LA-UR-18-20950
Approved for public release; distribution is unlimited.

Title:	Nukes in the Post-Cold War Era A View of the World from Inside the US Nuclear Weapons Program
Author(s):	Wood, Blake Philip
Intended for:	Presentation to undergraduate journalism and government classes at Claremont McKenna College, Claremont, California
Issued:	2018-03-01 (rev.1)

Nukes in the Post-Cold War Era

A View of the World from Inside the US Nuclear Weapons Program

Dr. Blake Wood
Global Security, Los Alamos National Laboratory
bwood@lanl.gov

Claremont Colleges
February 2018

Why do we have nuclear weapons?

What is in the US stockpile, how is it deployed and controlled, and how it has changed over the years?

What is in the “nuclear weapons complex” and what does each lab and plant do?

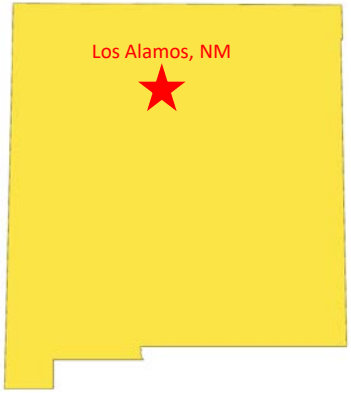
How do the DOE/NNSA Design Labs interact with the Intelligence Community?

How does the US stockpile, NW complex, and NW policy compare with those of other countries?

What is easy and hard about designing nuclear weapons?

Key Messages:

- Nuclear weapons have prevented unlimited war between the world powers since 1945 – over 70 years!
- Investments in computing, stockpile surveillance, and non-yield-producing testing have kept our stockpile safe, reliable, and effective over the 25 years since we stopped full-scale nuclear testing.
- The US has a Cold War stockpile – our newest weapon was designed in the 1980s.
- Other countries are modernizing their stockpiles, and developing new delivery systems and US-peer experimental facilities.
- Today's multipolar world of strong states has not been seen in a century.



Los Alamos National Laboratory

Government-Owned, Contractor-Operated (GOCO)

~$2.2B budget, ~11,000 employees

Los Alamos County

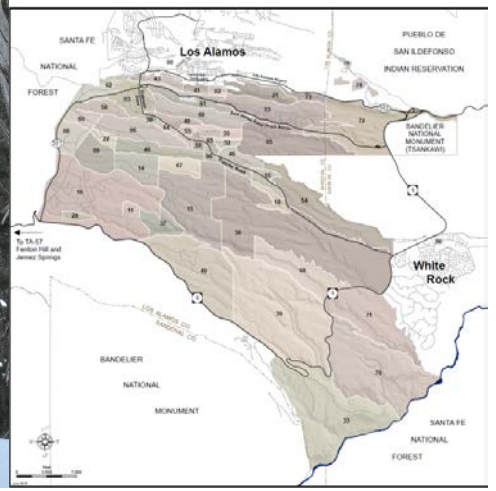
Located at 7000’ elevation in the Jemez Mountains of Northern New Mexico.

11,000 residents in Los Alamos,
7,000 in White Rock.

Extensive trail network.

Pajarito Ski Area just above town.

< 1 hour from Santa Fe.
< 2 hours from Taos and ABQ.



Why do we have nuclear weapon weapons?

"A safe, secure, and effective nuclear deterrent is there to ensure a war that can never be won, is never fought."

- James Mattis, US Sec Def

- Deterrence of nuclear and non-nuclear attack.
- Assurance to countries under our "nuclear umbrella" that they are safe and do not need to develop their own nuclear weapons.
- Achievement of US objectives if deterrence fails.
- As a hedge against an uncertain future and technological surprise.

The existence of nuclear weapons has effectively ended unlimited war between major nuclear states

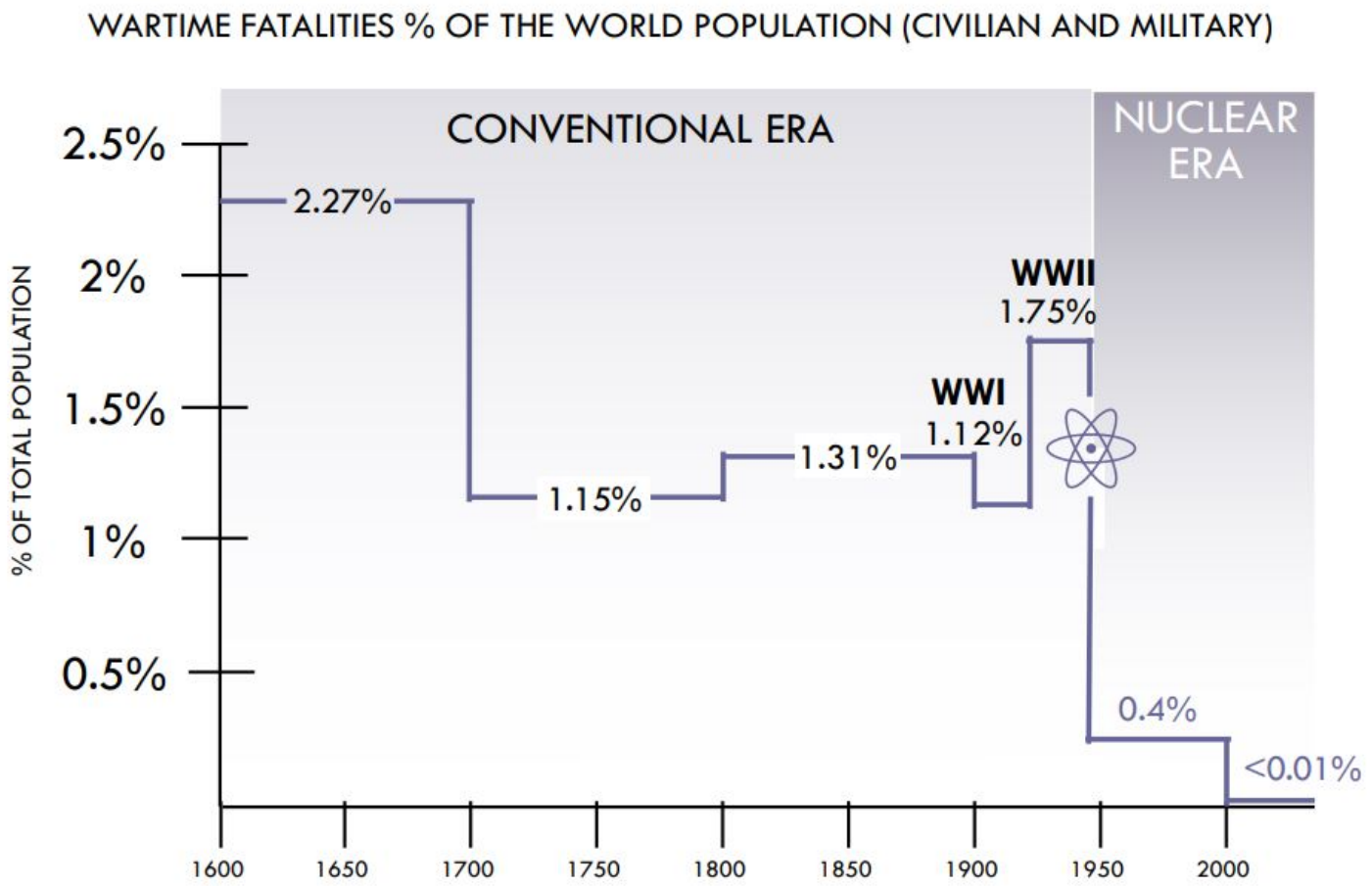
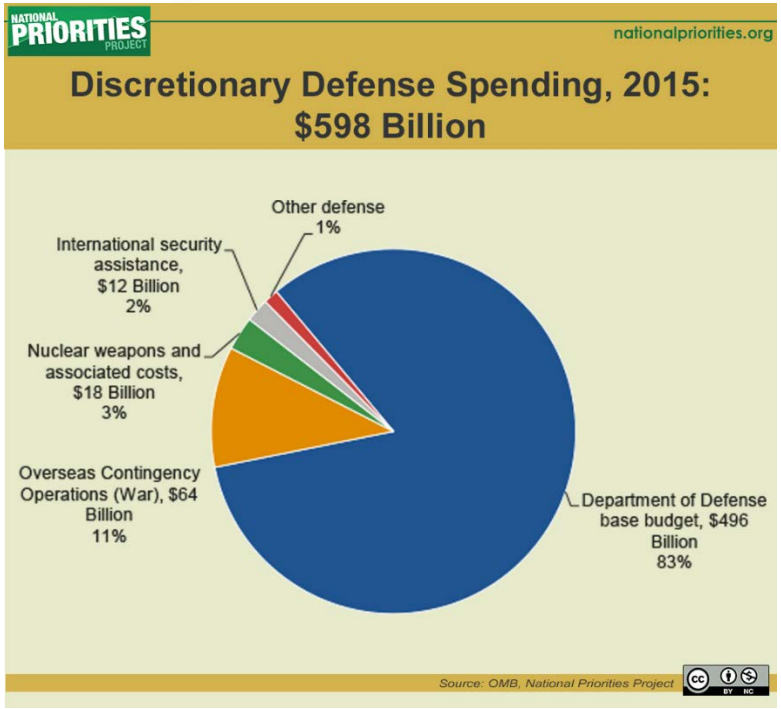


