Strategic Weapons in the 21st Century:
Hedging Against Uncertainty

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"Forces, Infrastructure, Science and Technology"

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My premise: U.S. has maintained a safe secure and reliable nuclear stockpile and deterrent for past 16 years without relying on nuclear explosive underground tests (UGT). The Stockpile Stewardship Program (SSP) has been successful, more so than many anticipated under a moratorium on UGTs; but,

We must recognize that continued success is not assured and, furthermore, global changes – both in political/strategic circumstances and in technology present new challenges.

I will focus on DOE. I recognize that DOD has major issues too, but leave that to Rich. In my time I will uncover some, but not cover all, important challenges.

Here are 2 figures which summarize where we are and illustrate the challenges and why we may even be facing a tipping point:

The number of nuclear weapons in the arsenals the United States and Russia (Fig. 1) has decreased significantly since 1986, and the number of states that have opted to develop nuclear weapons and maintain them in their arsenals still remains under ten (Fig. 2). But the international consensus that once favored fewer nuclear weapons states has eroded. Some states that decided to forgo nuclear weapons, thinking that their national security could be protected without them, reportedly are reconsidering their positions, and more will do so, inevitably, if present trends persist. Moreover, with the global spread of technology, the threat that the world's most terrible weapons might fall into the hands of terrorists has escalated. The trend as I see it is not favorable for our non-proliferation efforts. This is a serious challenge for our nuclear posture. Also a serious challenge to diplomatic efforts to forge effective political cooperation on a global scale not only with the nuclear but also with the more than 180 nations who so far have voluntarily agreed to forego nukes but who increasingly have the technical capability, certainly for single stage uranium gun type weapons.

The 800lb. gorilla in the room in formulating nuclear policy to meet U.S. security needs remains Russia. We have the 2001-2002 Moscow declarations announcing that U.S. and Russia have overcome the Cold War legacy and calling for "the creation of a new strategic framework," saying that "Neither country regards the other as an enemy or threat." I doubt any one is ready to put that in the bank today, and as long as that is so, nuclear deterrence is not about to go away.

During the Cold War, the US and the former Soviet Union relied on nuclear deterrence to navigate successfully through those perilous years. And, against what seemed to be insurmountable odds, not one of the many thousands of existing nuclear weapons was detonated in military combat, although there were numerous opportunities to have done so.

But it would be dangerously wrong to draw comfort from that achievement. The clarity of the bipolar U.S.-Soviet world has now given way to the ambiguities and uncertainties of a world in which international security is threatened by transnational terrorists, unstable and failed states, and regimes that scorn a world order based on broadly accepted principles. The dangers inherent in such a stew are magnified by easier access to nuclear technology, inadequately protected stockpiles of plutonium and highly enriched uranium, the growing availability of missiles worldwide, black-market nuclear supply networks, and a trend toward acquisition of "latent" nuclear weapons capabilities through the possession of the entire nuclear fuel cycle. (Recall President George W. Bush's statement that "the gravest danger this nations faces lies at the crossroads of technology and radicalism.")

These developments have led to increasing concerns that nuclear deterrence as implemented during the Cold War is becoming decreasingly effective and increasingly hazardous in a world in which nuclear know-how, material and weapons are spreading ever further and faster. Today the world is teetering on the edge of a new and more perilous nuclear era, facing a growing danger that nuclear weapons -- the most devastating instrument of annihilation ever invented -- may fall into the hands of "rogue states" or terrorist organizations that do not shrink from mass murder on an unprecedented scale.

We must face the challenge to adapt today's nuclear posture to address these concerns and to reduce the nuclear dangers we are facing.

What are our needs in the interest of U.S. national security? Up to the present, SSP has relied on the following assets to be successful. When I say successful I am referring to two fundamental measures: First, it has discovered causes for serious concerns in the stockpile, which is what it should do if such causes exist. Second, it has successfully addressed these concerns. The following discussion draws on the paper on "Technical Issues in Keeping the Nuclear Stockpile Safe, Secure, and Reliable," co-authored with Marvin L. Adams of Texas A&M, for a workshop on *The Role of Nuclear Weapons in National Security Policy* sponsored by APS, AAAS, and CSIS (April 2008).

