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Stewarding a Reduced Stockpile

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Stewarding a Reduced Stockpile

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The future of the US nuclear arsenal continues to be guided by two distinct drivers: the preservation of world peace and the prevention of further proliferation through our extended deterrent umbrella. Timely implementation of US nuclear policy decisions depends, in part, on the current state of stockpile weapons, their delivery systems, and the supporting infrastructure within the Department of Defense (DoD) and the Department of Energy's National Nuclear Security Administration (NNSA). In turn, the present is a product of past choices and world events. Now more than ever, the nuclear weapons program must respond to the changing global security environment and to increasing budget pressures with innovation and sound investments. As the nation transitions to a reduced stockpile, the successes of the Stockpile Stewardship Program (SSP) present options to transition to a sustainable complex better suited to stockpile size, national strategic goals and budgetary realities. Under any stockpile size, we must maintain essential human capital, forefront capabilities, and have a right-sized effective production capacity. We present new concepts for maintaining high confidence at low stockpile numbers and to effectively eliminate the reserve weapons within an optimized complex. We, as a nation, have choices to make on how we will achieve a credible 21st century deterrent.

I. Background

The Stockpile. Guided by national policy, the US nuclear stockpile reached a maximum of tens of thousands of weapons, leveled off as the strategic arms control process proceeded, and substantially decreased after the Cold War ended. In 2007, the government announced early achievement the goal to reduce the stockpile to less than one-quarter its size at the end of the Cold War and that it intends a further 15% reduction. The US retains a number of stockpile weapons over and above the number operationally deployed. This reserve stockpile assures sufficient units are available for destructive surveillance evaluation and for use as substitutes to operationally deployed weapons if a performance issue takes down a significant number of deployed weapons.

During the Cold War, new nuclear designs were introduced at a rapid pace. More than thirty different weapon systems were deployed. Many others were developed but not deployed. Steady development provided opportunities to dramatically improve the safety and security of the US nuclear stockpile. Improvements included use control, technology to avoid accidental spread of nuclear materials, and command disable of weapons. Unfortunately, these features are not deployed on all weapons currently stockpiled. For example, only one of four deployed ballistic missile warheads has insensitive high explosive and a fire-resistant pit.

Weapon designs met increasingly stringent military requirements, leaving some less than desirable characteristics in the current nuclear security environment. The limits of the possible were pushed. The goal was high yield-to-weight. Exotic and/or environmentally difficult materials were used to reduce weight. Production involved roughly a dozen steps that are hard to reproduce. Long shelf life and ease of manufacture were not priorities.

Since the end of new weapon development, the Life Extension Program (LEP) has sought to maintain warheads by replacing some components with newly made ones that stay as close to original as possible. Most Cold War nuclear weapons do not have large performance margins. This increases the difficulty and expense of sustaining them in stockpile. In the absence of nuclear testing, and we emphasize – we have been very successful in creating the capabilities that make it unlikely that we would need to nuclear test – the effects of aging or rebuilds with processes, materials, or engineering features different from the original design increases uncertainties that challenge confidence. In parallel to the LEP program, NNSA is dismantling retired nuclear warheads as rapidly as safe and secure operations permit. Since 1992, 13 different weapons types have been eliminated. Dismantlement rates increased significantly in 2007.

The Stockpile Stewardship Program. The President announced in 1995 that we would pursue a Comprehensive Nuclear Test Ban Treaty. In making that decision, he reaffirmed the importance of a safe and reliable nuclear deterrent and created the SSP to sustain stockpile reliability.

The SSP is based on the development of a detailed understanding of the science and technology governing nuclear weapons operation. This means that future stewards will have the tools to assess the performance of US nuclear weapons with confidence. They must be able to remake parts and rebuild weapons as needed and deal with whatever issues arise using a set of computational and experimental tools that excludes nuclear explosive tests.