Figure 2. Wartime Fatalities Percentage of World Population
Data from the DoD Historical Office

From 2017 Nuclear Posture Review

Nuclear weapons are a small proportion of the military budget



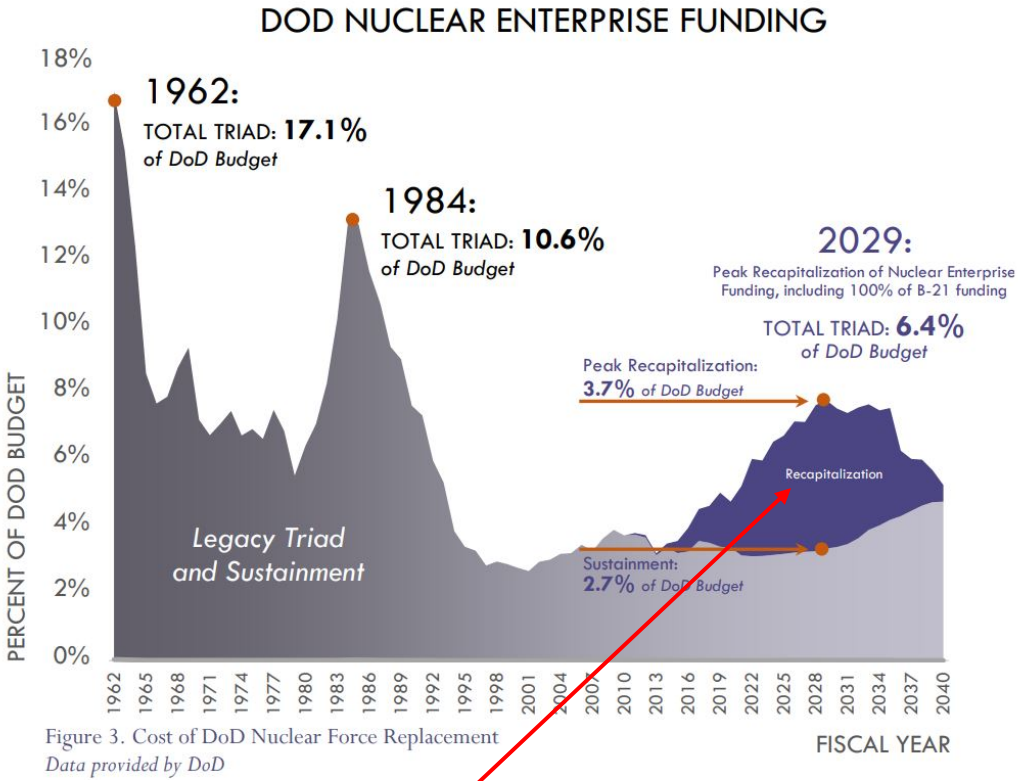
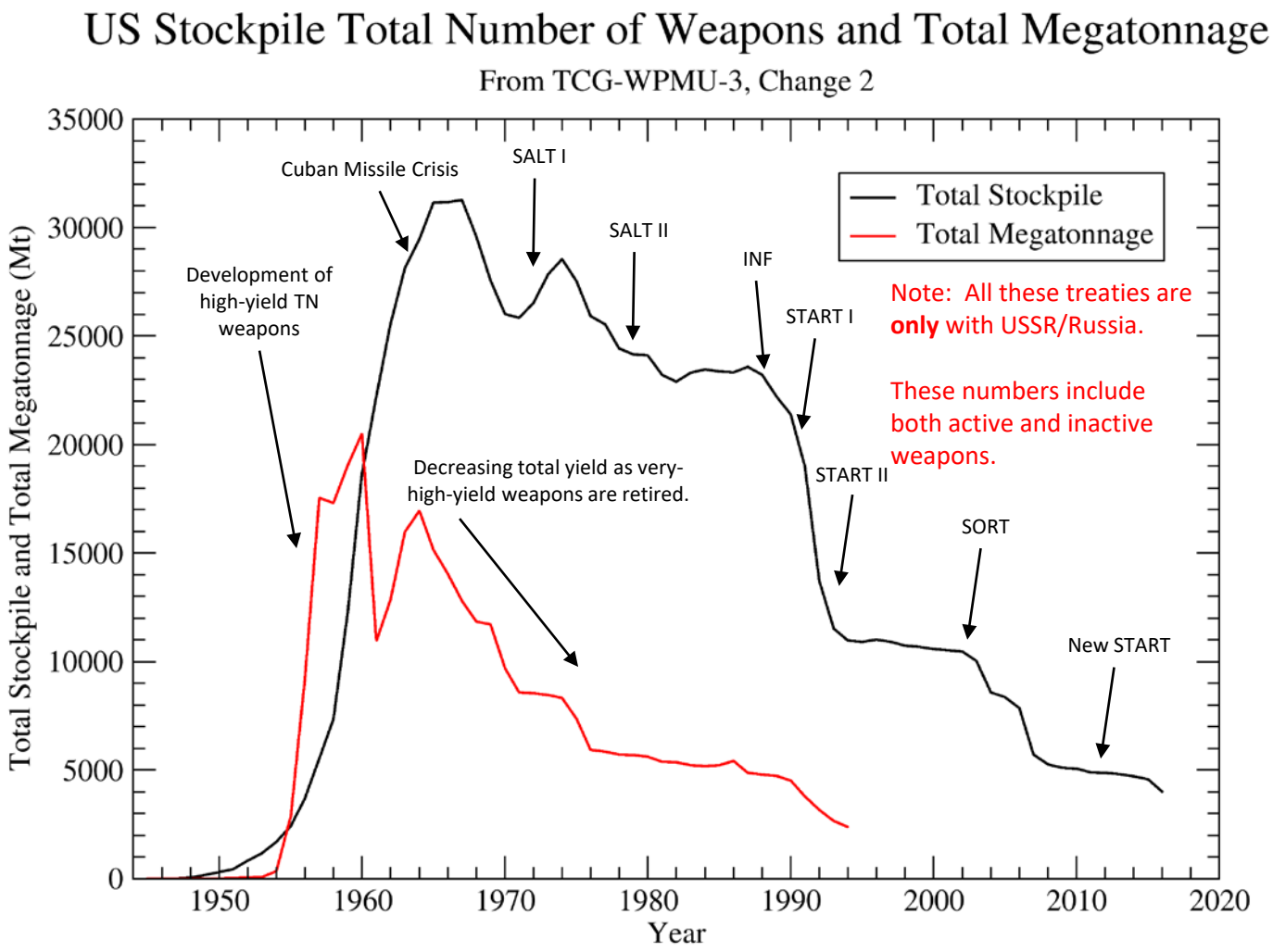


Figure 3. Cost of DoD Nuclear Force Replacement
Data provided by DoD

The 2017 NPR proposes to spend up to an **additional** $25B/year to "recapitalize" the nuclear weapons program, i.e. fix broken stuff and build some new stuff.

The number of weapons in the US stockpile hasn't been this low for 60 years



Application	US Stockpiled Weapons
ICBM	W38, W49, W53, W59, W62, W78, W87
SLBM	W47, W58, W68, W76, W88
Hypersonic Glide ICBM	
Air-Launched Cruise Missile (ALCM)	W28, W80
Sea-Launched Cruise Missile (SLCM)	W5, **W80**
Ground-Launched Cruise Missile (GLCM)	W5, W28, W39, W84
Megaton-Range Bomb	B14, B15, B17, B21, B24, B27, B28, B36, B39, B41, B53, B83
Kiloton-Range Bomb	LB, FM, B3, B4, B5, B6, B7, B12, B18, B43, B57, B61
Penetrator	B8, B11, B61
Land Short-Range Ballistic Missile (SRBM)	W7, W28, W39, W40, W45, W50, W52, W54, W70
Sea SRBM	W27, W30, W31
Intermediate Range Ballistic Missile (IRBM)	W49, W85
Surface-to-Air Missile	W7, W30, W31, W45
Air-to-Surface Missile	W28, W45, W69, W72
Air-to-Air Missile	W25, W40, W45, W54
Atomic Demolition Munition	T4, B7, W30, W31, W45, B54
Anti-Submarine Warhead	B7, W34, W44, W55, W57
Torpedo	W34
Artillery-Fired Atomic Projectile (AFAP)	W9, W19, W23, W33, W48, W79
Anti-Ballistic Missile (ABM)	W66, W71
Anti-Satellite Missile	W49, W50
Battlefield “Neutron Bomb”	W70, W79

The current US stockpile has a small subset of the variety it once had

Weapons in red are currently deployed

US Nuclear Weapons Triad

Air-Delivered Weapons – USAF

42 B-52H + 20 B-2A bombers + F-15E/DCA

Intercontinental Ballistic Missiles (ICBM)- USAF

400 Single-Warhead MMIII missiles

Submarine-Launched Ballistic Missiles (SLBM)- Navy

14 Ohio Class SSBNs, up to 24 missiles each

US Nuclear Weapons Triad

Air-Delivered Weapons – USAF

42 B-52H + 20 B-2A bombers + F-15E/DCA

B61 Bomb

B83 Bomb

W80 Air-Launched Cruise Missile (ALCM)

Advantages of Air-Delivered Weapons

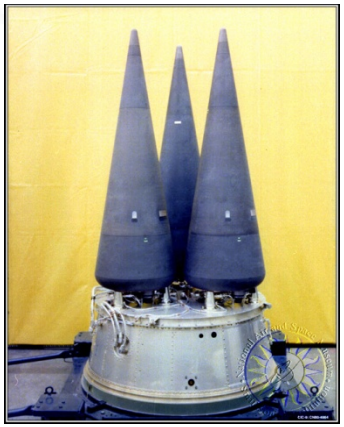
- Can be flown around to make a point and then recalled.
- Can be forward-based.
- Flexible effects.
- Non-ballistic trajectory.