Expertise

The most important component of a responsive infrastructure that can maintain a safe, secure and reliable nuclear weapons enterprise is personnel with the requisite expertise. This includes experts in surveillance, dismantlement, manufacturing, design, assessment, basic science, experimentation, computational simulation, etc. Success of the program, whose elements we discuss below, depends entirely on the expertise of the people who execute it.

Expert personnel constitute more of a deterrent to evolving threats than do facilities or even existing weapons. Given sufficient resources, people with the appropriate expertise can respond quickly to unanticipated problems or changes in requirements and can provide confidence in the solutions they produce. Without such people, no amount of resources will yield timely solutions, in which confidence is justified, to new problems.

Expert personnel have always been important to the complex. This was obvious in the earlier years when new and improved weapons were being designed and introduced into the stockpile to meet new military requirements. Although we no longer call for new designs for new military missions, we still rely on the expertise of designers to assess and solve potential problems as they are identified over time. They must devise and assess possible solutions that can be developed and employed with confidence without relying on nuclear explosive testing. This challenge calls for both innovation and adherence to change discipline so as not to introduce more unknowns that could result in lower confidence in the redesigned weapon. The record of success so far in SSP testifies to outstanding people who have led and executed it.

An increasingly broad spectrum of national-security problems requires nuclear-weapons expertise[1]. An example is the increasing need to assess proliferation risks under a variety of scenarios. Another is the desire for "nuclear forensics" to help identify the origins of interdicted nuclear material, radiological dispersion devices (exploded or interdicted), and nuclear explosive devices (exploded or interdicted). Yet another is the need for a capability to disarm and disable interdicted devices. There is also is the ongoing – perhaps growing – need to verify treaties and monitor nuclear weapons-related technologies: expertise will be needed to train the relevant inspectors. These additional requirements underscore the need for expert personnel as the foundation of a responsive nuclear-weapons complex.

As I have already emphasized, a flexible and responsive deterrent rests on a foundation of expert personnel, but these personnel must be embedded in a program that allows them to retain and hone their expertise while providing the tools necessary for appropriate responses to surprises and policy changes.

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[1] This has been emphasized by NNSA Administrator Thomas D'Agostino, in testimony to the Strategic Forces Subcommittee of the House Armed Services Committee on February 27, 2008, as follows: "In addition, our 21st century enterprise will continue to leverage the scientific underpinnings of the historic nuclear weapons mission to respond to a full range of national security challenges that we have, and beyond nuclear weapons sustainment but shift those more towards nuclear counterterrorism and nuclear nonproliferation activities. And as an example, we provide technical support to the Defense Department and the FBI and emergency render-safe and post-event nuclear technical forensics activities. And a lot more needs to be done in that area and we're going to be looking to shift more towards that area."

Search and Discovery

One cornerstone of the nuclear weapons program must be vigilance in the search for and discovery of problems in the stockpile, arising for example from design errors, aging, or birth defects in the original manufacturing process. This must continue to include rigorous and aggressive surveillance and forensics designed to detect problems early, with high confidence that problems are not missed. The record on this to date appears to be very good, with the surveillance program having supported twelve years of successful annual assessments. In addition to surveillance, search and discovery must include modern assessment of legacy designs. This can be viewed as time-delayed peer review that brings to bear tools and knowledge developed since the designs were originally certified.

Computational simulation

This refers to:

- high-fidelity computational simulations of phenomena relevant to nuclear weapons
- computational hardware, model development and validation, software implementation of models and verification thereof, quantification of uncertainties and assessment of predictive capability, and ability to adapt simulation capability in response to new findings and/or changes in the spectrum of problems that need to be addressed

High-fidelity simulations of some important phenomena – phenomena that in many cases dominate the uncertainty in our simulated results – remain well beyond the capability of today's computers. While the next generations of computers (Roadrunner and then Sequoia) will lessen this problem, they will not eliminate it. Pursuit of advanced computers, as in the Sequoia acquisition, should continue, but simultaneously there should be continued cost/benefit evaluation of how much reduction in uncertainty can be gained by further increases in computing power.

Robust Experimental Program

Experimental science, ie. a robust and advanced experimental capability is essential in discovery science for phenomena that are not sufficiently understood, as in the ongoing efforts in the National Boost Initiative and in efforts to resolve "energy-balance" questions. In this role they inform model development and help to assess model validity.