To date, the SSP has achieved remarkable successes. It has enabled the laboratory directors to assure the nation that we do not need to conduct a nuclear test to certify the deterrent is safe, secure, and reliable. Still, it is a work in progress. In 2004, the W87 ICBM warhead was the first to be successfully LEP'd. SSP enabled the restoration of pit production in 2007 using new, validated processes. In 2006, after a long program of experiments, simulations, and analysis of previous nuclear test data, scientists concluded that US nuclear weapon performance would not decline sharply due to plutonium aging effects. Enabled by the Advanced Simulation and Computing program (ASC), many other advances in understanding and modeling of nuclear weapons have been made, settling many issues left unresolved at the end of testing. To date, the SSP has achieved more than $10B in LEP cost avoidance and eliminated more than $4B in pit manufacturing facility cost. A few overarching goals remain for the SSP. The key and most difficult is the development of a validated, predictive boost model that addresses weapon performance. Advances in high performance computing, pursuing the next logical steps in computer model development, and data from experimental facilities such as NIF and DARHT will enable this transformation to "predictive capability." The next steps in the SSP, the ability to fully and accurately simulate weapons performance, will give decision makers confidence in certification of weapons as they deviate from their nuclear-tested state.

Complex Transformation. NNSA's plans to transform the nuclear weapons complex are described in a January 2008 draft Supplemental Programmatic Environmental Impact

Statement. The goal is to make the complex smaller, safer, more secure, and more cost effective while restoring its ability to make nuclear weapons. Originally, transformation plans hinged on the streamlined manufacturing environment enabled by RRW, however the future remains undecided and so we must prepare to sustain the deterrent with LEPs for Cold War weapons.

II. Future Requirements for Nuclear Weapons

We do not believe that nuclear weapons will be eliminated any time soon. For over sixty years nuclear weapons have preserved world peace. Some believe that advanced conventional weapons (ACW) will displace and eliminate nuclear weapons. We doubt this will happen. Today, the number of states believed to possess nuclear weapons has returned to its historical high of nine, but several times that have the potential to acquire weapons in a short period of time. About half the world's population lives in states that have nuclear weapons and about three-fourths live with their own or are under the nuclear umbrella provided by security assurances, or at one time explored the prospect of acquiring their own weapons. In the Cold War, of the more than a dozen nations that started developing nuclear weapons, most subsequently terminated their programs. Since the Cold War ended, India and Pakistan have become nuclear weapons states; North Korea has tested a nuclear device; and, Iran is determined to become part of the nuclear club. There is no correlation (or perhaps a negative correlation) between US stockpile size or activities and proliferation. There is likely a strong correlation between ACW and nuclear proliferation. Presently, over 30 nations rely on our extended nuclear deterrent. There is a strong relationship between ally nonproliferation and the US extended deterrent. Since the US ceased its nuclear testing program in September 1992, there have been over a dozen foreign nuclear tests. While the US does not presently have the capability to remanufacture its Cold War stockpile, Russia, China, the UK, and France do and are actively pursuing modernization of their strategic nuclear forces.

Achieving a sustainable 21st century US nuclear deterrent is one of the main challenges we face. The US deterrent must continue to maintain world peace. It has been and will continue to be a means by which the US can convince adversaries that we have a capability to hold what they value at risk. This deters adversaries from using WMD against the US and its allies, convinces our allies they need not pursue development of their own nuclear force, and assures the American people, our allies, and our friends that we are capable of defending them against intimidation or attack. Unfortunately, as a nation, we have yet to agree on how to maintain the credibility of this deterrent. We are encouraged that the 2008 Congressional Commission on US Strategic Posture will help define 21st century nuclear policy and the role nuclear weapons play in meeting the challenges of today's global security environment.

The nuclear weapons laboratories offer valuable, credible, and essential advice on stockpile and weapons complex options. Determining US stockpile size, make up, and related production rates must take into account the military roles and evolving target base that conventional weapons cannot meet, be able to meet threats to its safety and security, and be survivable in light of technical advances in other nations. The arm of the deterrent provided by NNSA must balance risk against budget pressure, human capital against floor space, investments in efficient, high confidence, modern technologies against proven though less sustainable Cold War technologies. The laboratories are ideally suited to inform decision makers on the available options, advance innovative technologies to minimize capital investments, and explore options and quantify risks associated with maintaining a credible, but much smaller stockpile.

III. Optimizing the Program to Support a Reduced Stockpile

A sound 21st century strategic posture must be consistent with a viable stockpile and weapons complex. While the strategic posture has yet to be developed, it is worth exploring issues and innovative approaches —from a stockpile steward's perspective—in making significant further reductions in the size of the US nuclear stockpile and weapons complex while maintaining a credible deterrent. For the purposes of argument, we assumed a stockpile size on the order of ~2000 warheads. However, most of these concepts and arguments apply as stockpile numbers approach zero.