Disadvantages of Air-Delivered Weapons

- Can be shot down.
- Can take a long time to reach their targets if not forward-based.
- Puts air crew in harm's way.

US Nuclear Weapons Triad

Intercontinental Ballistic Missiles (ICBM)- USAF **400 Single-Warhead MMIII missiles**



W78 and W87 warheads on Minuteman III missile

Advantages of ICBMs

- Can only be destroyed by a precise nuclear hit.
- Can be launched very quickly.
- "Inexpensive" – no sub or airplane.
- Originally more accurate than SLBMs. No longer the case for US weapons.

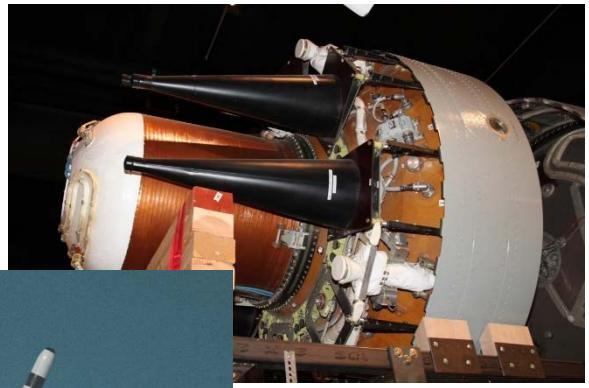
Disadvantages of ICBMs

- Cannot be called back, once launched.
- Permanent, known locations make them a target.

US Nuclear Weapons Triad

14 Ohio Class SSBNs, up to 24 missiles each

Submarine-Launched Ballistic Missiles (SLBM)- Navy



W76-1 and W88 warheads,
MIRVed on Trident II/D5 missile

Advantages of SLBMs

- Well hidden in a vast ocean.
- Since submarine can approach target, the missile can be smaller, the flight-time shorter, and the direction unknown.
- Provides an assured second-strike capability.

Disadvantages of SLBMs

- Not in immediate communication.
- Cannot be called back, once launched.
- Submarine can be taken out by conventional weapons.
- Once one missile is launched, the submarine becomes an easily-destroyed target.

The US Nuclear Weapons Complex is dramatically smaller than it once was

~~Hanford~~	Los Alamos	Oak Ridge Y-12	~~Oak Ridge K-25~~
~~Salt Wells~~	Sandia	Savannah River	~~Mound~~
~~Burlington~~	Livermore	Kansas City	~~Pinellas~~
~~Dayton~~	Nevada	Pantex	~~Rocky Flats~~
~~Albuquerque~~	~~Fernald~~	~~Weldon Spring~~	~~Scioto~~
~~Picatinny~~	~~Medina~~	~~Clarksville~~	~~Rock Island~~
~~Oak Ridge S-50~~	~~Portsmouth~~	~~Paducah~~	~~Newport~~

Source: "Building the Bombs - A History of the Nuclear Weapons Complex", Charles R. Loeber, SAND2002-0307P 2002

Design Labs:

Los Alamos National Laboratory, $2.2B, 11200 employees, designs NEP, pit production.
Lawrence Livermore National Laboratory, $1.3B, 7000 employees, designs NEP.
Sandia National Laboratories, $1.5B, 11000 employees, non-NEP engineering.

Test Site:

Nevada National Security Site,
$350M, 2000 employees, weapon testing.

Production Complex:

Y-12 Plant (Oak Ridge), $900M, 4600 employees, assembles/disassembles secondaries, uranium storage.
Savannah River Site, $1.6B, 12000 employees, tritium handling, MOX fuel.
Kansas City Plant, $500M, 2500 employees, produces weapon components.
Pantex Plant, $650M, 3600 employees, assembles/disassembles weapons, high explosive production.

Why can't we just rebuild nuclear weapons to original specs?

- Modern stockpile nuclear weapons are complicated:
  - They contain exotic and hazardous materials.
  - They were manufactured with high precision and tight tolerances.
  - They are highly optimized.

- We **can't** rebuild them in the same fashion and condition:
  - Some original build methods were hazardous and environmentally unacceptable.
  - Specialized equipment and craftsman skills are no longer available.
  - Some materials and components are no longer available.
- We wouldn't **want** to rebuild them in the same fashion and condition:
  - Need to incorporate improvements, both necessary and desired.

Why do we still need nuclear weapon designers?

- We need designers to evaluate changes due to:
  - Problems found with the original build (birth defects).
  - Problems developing over time (aging defects).
- We need designers to design:
  - Improvements to and rebuilds of weapons (LEPs)
  - Replacement weapons (e.g. RRW, RNEP)
  - New weapons – there may someday be a need for capabilities not presently in the stockpile.
  - Assessment of foreign weapon developments.

Accuracy, reliability, and safety matter to us. They may matter less to other countries.

Most US design advances worked "well enough" the first time they were tested, but often required extensive testing to be weaponized into an efficient, reliable, and safe stockpile.

Typical US stockpile requirements:

- Accuracy and range (requiring high efficiency): Loft 6000 nm and hit target with high accuracy.
- Reliability: Yield ±10%, high reliability.
- Safety: one-point safety ($< 10^{-6}$ chance of > 4 lbs nuclear yield), ENDS, IHE, PAL with APS for OCONUS.

Relaxing these requirements makes the design process significantly easier.

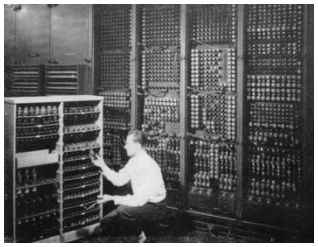
That was then, this is now….

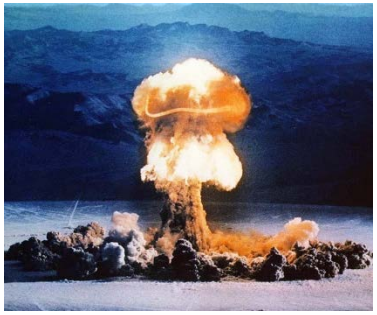
The US nuclear weapon design path resulted from particular political and technological drivers, but today's environment is different:

- The size of our stockpile and yield of individual weapons was matched to the Soviets and (eventually) to constraints imposed by ICBM development.
- We had to figure it out for ourselves.
- Extensive testing compensated for limited computational capabilities.