It is important to recognize that the ability to respond to problems requires an ongoing capability to design and field experiments. It is not possible to anticipate all future problems and perform the needed experiments in advance.

Experimental measurements are an essential ingredient in the validation of mathematical models of physical phenomena, the quantification of uncertainties in simulations, and the assessment of predictive capability.

Peer Review

In the absence of a confirmatory nuclear test, it is appropriate to take great pains to carefully assess any modification to or replacement of an existing tested design. It is equally important to subject the assessment to careful scrutiny to either discover any weaknesses in the assessment or to build high confidence in its validity and rigor. An essential part of such scrutiny is detailed independent peer review. This requires an independent set of weapons experts using an independent set of analysis tools (such as different simulation codes).

Research and Development

The program elements described above cannot succeed without research and development (R&D).

Summary

Any program that is expected to maintain a safe, secure, and reliable nuclear weapons stockpile should be tailored to support a nuclear-weapons policy that must be formed by the new and subsequent administrations. While specific programs and emphases should be policy-dependent, the ingredients we have listed will be required under any foreseeable policy. These ingredients form the basis of a nuclear weapons program that can be flexible enough to support U.S. policy as it inevitably evolves in response to a changing world.

The Future

Will the U.S. be able to maintain a safe, secure, and reliable stockpile by adhering closely to original designs of today's stockpile weapons, will we need to introduce new designs, or will we need an evolving combination of both?

There is a spectrum of modernization options ranging between two extremes. At one extreme, we contemplate making heroic efforts to replicate weapons as they were introduced into the stockpile, using hazardous materials and outdated manufacturing processes, regardless of costs or modern assessments of the designs. At the other extreme, we contemplate replacing weapons using new designs that have not been subjected to nuclear tests, trusting our ability to predict their performance. To date the LEPs have operated toward the replication end of the spectrum, while the RRW program was intended to be a venture toward the other end. A "hybrid" strategy in between could involve repackaging "old" components, tested as part of old designs, into new designs. LEPs have not stayed completely at the replication end of the spectrum. Outside the Nuclear Explosive Package (NEP) of a weapon there are components that can be tested to a significant extent. Some of these have been replaced by newly designed components, which is an example of the new-design end of the spectrum. Some components inside the NEPs have been replaced by components that differed from the originals to some extent in design and/or processing. For example, the replacement W88 pit employed new personnel using new manufacturing processes and different facilities. In certifying this pit we have declared success in venturing, to some degree, away from identical replicates, even inside the NEP. Our confidence in the modified warhead is based on careful experiments and analyses performed as part of the SSP. It is reasonable to assume that in future LEPs we will continue to see replacement components that are not exact replicates of the originals.

The best option along the spectrum will depend on the issue being addressed and the requirements that are imposed. That is, my answer to the main question of this section is: “It depends on the problem.”

It is also critically important to weigh carefully additional performance risks that may be introduced by design changes made without the benefit of UGTs. How does one measure the evolution of risks due to multiple changes during the lifetime? One frequently hears the following statement: “Over time, accumulating changes lower confidence and difficulties increase.”

It is also necessary in evaluating risk to include the impact of the important gains in our understanding of nuclear processes under explosion conditions that we have gained from the SSP program over the past decade and more. The quantity of importance in measuring risk or confidence is the ratio M/U of margins M to uncertainties U, which should be significantly larger than unity. Predictive science in conditions of nuclear explosions is making progress but has a long way to go. The experiments and analyses that exploit the latest advances in supercomputers are opening new avenues of progress. Some successes recently include more than doubling plutonium pit lifetimes and a growing ability to understand boost physics that is being gained from the National Boost Initiative. Then there are also significant increases in margins M as a result of more robust boost gas systems. Relaxing Cold War requirements for operations in hazardous environments, viz. neutron pre-initiation and fratricide also will enhance margins. Soon the National Ignition Facility will make it possible for us to get data in the lab on the behavior of matter at extreme pressures and temperatures as occur in nuclear explosions. We are working our way to important progress in predicting changes in M/U over time.

Before it was cancelled, the LLNL/SNL design for WR-1 had not yet reached a point where one could say with confidence whether it could achieve its goal of developing a warhead, with improved safety, security, and reliability, that could be deployed without underground tests and with higher confidence than the legacy warhead it was designed to replace. Moreover the program had not yet instituted the desired peer review process.