How to build this optimized program? Detailed plans must be designed to meet three overarching objectives: First, to keep the stockpile safe, secure, and reliable given the evolving security environment. Second, to approach elimination of any likelihood that the US would have to conduct a nuclear test by advancing the necessary skills, expertise, and tools to make sound decisions on how best to meet the first objective. Third, to retain the capability and sustain the minimum capacity to respond to changing international circumstances. The plans must meet these objectives in an affordable, sustainable way that is fully consistent with US national security objectives (e.g., nuclear nonproliferation) and international obligations (e.g., extended deterrence).

A mature SSP—with transparent internal and external review mechanisms—is the foundation. Three important questions to address: What types of weapons should be produced? What are the long-term scientific and technical capabilities required to sustain, not just the stockpile, but the deterrent? What should be the capacity of the production complex?

What types of weapons should be produced? life-extended, Cold War weapons vs. modernized, high-margin warheads. Stockpile Stewardship has enabled us to maintain a stockpile that is safe and, with manageable exceptions, reliable. But the risks to the stockpile are real. Through the stockpile surveillance program we continue to identify problems with warheads that in the past would have been resolved with nuclear tests. After more than a decade of SSP experience, we have concluded that our current path – maintaining the certification of a high yield-to-weight, finely tuned Cold War stockpile through successive *incremental* life extension programs (iLEP) – involves increasing risk. Given this increasing risk, it is prudent to explore alternate means to ensure stockpile reliability over the long term. A stockpile based on fewer types of Cold War weapons also increases risk. As we have learned through hard experience, unless there is type diversity in the stockpile, common mode failure will have serious consequences.

We have sought ways to mitigate that risk by increasing margin-to-failure and simultaneously address 21st century security threats with surety enhancements. For example, the Reliable Replacement Warhead (RRW) is optimized for high-performance margin, for ease of manufacture, for eliminating hazardous materials, and to increase safety and security. The laboratory directors stated that, in their technical judgment, it would be less likely that we will need nuclear testing to maintain the safety, security, and reliability of the stockpile if we pursue modern replacement warheads than if we rely on iLEPs of existing Cold War warheads.

It is useful to contrast these two polar possibilities: that current Cold War weapons stay in the stockpile indefinitely through iLEPs that could grow more difficult over time as more and more parts of aging weapons need to be replaced; or that over time, modern high-margin technologies achieve high confidence in the enduring stockpile. Both approaches carry baggage. Some believe RRWs have the stigma both of being "new" designs and not having the benefit of fully integral nuclear tests. The LEP approach may very well require long-term preservation of a reserve stockpile to hedge against a quickly arising problem that exceeds small margins to failure. Preliminary studies indicate that the RRW approach should be less expensive than iLEPs because RRW is specifically designed with ease of manufacture, no exotic materials (save plutonium and enriched uranium), and smaller facilities in mind. Are we better off with a weapon that, while tested, has not specifically been tested as weaponized but is designed to have large performance margins and comparatively simple engineering features? Or, are we better off with a weapon with small performance margins and many design alterations from that tested in its original instantiation? It is clear to us that RRW provides the best path forward to a smaller stockpile. It will take some time for sufficient numbers of RRW to enter the stockpile in order to alleviate the issues presented by the iLEP approach to the Cold War stockpile. An intermediate, temporizing approach to this transition is needed. This will be even more the case absent an opportunity to explore potential RRW advantages because iLEPs then become the default solution.

Fortunately, there is a temporizing measure to this dilemma if we truly are on the road to a substantially smaller stockpile. It involves an innovative extension to the present iLEPs. An extensive reuse LEP (erLEP) approach can be tailored to upgrade surety, increase margin, and increase system life. As with an iLEP, an erLEP would not add military capability, other than surety and safety. In a sense, erLEP sits in a continuum between the iLEP and the high-margin, high-surety RRW. It brings much benefit to the stockpile, but not all the benefits to all the stockpile. Not all systems can be LEP'd via this route. There are just not enough of the appropriate parts. The remaining Cold War weapons could be "cherry picked" to avoid known aging concerns. While not the ideal solution embodied in RRW, this temporizing method can better life extend Cold War weapons and avoid many large investments.