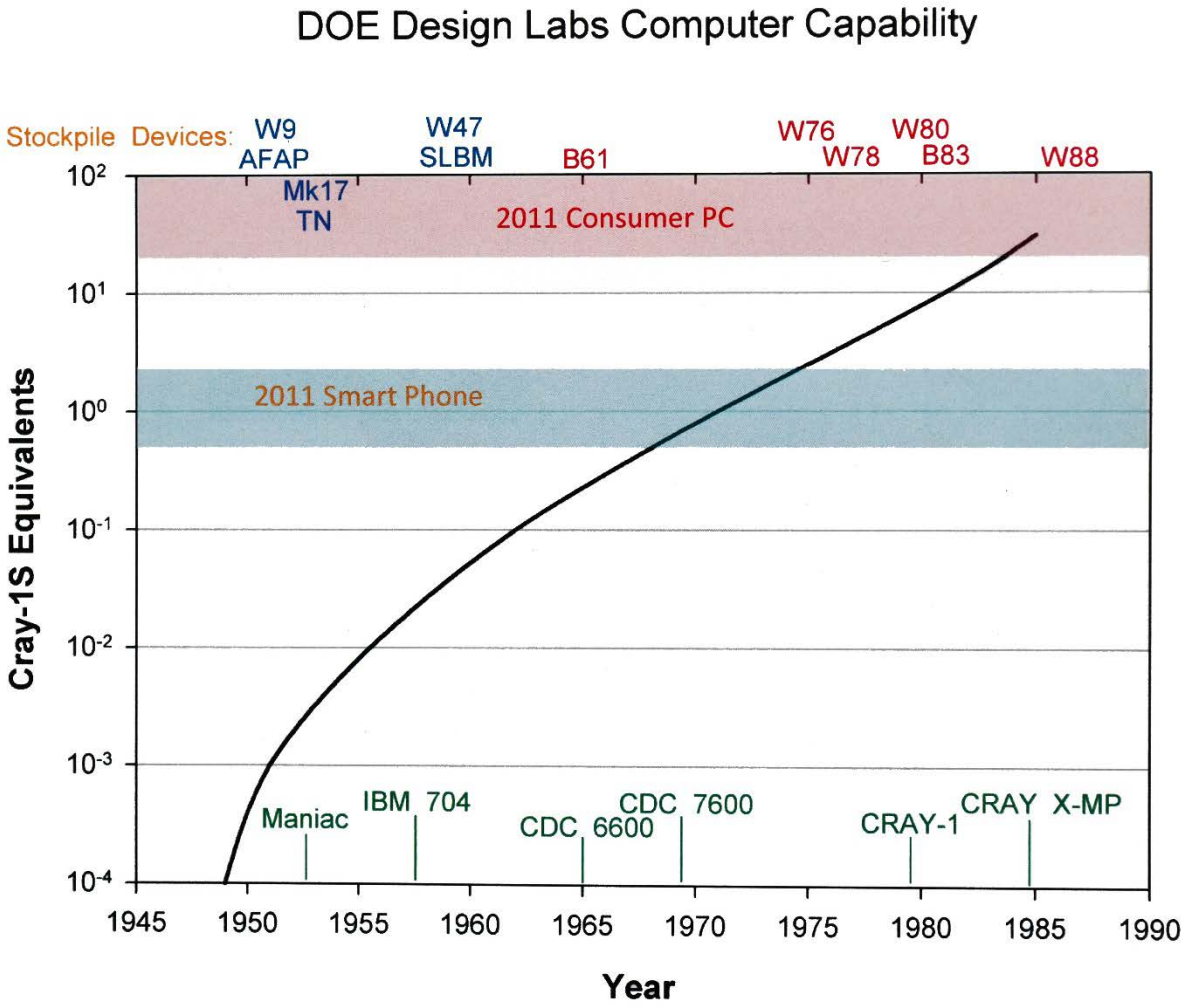
Today's situation is the opposite:
vastly increased computational capabilities, but strong limitations on nuclear testing.

Today's proliferants will not necessarily follow our nuclear weapon development route.





Your cellphone is vastly more powerful than the computers used to design our nuclear weapons!



The State of the World

Many other countries have active or developing nuclear weapons programs:

Adversarial Peers:

- **Russia and China:** Modernizing their stockpile, production complex, and developing new delivery systems, US-peer experimental facilities, and HPC. Both maintain a nuclear triad. China has "No First Use" policy.

Developing nuclear powers:

- **India:** Has a nuclear triad and claims to have TN weapons. "No First Use" policy.
- **Pakistan:** Developing a wide range of delivery systems. Nukes are chiefly seen as defense against India.
- **North Korea:** Claims to have TN weapons. Recently tested two ICBMs. Not clear their NWs are deliverable.

Future nuclear powers:

- **Iran:** Claims not to have a nuclear weapons program. But if it walks like a duck, and quacks like a duck, ….

Friendly peers:

- **United Kingdom:** Uses American SLBMs on their own submarines and with their own warheads.
- **France:** Has nuclear dyad – SLBMs and air-delivered weapons.

"Rest of the World": We evaluate other country's technological capabilities and political drivers for developing NWs.

Non-state actors: They would like to hit us with an IND.

Adversary countries are dramatically upgrading their delivery capabilities

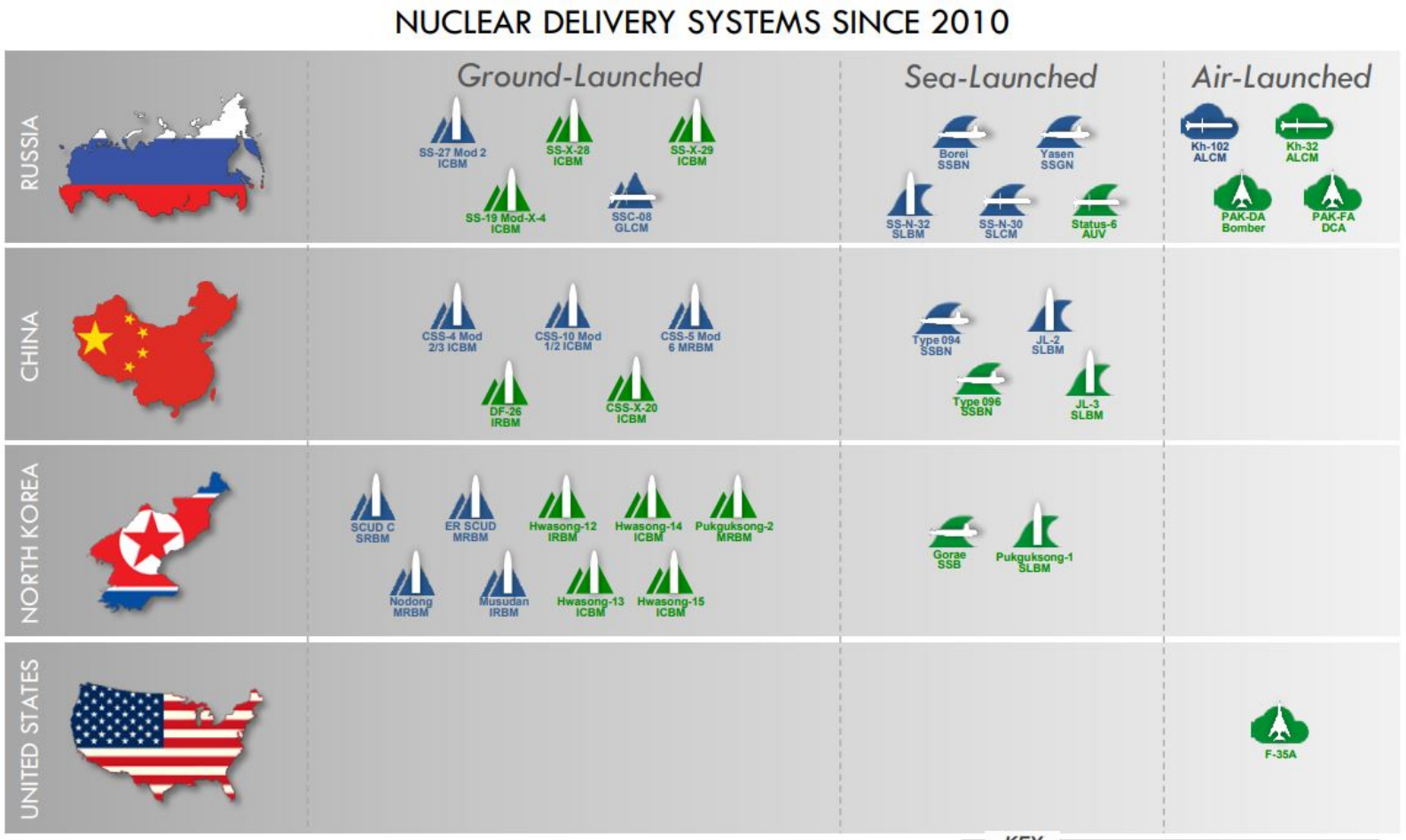
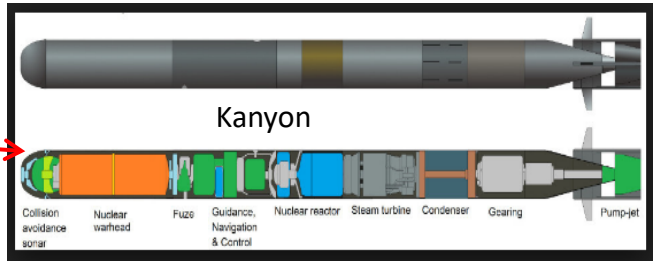


Figure 1. Nuclear Delivery Systems Since 2010
Data provided by the DoD

From 2017 Nuclear Posture Review

Russia

- Sees nuclear weapons as inexpensive alternative to large conventional military forces.
- Retains large numbers of tactical nukes, critical to "escalate to de-escalate" doctrine.
- Developing new and upgraded delivery systems, including:
  - Retiring all Soviet-era ICBMs and replacing them with new systems: Topol-M, Yars, Sarmat, …
  - Deploying Borei-class SSBN with new Bulava SLBMs.
  - Conventional/nuclear Iskander SRBM, now available for export!
  - Declared by US to be in violation of INF treaty with SSC-8 GLCM.
  - Reported (on Russian state television) to be developing "Kanyon" nuclear-armed drone submarine for use in coastal areas.



