Team (STRATCOM)
SEAB	Secretary of Energy Advisory Board
SLBM	submarine launched ballistic missile
SNM	Special Nuclear Material
SSP	Stockpile Stewardship Program
STRATCOM	United States Strategic Command; controls the nuclear assets of the U.S. military
TA-55	Plutonium Facility Site at LANL
TRAC	Threat Reduction Advisory Committee (DTRA)
Y-12	nuclear pit manufacturing facility in Oak Ridge, TN
Z	SNL machine designed to study fusion

APPENDIX D: Endnotes

[i] These reports and other useful background materials are listed below:

Gene Aloise, *Views on Proposals to Transform the Nuclear Weapons Complex*, Testimony before the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives. GAO-06-606T, April 26, 2006.

Defense Sciences Board Task Force, *Nuclear Capabilities Report Summary*, December 2006.

Lewis Dunn, Gregory Giles, Jeffrey Larsen, and Thomas Skypek, *Foreign Perspectives on U.S. Nuclear Policy and Posture*, Prepared by SAIC for the Defense Threat Reduction Agency, December 4, 2006.

Jonathan Medalia, *Nuclear Weapons: The Reliable Replacement Warhead Program*, CRS Report for Congress RL32929, February 8, 2007.

"Notice of Intent to Prepare a Supplement to the Stockpile Stewardship and Management Programmatic Environmental Impact Statement—Complex 2030," U.S. National Archives and Records Administration, Office of the Federal Register, *Federal Register* (October 19, 2006): 61731–61736.

K. Henry O'Brien, Bryan L. Fearey, Michael R. Sjulin, and Greg A. Thomas, *Sustaining the Nuclear Enterprise—A New Approach*, UCRL-AR-212442, 20 May 2005.

Office of Defense Programs, NNSA, "Report on the Plan for Transformation of the National Nuclear Security Administration Nuclear Weapons Complex," January 31, 2007.

Office of Defense Programs, NNSA Press Release, "Design Selected for Reliable Replacement Warhead," March 2, 2007.

Office of Defense Programs, NNSA Press Release, "Studies Show Plutonium Degradation in U.S. Nuclear Weapons Will Not Affect Reliability Soon," November 29, 2006.

G. P. Schultz, W. J. Perry, H.A. Kissinger, and S. Nunn, "A World Free of Nuclear Weapons," *Wall Street Journal*, January 4, 2007, A15.

Secretary of Energy Advisory Board, Report of the Nuclear Weapons Complex Infrastructure Task Force, *Recommendations for the Nuclear Weapons Complex of the Future*, July 13, 2005.

U.S. Department of Energy. National Nuclear Security Administration. Office of Defense Programs, *Complex 2030: An Infrastructure Planning Scenario for a Nuclear Weapons Complex Able to Meet the Threats of the 21st Century*, DOE/NA-0013, October 2006.

[ii] *Pit Lifetime*, JASON Report JSR-06-335, November 20, 2006.

[iii] Testimony of General James E. Cartwright, USMC, Commander, United States Strategic Command before the Senate Armed Services Committee Strategic Forces Subcommittee on Strategic Forces and Nuclear Weapons Issues in Review of the Defense Authorization Request for Fiscal Year 2006, April 4, 2005.

[iv] 50 U.S. C. 2524 and Public Law 109-163, SEC. 3111. RELIABLE REPLACEMENT WARHEAD PROGRAM.

a) Program Required—The Secretary of Energy shall carry out a program, to be known as the Reliable Replacement Warhead program, which will have the following objectives:

1) To increase the reliability, safety, and security of the United States nuclear weapons stockpile.

2) To further reduce the likelihood of the resumption of underground nuclear weapons testing.

3) To remain consistent with basic design parameters by including, to the maximum extent feasible and consistent with the objective specified in paragraph (2), components that are well understood or are certifiable without the need to resume underground nuclear weapons testing.

4) To ensure that the nuclear weapons infrastructure can respond to unforeseen problems, to include the ability to produce replacement warheads that are safer to manufacture, more cost-effective to produce, and less costly to maintain than existing warheads.

5) To achieve reductions in the future size of the nuclear weapons stockpile based on increased reliability of the reliable replacement warheads.

6) To use the design, certification, and production expertise resident in the nuclear complex to develop reliable replacement components to fulfill current mission requirements of the existing stockpile.

7) To serve as a complement to, and potentially a more cost-effective and reliable long-term replacement for, the current Stockpile Life Extension Programs.

[v] See endnote i.

[vi] Statement of Thomas P. D'Agostino, Deputy Administrator for Defense Programs, National Nuclear Security Administration, before the House Armed Services Committee, Subcommittee on Strategic Forces, April 5, 2005.

[vii] S. S. Hecker, "Comments on the JASON Report on 'Pit Lifetime'," March 22, 2007; and letter to Thomas P. D'Agostino, March 29, 2007.

[viii] See endnote vii.

[ix] K. Johnson, J. Keller, C. Ekdahl, R. Krajcik, L. Salazar, E. Kelly, and R. Paulsen, "Stockpile Surveillance: Past and Future," SAND95-2751, January 1996.

[x] Nuclear policy statements have been made at the NNSA program administrator level and by the commander, Strategic Command, but in both cases they have been accompanied by a call for a national debate at a much broader and higher level.

[xi] The last comprehensive statement of U.S. nuclear weapons policy came in the classified Nuclear Posture Review Report of December, 2001.

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