A very large number of components from nuclear-tested designs sit in storage, either separated from weapons or integral to weapons slated for disassembly. These components form the basis for an erLEP approach possible with lower stockpile numbers. The SSP, for example, has confirmed long lifetimes in stockpile pits. Through smart choices in reusing pits in LEPs, higher margin systems can become a stockpile norm. Smart choices of pit reuse can also eliminate many hazardous materials from the stockpile and increase the safety of the weapons. An important objective is to evolve the stockpile into compliance with the goals of NSPD-28 where "unauthorized use of a US nuclear weapon is impossible....". Recent advances in SSP have identified advanced security technologies achievable in erLEPs with relaxed yield-to-weight limits. Provided SSP surety research continues, this technology would enable a substantial number of stockpile erLEPs to become high-surety weapons. Use control development leverages and integrates the strengths and capabilities of the two nuclear design laboratories. It builds upon continuing advances in SSP capabilities.

The reuse concept is not limited to pits. Even greater benefits can be reaped if reuse extends to other tested weapon components. Secondaries do not suffer aging of the sort that is of concern in pit aging. Appropriately made secondary parts, vetted in surveillance, are available for reuse. Studies have shown reused secondary components, with a nuclear-tested pedigree, offer high-confidence alternatives to iLEPs.

In addition, modern technologies to extend our knowledge of the condition of weapons can be seamlessly incorporated into erLEPs. For example, the use of embedded micro-sensors monitoring a weapon's health can provide a continuous stream of data on the condition of an individual weapon. Imbedded sensors that self identify minimize shipping, surveillance disassembly, and destructive evaluations except where the weapon's data stream indicates an actual issue. These sensors, developed by the SSP and targeted for RRW, are now mature enough for final testing in weapon assemblies.

By incorporating micro-sensors into erLEPs, we can increase our confidence in each weapon. A small stockpile increases the deterrence value of each individual weapon. Thus, the impact of weapons failure increases as the stockpile decreases. Diversity of type becomes even more important. Traditional statistically based disassembly surveillance becomes unworkable at low numbers. Thus, embedded micro-sensors move from a good idea to a necessity. In traditional surveillance, disassembly and inspection mandate an increase in stockpile numbers just to have units to inspect. Modern, embedded sensor technology minimizes the logistics backup from the stockpile by eliminating transport, disassembly, and inspection of healthy units.

erLEPs combined with "cherry picking" of existing weapons would enable a smaller production complex, reducing or even eliminating the need to rebuild some Cold War facilities. Reuse eliminates the costly production of many weapon components. Current reuse of stockpile pits has dramatically reduced the need for new pit production. Essentially pristine secondary components currently in storage represent more than two decades of future production in the planned complex. To simply discard these components and build new is a huge waste of national resources. Because these components exist, we could respond faster to stockpile issues.

In summary, the future stockpile strategy, when coupled with a weapons complex that has a fully proven and mature capability and capacity, should afford the opportunity to minimize the reserve stockpile and provide confidence to consider the means to lower stockpile numbers. While RRW represents the "end state" on the continuum, an erLEPed approach can serve as the bridge to accelerate a transition and represents significant progress toward a safer, more secure, and reliable nuclear deterrent. Building on its successes, the SSP is on the path to build a capability that can provide confident certification of reuse weapons or RRWs without nuclear testing or at its logical end—the need to rely on a particular past nuclear test result. Confidence in the future stockpile, coupled with a sustainable and agile laboratory and production complex, eliminates concern over whether the nation can respond in time to national needs.

Capability and Capacity. It is convenient to split discussion of the future status of the weapons complex into two parts: capability and capacity. Capability includes the weapon design, engineering development, assessment, and certification skills and tools within the weapons complex. Largely (but not exclusively) residing at the three NNSA laboratories, most of these activities can be thought of as the evolution of "science-based stockpile stewardship." Capacity deals with production—how quickly can weapons be made and what special nuclear materials and components are on hand or can be made.

Capability provides the basis for rebuilding the US nuclear stockpile in response to international events or technological surprise. Capacity determines the response rate. Capability also provides the essential source of technical input into arms control negotiations and implementation, including the development of verification technologies, and interpretation of intelligence information. It is essential for effective nuclear emergency response and avoidance of technical surprise. Finally, the SSP embodied in capability is the only safeguard the nation has to avoid nuclear testing when a weapon problem arises.