Russia has maintained ~2000 non-strategic nuclear weapons on a variety of delivery platforms

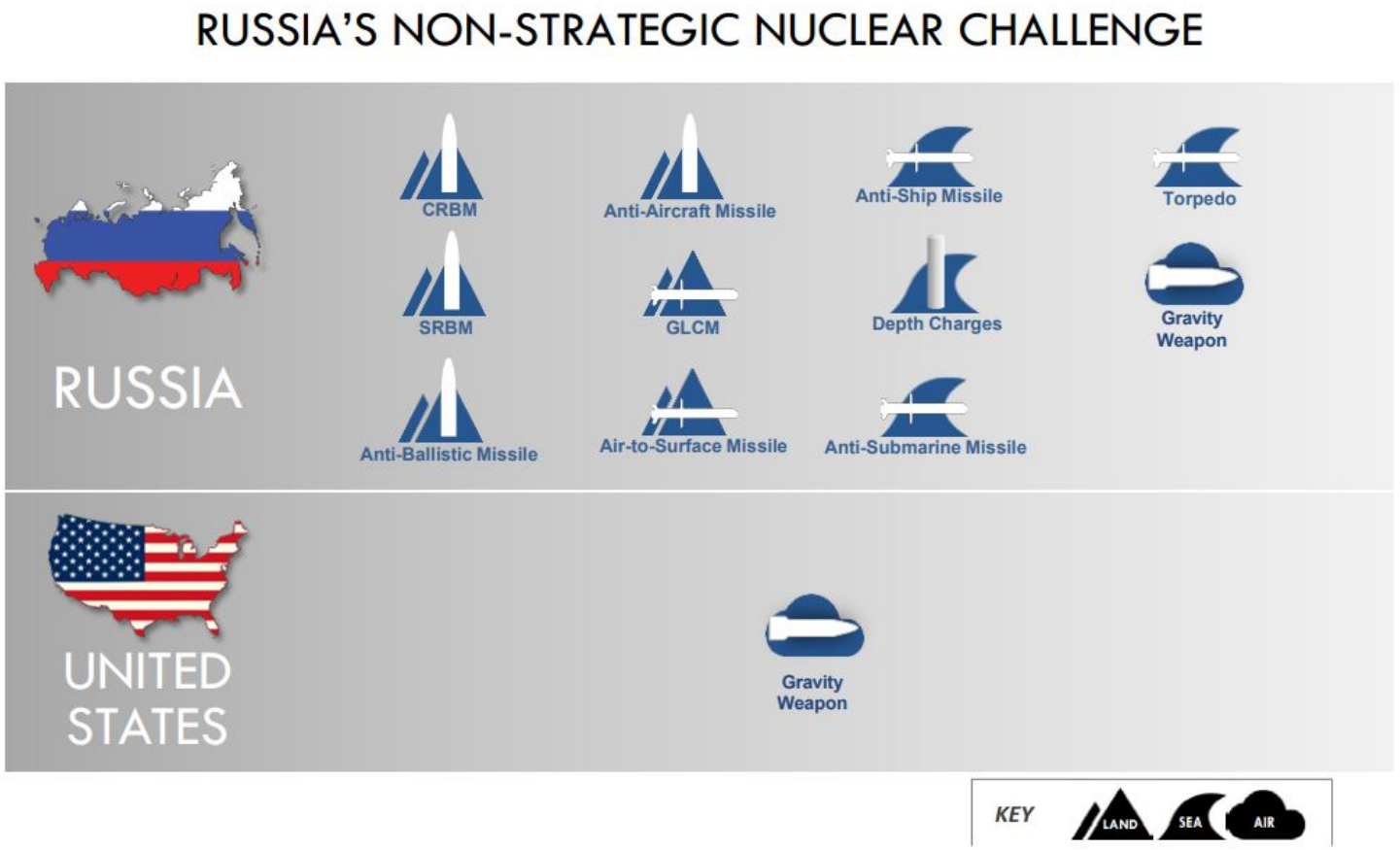
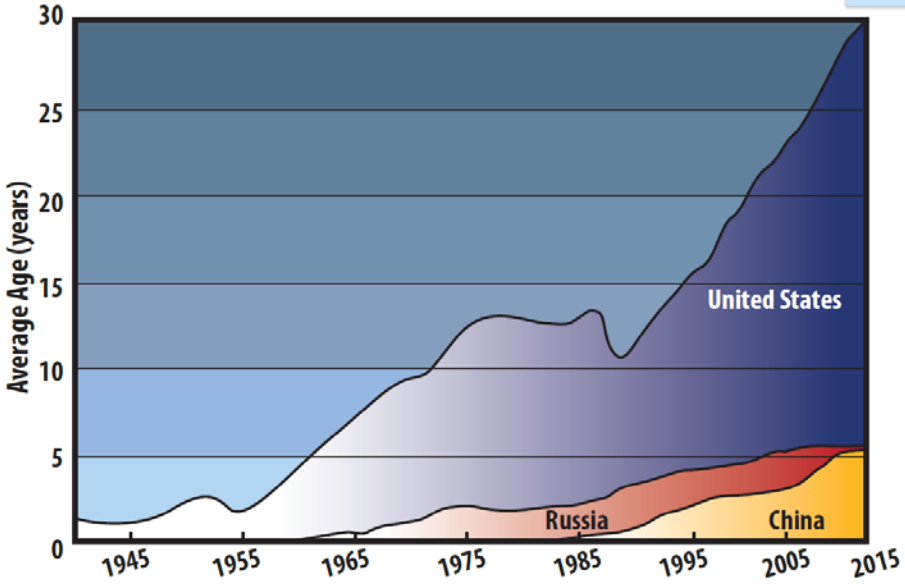


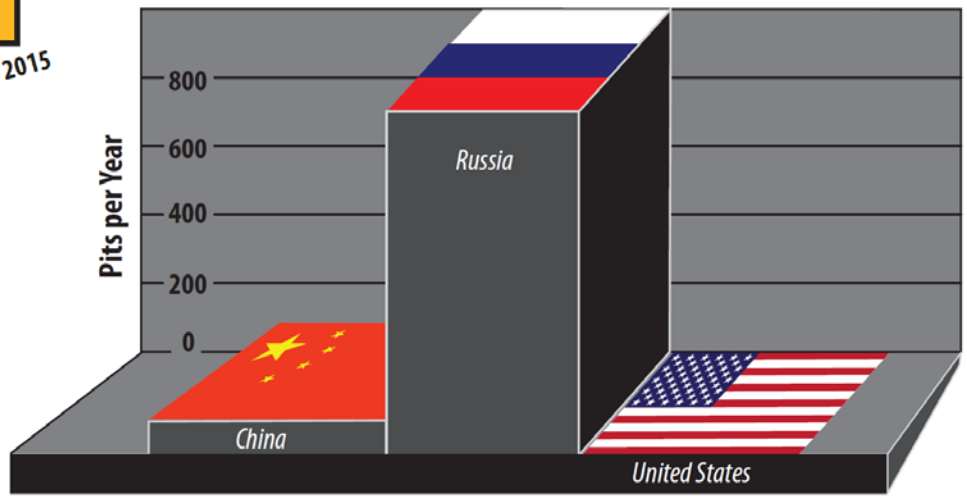
Figure 4. Russia's Non-Strategic Nuclear Challenge
Data provided by the DoD

From 2017 Nuclear Posture Review



Russia's design, engineering, and manufacturing capabilities remain intact and well-exercised.

Russian nuclear weapon research and production sites.

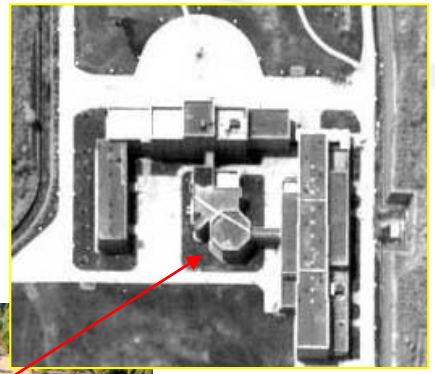


Plutonium pit production estimates for 2014. Russia has the ability today to produce at least 1,000 plutonium pits per year for use in building their new nuclear weapons. The United States, in contrast, has only one plutonium pit facility—an improvised one at Los Alamos—which has produced 29 certified pits since 1989.

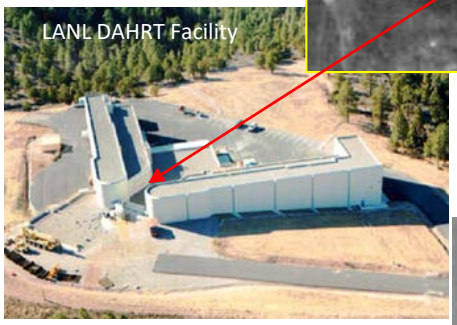
The 2017 Nuclear Posture Review calls upon the US to produce at least 80 new pits per year by 2030.

China

- Sees nuclear weapons as protection against US and Russian nuclear capabilities.
- Provides a counter to improving Indian nuclear capabilities.
- Lingering distrust of Japan as potential nuclear power.
- Evidence that China is a “great power”.
- Maintains nuclear triad.
- Development of accurate, low-yield weapons is not consistent with a “no first use” policy.
- Not constrained by US/Russian nuclear treaties.
- Developing US-peer experimental facilities.