The RRW Program asked important questions that should be answered. The three weapons laboratories did excellent work, for which they should be highly commended, in attempting to answer whether the WR-1 design could successfully achieve its ambitious goals within the restraints that were imposed: no new designs for new military missions and no underground explosive tests. These restraints were imposed on the basis of a judgment by the government that they are important in order not to harm prospects for achieving U.S. strategic/political goals of reducing the nuclear danger and of strengthening the nonproliferation regime, which rely on broad international cooperation. A detailed technical review of the RRW program that had been mandated by Congress was completed by JASON in the summer of 2007. After complimenting the three weapons labs for excellent work the review summarizes its findings as follows:

"certification is not yet assured. The certification plan presented needs further development. For example, additional experiments and analyses are needed that explore failure modes, and assess the impact on performance of new manufacturing processes. Substantial work remains on the physical understanding of the surety mechanisms that are of high priority to the RRW program. Establishing that the case for confidence in any RRW has been satisfactorily made will require a new peer review process."

Based on what we have learned so far from the LEP and RRW experiences, we should proceed as follows: Given the difficulty of the challenge to create a certifiable new design, a program for maintaining a safe, secure, and reliable stockpile should explore a wider segment of the spectrum of options. We still have far to go before answering whether new designs can be created that incorporate all the desired attributes, can be fielded without UGTs, and provide confidence as high as or higher than we have currently in the legacy weapons. Further, there is always the possibility that a new design could contain unrecognized flaws that could lead to unanticipated problems, perhaps generating more significant findings than today's designs. In making design changes it is important to keep this danger in mind and exercise careful change discipline. As we attempt to resolve these issues, perhaps it would be prudent to also address them for a point in the middle of the spectrum, such as new designs that repackage components from previously tested designs.

Exploration of multiple options along the spectrum would create greater flexibility to respond appropriately to changing requirements and to potential surprises (such as those that may arise from continued search and discovery under stockpile stewardship). Each point in the spectrum represents an approach that has strengths and weaknesses. Until an approach is explored in some detail we will not know these strengths or weaknesses in sufficient detail to support informed decisions about how best to address a given stockpile issue. Investigation of multiple options thus supports the flexibility and responsiveness that is desired in the complex. It also meshes well with the R&D program as already described. It provides a means by which personnel (including designers) can hone their expertise, and could help attract outstanding minds into the weapons program.

Maintaining flexibility in the programs has a direct impact on the infrastructure that NNSA will have maintained, including support for elements of the legacy stockpile. How large a uranium production capability will we need at Y12? Decisions on targeting requirements, force size and component reuse will be critical to any decision sizing and staging a decision.

This is also true for plutonium pit production and surge capacities for the CMRR at LANL. The need for flexibility will also impact how NNSA organizes its R&D and certification programs. Rather than measuring the success of R&D primarily in terms of its leading to new deployments through a direct acquisition process, we should view its success in terms of preparing potential capabilities that will be available if and when needed at a later date. This point was addressed in a broader context for the U.S. defense establishment by Richard Wagner and Ted Gold in 1990 in their paper "Long Shadows and Virtual Swords"(published by the American Association for the Advancement of Science, in a volume entitled "Science and International Security" edited by Eric Arnett).

While our discussion has focused on the technical issues, it will be essential to keep in mind the strategic/political implications of actions initiated in maintaining and modernizing U.S. nuclear forces. Not only what we do but how we do it will be important. U.S. decisions and actions about nuclear weapons can be expected to affect the nuclear policy choices of other nations – non-nuclear as well as nuclear – on whose cooperation we must rely in efforts to reduce the global nuclear danger. Relevant factors include structuring new programs with the maximum transparency, and making clear their unambiguous purpose and our intention to reduce reliance on nuclear weapons.

Finally I repeat, continued success of stockpile stewardship is not a foregone conclusion. A responsive infrastructure that can continue to maintain a safe, secure and reliable nuclear weapons enterprise must include several key components. The most important component is top-notch expert personnel, without whom confidence in the U.S. nuclear deterrent will erode along with U.S. ability to respond to changing threats and other national-security requirements. These experts must be engaged in a stable program that includes several cornerstone elements: 1) Vigilance in the search for and discovery of problems in the stockpile; 2) High-fidelity computational simulations; 3) A robust experimental program; 4) Strong peer review; 5) An active research and development program exploring a range of stockpile options.