What are the long-term scientific and technical capabilities required to sustain, not just the stockpile, but the deterrent? Capability: The Science and Technology Base. As mentioned above, capability is the only safeguard the nation has from the need to resume nuclear testing as issues arises. It is also the nation's insurance to guard against strategic surprise. In many respects, the need for outstanding capability—the ultimate objective of SSP—becomes even greater as the size of the stockpile decreases. The lower the number of weapons, the more important becomes the performance of each weapon type (and at extremely low numbers, each weapon). Through sensor-enabled surveillance coupled with advances in computer simulation, SSP is poised to deliver a capability to precisely characterize the individual performance of each and every nuclear weapon from cradle to grave. In fact, by maintaining the pace of SSP advances through the next decade, stewards will deliver this capability not just for stockpile weapons, but for nuclear weapons whose configuration has diverged from those that have been nuclear tested.

Why were nuclear tests conducted? They were conducted to measure a few parameters used to set adjustable performance factors in simulation codes. When relevant nuclear test data is not available, stockpile stewards rely on basic understanding of the weapons, developed through theory, non-nuclear experiments, simulation, and sophisticated methods under development to quantify margins to failure and weapon uncertainties (QMU). Issues that arise in stockpiled weapons are typically not recurrent problems. They are usually unforeseen. Thus, if sustaining the stockpile depends on a previous nuclear test of a potential problem, we are hostage to good luck. So far we have been lucky (and because of SSP, smart). Stockpile stewards are working to remove design-dependent adjustable factors in their simulation models for energy balance, boost, and secondary performance. To eliminate dependence on the results of any particular nuclear test, stewards need to complete these keystone deliverables and have sufficient computational capacity for QMU risk analysis. This will enable confident extrapolation from experimental test data as weapons age and problems arise.

A major goal of the stewardship program was the demonstration of an entry-level simulation ability through a million-fold increase in computational capability. That was achieved in 2006 with the operation of the ASC Purple machine capable of 100 teraflops (10^{14} operation/sec). To retain international leadership in weapons capability and to eliminate reliance on nuclear test benchmarks requires those keystone models combined with QMU simulation ensembles. This sets the scale for simulation. It will require exaflop (>10^{18}ops/sec) scale computing. Currently our fastest (and the world's fastest) machine is Blue Gene/L at about 0.0005 exaflops. While high-margin systems would be less prone to single-point failures than Cold War designs, they are no less in need of this capability. There is no technology that eliminates the vagaries of nature or the advance of time.

Exercising the combination of weapon design and development engineering is also essential to sustaining the steward's skill level. The steady development of new systems before 1992 maintained the experience of nuclear weapon designers and engineers. It provided experience both broad and deep. Such training is a crucial part of nuclear weapons stewardship because new employees do not arrive with the required skills. Knowledge of the details of nuclear design and engineering is important beyond stockpile maintenance; it also underpins the avoidance of technical surprise, development and implementation of effective nonproliferation strategies, and negotiation of prudent arms control treaties and verification measures. Periodic prototyping of components, subassemblies, and complete designs serves to keep capability for weapons development sharp and credible.

The National Ignition Facility is nearing completion. Operating with of 192 laser beams in March 2009, it will deliver 60 times more energy than any other high-energy-density experimental tool. It will be able to attain the grand challenge goal of laboratory fusion ignition, will provide an unprecedented venue for mathematically scaled, non-ignition weapons physics experiments, and will provide, for the first time, the ability to conduct laboratory experiments in the physics of nuclear weapon thermonuclear processes. While a wide range of stewardship's experimental capabilities are required to resolve the final uncertainties surrounding weapons performance, NIF will be at the forefront of understanding both fundamental physics and integrated phenomena central to predicting weapons performance. The final keystone models of SSP can only be validated at NIF. The centrality of fusion burn to boost is self-evident. The leap to a simulation capability that frees the nation from ever again requiring nuclear test data is contingent upon the understanding gained from NIF experiments conducted at the pressures and temperatures arising in a nuclear explosion. NIF is where the capabilities of both primary and secondary nuclear weapons designers will be tested.