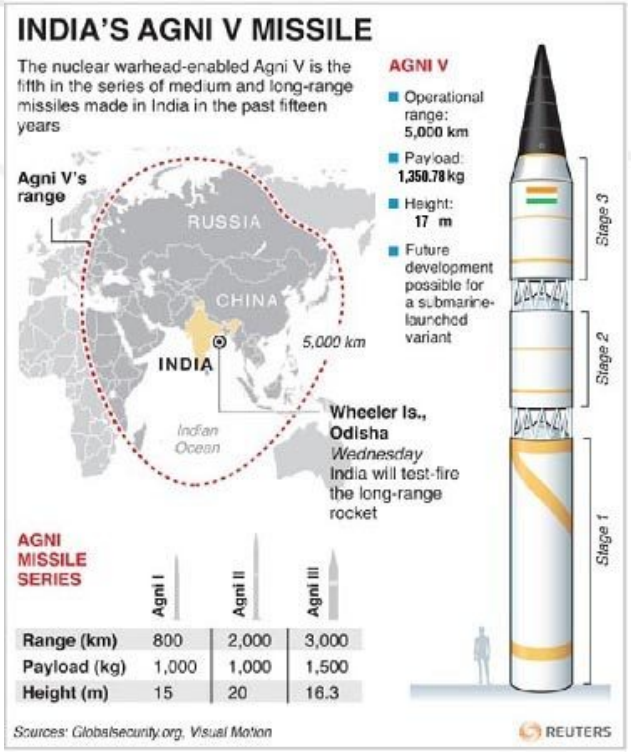


DigitalGlobe by Quick Bird



India

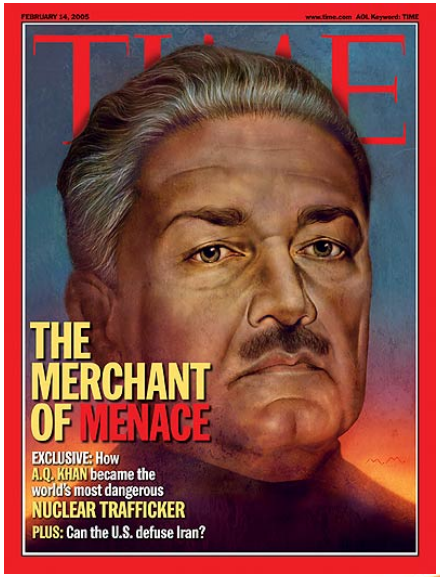
- Mostly sees nuclear weapons as deterrent against Pakistan, but also as counter to China.
- Conventional “Cold Start” doctrine targeted against Pakistan. Claims “No First Use” policy.
- Historically non-aligned, but is friendly with US.
- Maintains nuclear triad and claims to have thermonuclear weapons.
- Recently completed final test of road-mobile Agni V. Working on MIRVed Agni VI ICBM.



Pakistan

- Sees nuclear weapons as deterrent against India.
- Developing “short-range tactical weapons, sea-based cruise missiles, air-launched cruise missiles, and longer-range ballistic missiles”.*
- Short-range, forward-based, battlefield nuclear weapons seen as defense against Indian “Cold Start” doctrine.
- Historically an ally of the US, but this has always been a very dysfunctional relationship.
- AQ Khan widely proliferated nuclear weapon technology.


Ghauri MRBM



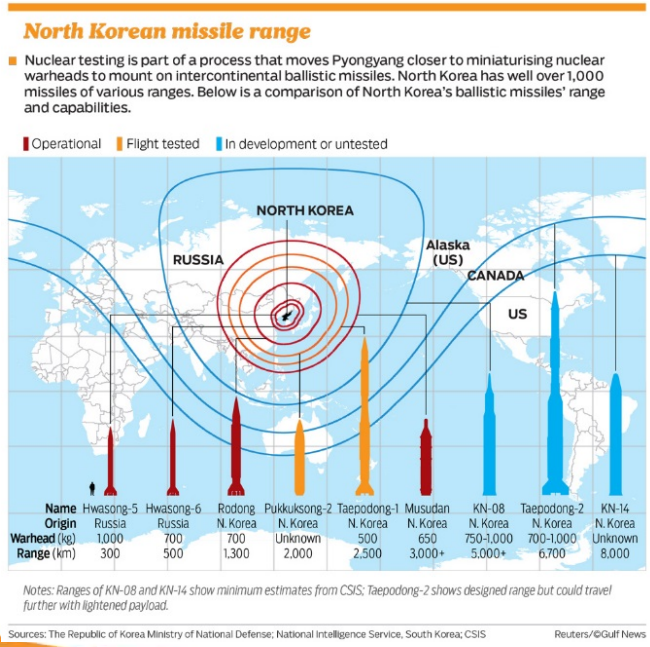
NASR SRBM


Shaheen III MRBM

Worldwide Threat Assessment of the US Intelligence Community, Dan Coates, DNI, 2/13/2018

North Korea

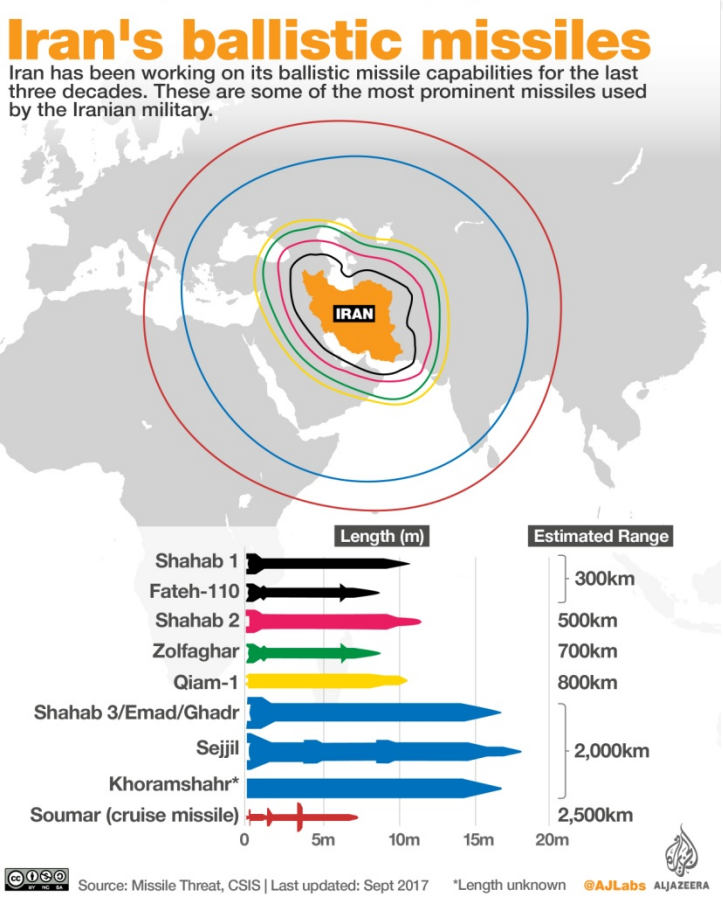
- Full speed ahead on development of nuclear weapons and weapon delivery systems.
- Claims to have tested a thermonuclear weapon.
- Claims to be able to hit the US with nuclear weapons on ICBMs.
- Is a huge headache for China, their only significant trading partner.



Iran

- Claims its nuclear program is for peaceful purposes only.
- Has agreed to constraints on its nuclear program in the Joint Comprehensive Plan of Action (JCPOA).
- Could probably produce a nuclear weapon within one year of deciding to do so.*
- Vigorously developing long-range ballistic missiles, with technology assistance from North Korea.*
- "America is the number one enemy of our nation."

  - Supreme Leader, Ayatollah Ali Khamenei

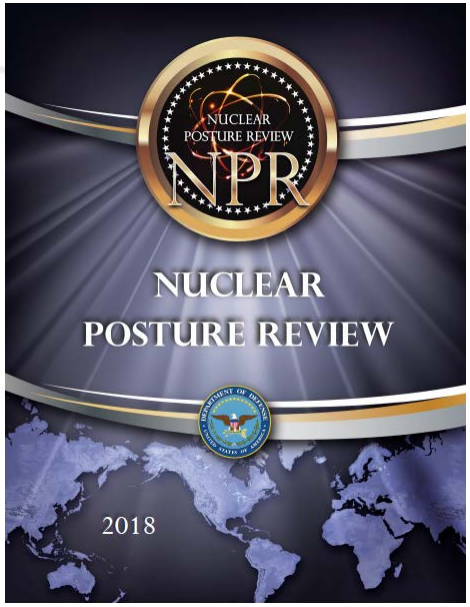


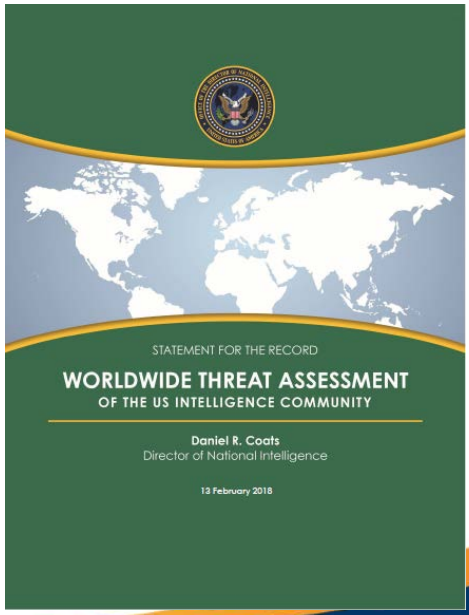
*From 2017 Nuclear Posture Review

What has been proposed to address these issues?