Figure 1

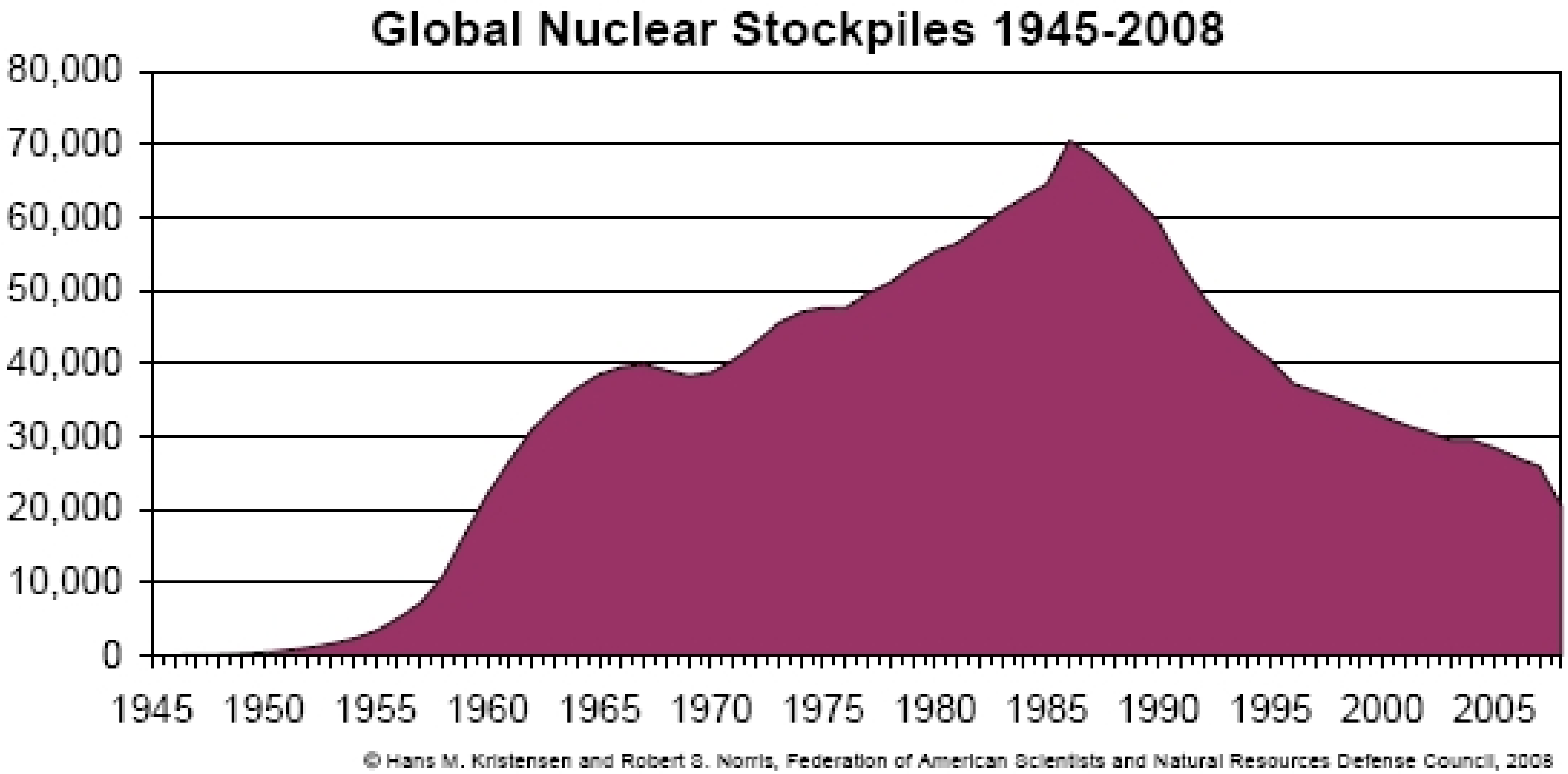
Global Nuclear Stockpiles 1945-2008
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
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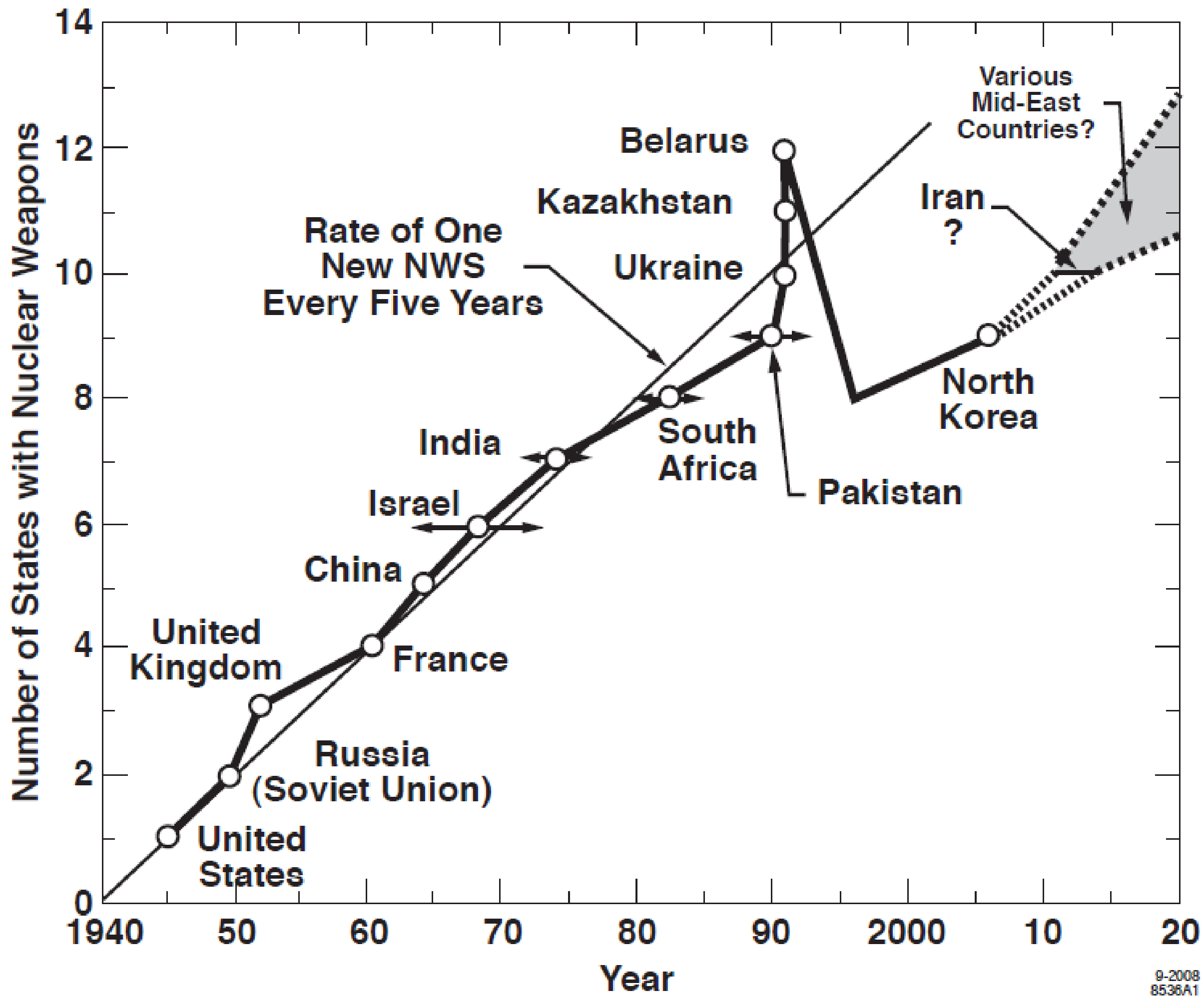
Figure 2


Number of States with Nuclear Weapons
Year
0
2
4
6
8
10
12
14
1940
50
60
70
80
90
2000
10
20
United States
Russia (Soviet Union)
United Kingdom
France
China
Israel
India
South Africa
Pakistan
Ukraine
Kazakhstan
Belarus
North Korea
Iran ?
Various Mid-East Countries?
Rate of One New NWS Every Five Years
9-2008
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