The recent success of the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) is central to sustaining skills as well as maintaining weapons. DARHT is where primary designers are tested. DARHT produces unprecedented high-resolution images from two separate views at multiple times of the hydrodynamic behavior of an imploding nuclear weapon primary pit. This will give greater confidence in the understanding and accuracy of 3-D simulations of weapons performance. Such capability is particularly important to answer recent JASON concerns regarding the certification of safety and security technologies.

An unresolved long-term sustainment issue is born of the success of ASC simulation. As simulation fidelity increases, the number of experiments needed to verify performance decreases. As this trend continues in a financially constrained program, the enterprise will be challenged to sustain large-scale facilities as the experiments in those facilities become infrequent. We will have to get our data in a very different way. Production facilities face a similar problem if operated far below their base capacity. Ultimately, financial exigency will demand a "facility-free" approach because it is the data, not the facility that must be sustained.

The single integrating capability absolutely required for any size deterrent is that of human intellectual capital. Recruitment and retention of an expert workforce is a substantial challenge, particularly in an environment where the principal deliverable is being downsized. In coming years, we will face the retirement of the last of the workforce experienced in nuclear testing. In the face of this reality, the laboratories continue to hire the best and brightest. These scientists and engineers have, to date, kept the laboratories at the leading edge of technology. The workforce must be expert and diverse, able to take advantages of the strides made in multidisciplinary science. Working with the best simulation and experimental facilities the workforce is inspired and empowered to anticipate technological surprise. The workforce engaged specifically in nuclear weapons is shrinking as the SSP succeeds. This is not a new trend. The number of scientists required to field a weapon in the 1960's was vastly larger than we need today. Simulation enables us to do significantly more with many fewer people. So it is natural that numbers will decline, making each individual that much more essential. As SSP succeeds, these skills are being brought to bear on a broader suite of national security research needs. This broader suite of research will also help to attract and retain the best and keep them at work in areas that will give rise to disruptive technological surprise. Maintaining the human capability element is usually an unspoken risk, but we believe it is the greatest risk to maintenance of a credible deterrent.

In light of the challenges of the 21st century global security environment and the challenges for maintaining the stockpile, we must not starve capability in favor of investments in capacity. Keeping the momentum of SSP capability advances is required to maintain the aging stockpile, offering credible future stockpile options, and forms the insurance policy against technological surprise. Without substantial sustained investment in SSP capability today that capitalizes on the available expert workforce and investment in SSP tools, the country cannot propose to maintain a credible nuclear deterrent with small numbers of nuclear weapons.

What should be the capacity of the production complex? Production Facilities and Special Nuclear Materials. To sustain nuclear weapons deterrence we must also transform the supporting nuclear weapons R&D and manufacturing infrastructure. In this regard, we are continuing to make progress on restoring many capabilities, including production of tritium and plutonium pits.

The best approach to capacity for a small stockpile is a very different model than we have today or had during the Cold War. The Cold War stockpile contains a large number (about 10) of very exotic, non-commercial processes that make long-term sustainment problematic (and so expensive). Further, the block iLEP approach driven by the block construction approach of the Cold War means that production rates are not sustained. Specifically, a future small stockpile based upon these systems and approach will undergo the sort of financial and technical dislocations that the current LEP program is experiencing (i.e., investing to reestablish processes, running them, and shutting them down, then recapitalizing them for a smaller run 10 or 20 years later). Elimination of many in-house processes by material elimination and/or outsourcing allows transition to minimum facilities or even facility-free technologies. This then enables a change to sustained, trickle production and so avoids huge demand swings.

Two important weapon production issues are rate of production and what is produced—both factors affect the size and design of the production complex. A minimum production complex to sustain a reduced-size stockpile would have a one-shift production rate of about ~50 weapons per year, such as the planned pit facility at LANL. A capacity sized to a small stockpile should entail this model of production. Lower numbers make the maintenance of Cold War multiple-technology, big factories problematic. The huge brick-and-mortar costs are not commensurate with ~50 weapons per year trickle production. This argues for minimum facilities, elimination of special materials wherever possible, and facility-free capabilities. This also argues for simplicity of materials, assembly, and disassembly.