The 2017 NPR proposes to spend up to an **additional** $25B/year to "recapitalize" the nuclear weapons program, including:

- Alter a small number of SLBM warheads to provide low-yield option.
- Develop a nuclear sea-launched cruise missile (SLCM).
- Replace Ohio-class subs with Columbia-class subs with 2031 IOC. Replace Minuteman III ICBMs with GBSD missiles with 2029 IOC. Complete the new B-21 strategic bomber with mid-2020's IOC.
- Complete LEPs and alterations for the B61-12, W78, and W88.
- Develop the capability to produce 80 new pits/year by 2030.
- Complete the new Uranium Processing Facility at the Y-12 Plant.
- Reconstitute capability to produce sufficient tritium and lithium.
- Ensure the US can still produce radiation-hardened microelectronics.
- Modernize the US Nuclear Command, Control, and Communication systems (NC3).



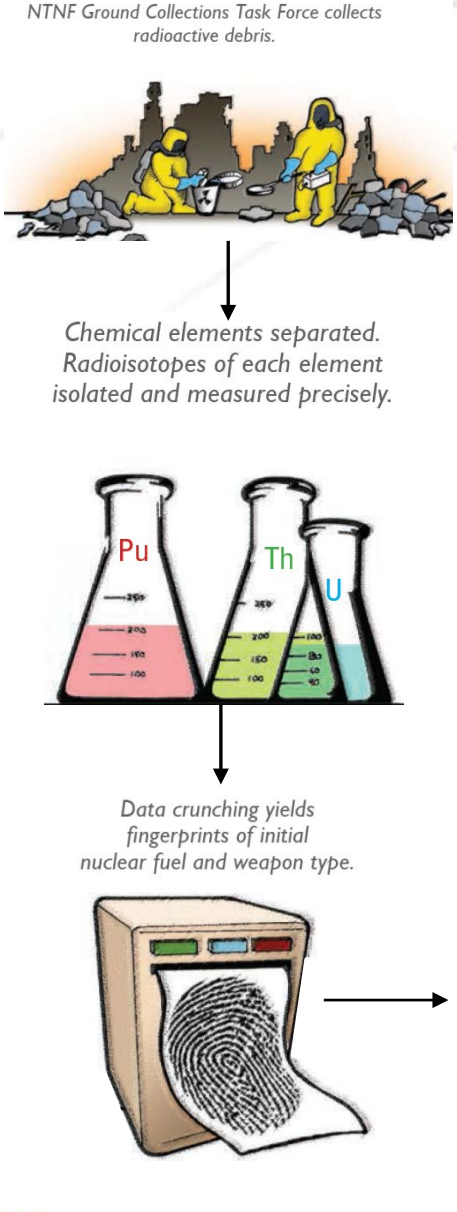


What do we have to address Non-State Actors?

Nuclear Emergency Response:

- Detect, diagnose, and disable/contain RDDs and INDs.
- Investigates and evaluates the use of materials for RDDs and INDs.
- Has capability to look for lost or diverted nuclear weapons, components, and SNM.
- Studies potential booby-traps, and has equipment for their defeat.
- Participates in exercises and drills for this mission.

Harvey's Hotel bombing, 1980.
What if it had been nuclear?



National Technical Nuclear Forensics (aka "Post-Det"):

- Collects debris from site and data from ground and space sensors.
- Deduces possible device design and materials from analyzed debris, sensor data, and intelligence data.
- LANL and LLNL have independent, but communicating, teams to assess potential designs.
- Attribution community provides WH with assessment of who is responsible and whether any other devices might be out there.

What is easy about designing nuclear weapons?

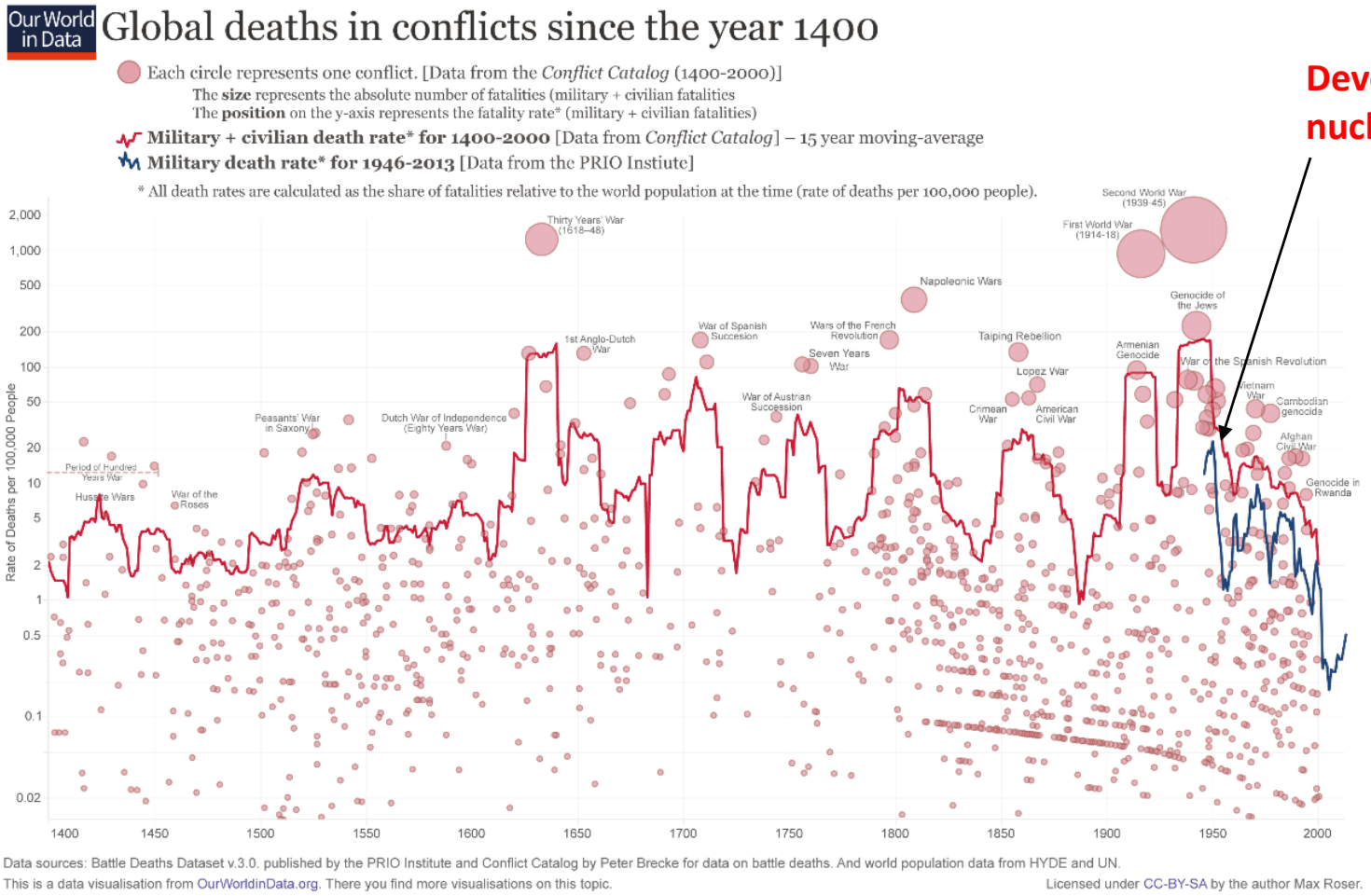
- Simple U.S. and Soviet designs were developed without significant computing resources, and worked the first time they were tested.
- 1-D codes for rad-hydro transport, neutron transport, and nuclear burn are easy to write.
- Open source equation-of-state (EOS) and opacity tables are available. All nuclear cross-section data is unclassified due to use by the nuclear power industry.

What is hard about designing nuclear weapons?

- Advanced designs – hollow boosted primaries and two-stage TN weapons – are very difficult to get right without testing.
- 2-D and 3-D codes can improve the design process, but are difficult to write, and there are many hidden “gotchas” without validation against nuclear test data.
- Advanced designs are sensitive to details of EOS and opacity at high temperatures and pressures. This information is not available from open sources, and is typically benchmarked against nuclear test data.
- Acquisition or production of special nuclear material is difficult.