Continuous trickle production would be consistent with a stockpile of ~2000 if a combination of refurbishment/replacement every twenty years and erLEPs (with perhaps RRWs) becomes the norm. A slow, steady production rate mitigates risks that arise from start-and-stop batch manufacturing. If you make some weapons and then stop for years, problems will arise when you start up again (such is the case in current iLEP production). Trickle production, which is the way the United Kingdom and France sustain their stockpiles, helps to preserve know-how and skills in the production complex as well as minimize facility size. Trickle production with both outsourced and minimized in-house facilities also avoids the unintended external perception that a recapitalization project is driven by an arms build up. Stability of production for a stable, smaller deterrent stockpile enhances the stability of perceptions of that deterrent.

What you produce is very important; there are significant differences between a future stockpile of iLEP'd Cold War weapons or high-margin warheads. While not as comprehensive as an RRW approach, erLEP would help eliminate many hard to sustain and hazardous materials processes. Fewer components need to be produced because nuclear-tested components already exist. While it is likely erLEP weapons are less costly to produce than iLEP weapons, they would still require some investment in plutonium and highly enriched uranium facilities. The costs of construction, operation, and maintenance of these facilities in today's environment are large and the costs are only likely to increase. This argues for improved design technologies to enable reduced investment and reduced reliance on traditional approaches to special nuclear material manufacture. It also minimizes the long-term costs, environmental impacts, etc. (e.g., Rocky Flats, Hanford) that might be incurred.

If the stockpile is smaller and the US takes the constrained approach to production proposed here, reconstitution of large stockpile sizes or variations in design would be enabled by basic sets of skills, tools, established processes, and an experience base in an optimized, effective complex. Should the world become a more troubled place, a strategy of modular expansion of minimum facilities could address increased needs. Building on concurrent engineering and advanced prototyping methods, the time to go from design to production could be revolutionized. A streamlined design-to-production process would increase confidence in the responsiveness of the capability-capacity link thereby allowing a smaller stockpile and cutting weapons acquisition costs in the near term. This process and the potential for modularization of production would provide readiness required to respond to national security threats in a time of national need.

A capable production complex offers decision makers a variety of choices regarding the size and make-up for the stockpile. For instance, one can envision a small stockpile of high-margin, high-surety warheads augmented by a production complex able to respond quickly to an emerging threat. Establishing confidence in both the capability to diagnose and address weapons performance issues and confidence in the timely ability to produce required weapons, would eliminate the need for the reserve stockpile. While there is a limit to the number of high-surety warheads that could be immediately produced via pit reuse, future decision makers may opt for that stockpile size, or trickle production could eventually eliminate the problem. Such a decision would better assure the safety and security of the stockpile and reduce the size of the infrastructure required for new pit production, among other things. In a time of national need, additional warheads could be built from modularized expansion of the facilities described above, or alternatively, very quickly assembled from reuse materials and components, unsuitable for the high-surety stockpile. With confidence in the capability to rapidly design to the threat, the DoD could have weapons beyond those in the enduring stockpile tailored to meet future threats, and the US could maintain very small stockpile numbers.

IV. Concluding Remarks

Peace is the paramount goal. To maintain our deterrent and the nuclear umbrella, the US must maintain vital technical capabilities; capabilities that can be brought to bear quickly to meet any challenge. First and foremost, under any stockpile size, we must maintain essential human capital and provide them with forefront capabilities and have right-sized responsive, production capacity. The Stockpile Stewardship Program continues to be hugely successful. Coupled with the right complex, SSP can sustain a credible nuclear deterrent. A framework for the enduring deterrent has not yet been defined, nor the stockpile to fit that framework. The Congressional Commission on US Strategic Posture and the upcoming Posture Review should help define that framework. However, we must not let the lack of a framework cause stewardship to stall nor workforce skills to atrophy. It would also be irresponsible to make major investments in recreating a Cold War complex before the country decides upon the proper framework. The stewardship program has brought forth innovative solutions to maintaining the deterrent and optimizing investments. We have an unprecedented opportunity to consider alternate approaches; to use existing stockpile resources to manage the stockpile while we make transformational decisions. Continuing to invest in capability for the deterrent broadens the solution options the country can draw for in the future. By deciding now to sustain investments in capability we can secure a much smaller, science-based stockpile with enhanced security and safety that is sustained by a responsive, right-sized production complex.