Backup Slides

The existence of nuclear weapons has effective ended unlimited war between major nuclear states



Development of nuclear weapons

The DOE/NNSA National Laboratories are an integral part of the US Intelligence Community

Foreign Assessment:

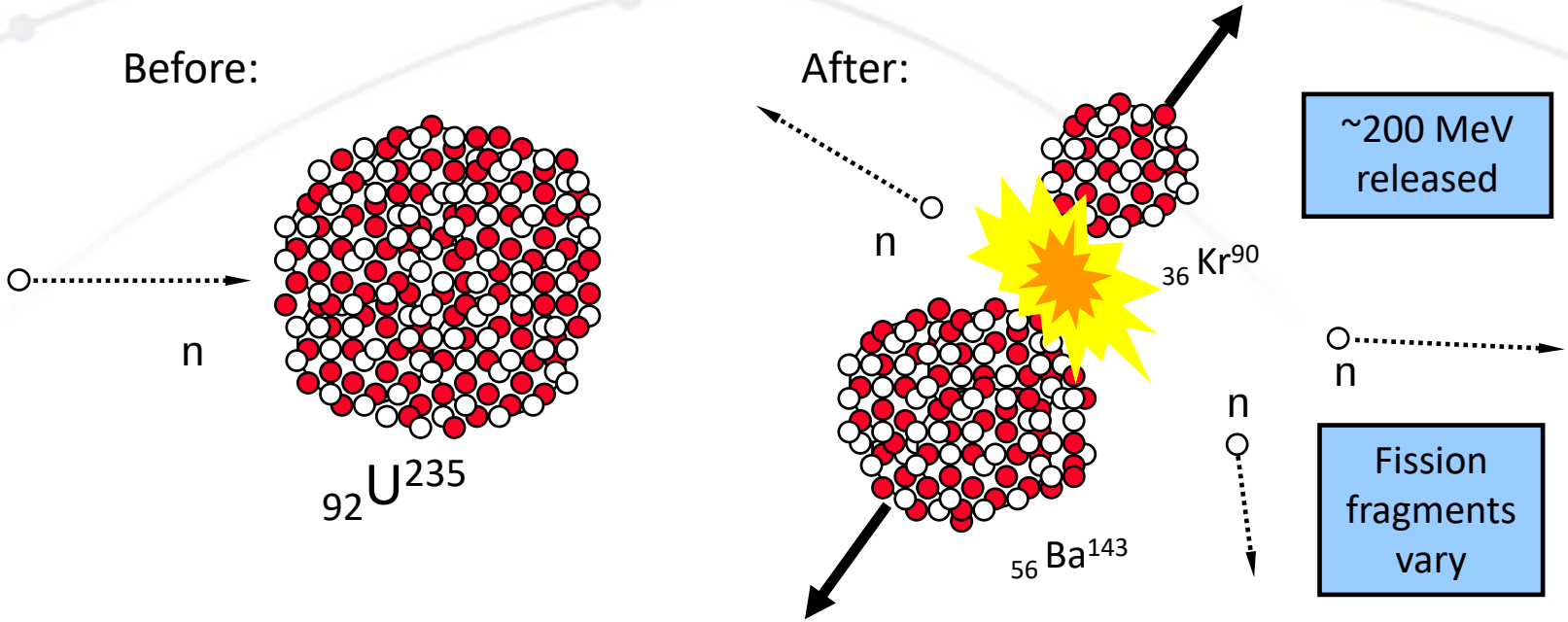
- Assess capabilities of adversarial country's nuclear weapons and the evolution of their NW programs.
- Avoid technological surprise.
- Give "today's best answer" to IC questions.

Nuclear Emergency Response:

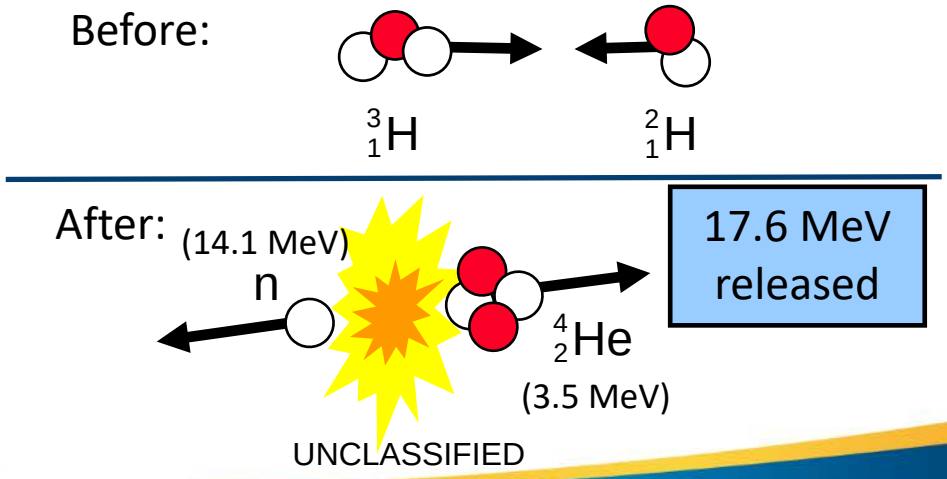
- Detect, diagnose, and disable/contain RDDs and INDs.
- Investigates and evaluates the use of materials for RDDs and INDs.
- Has capability to look for lost or diverted nuclear weapons, components, and SNM.
- Studies potential booby-traps, and has equipment for their defeat.
- Participates in exercises and drills for this mission.
- Accident Response Group addresses incidents involving US weapons.

Harvey's Hotel bombing, 1980.
What if it had been nuclear?

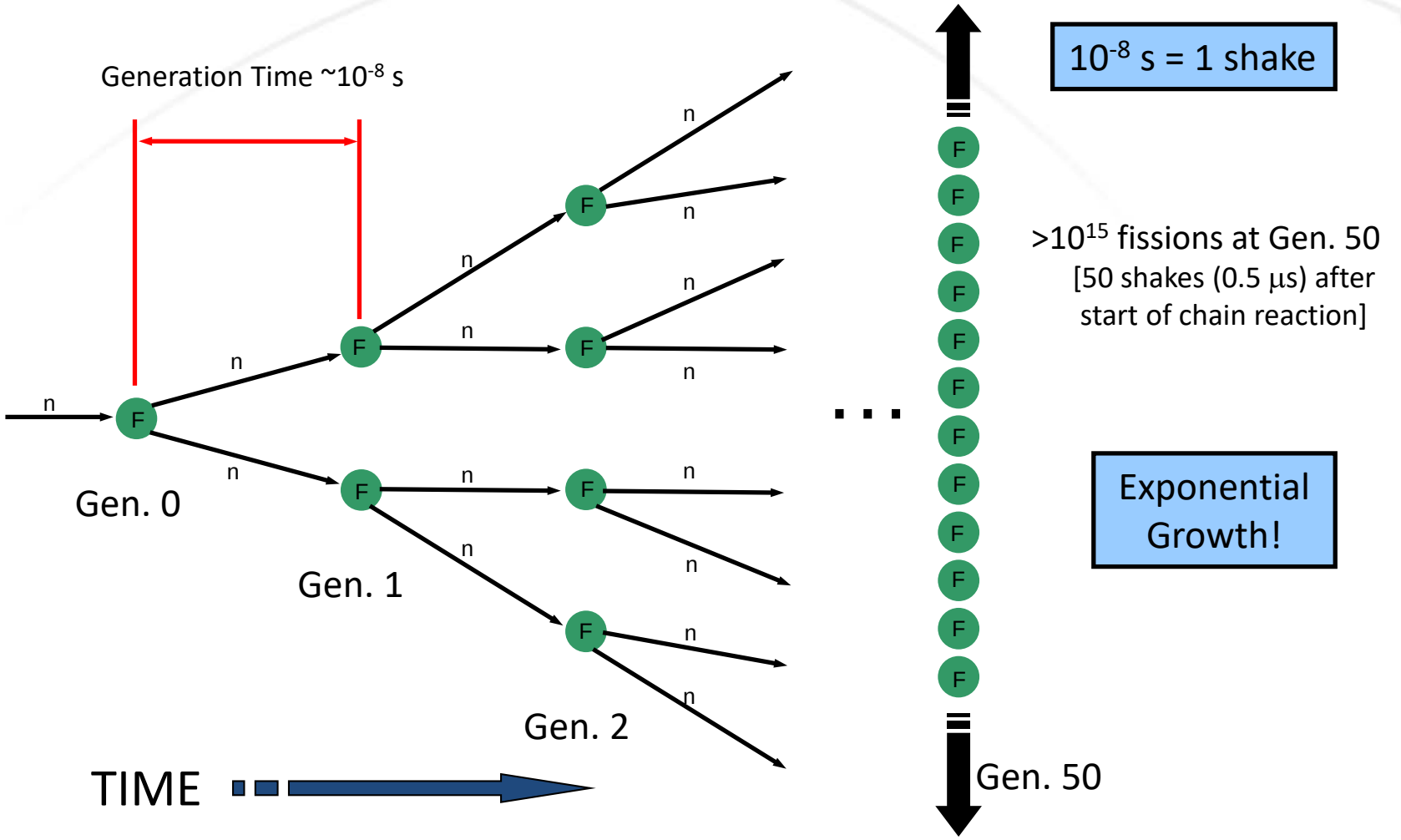
Nuclear Fission



Nuclear Fusion

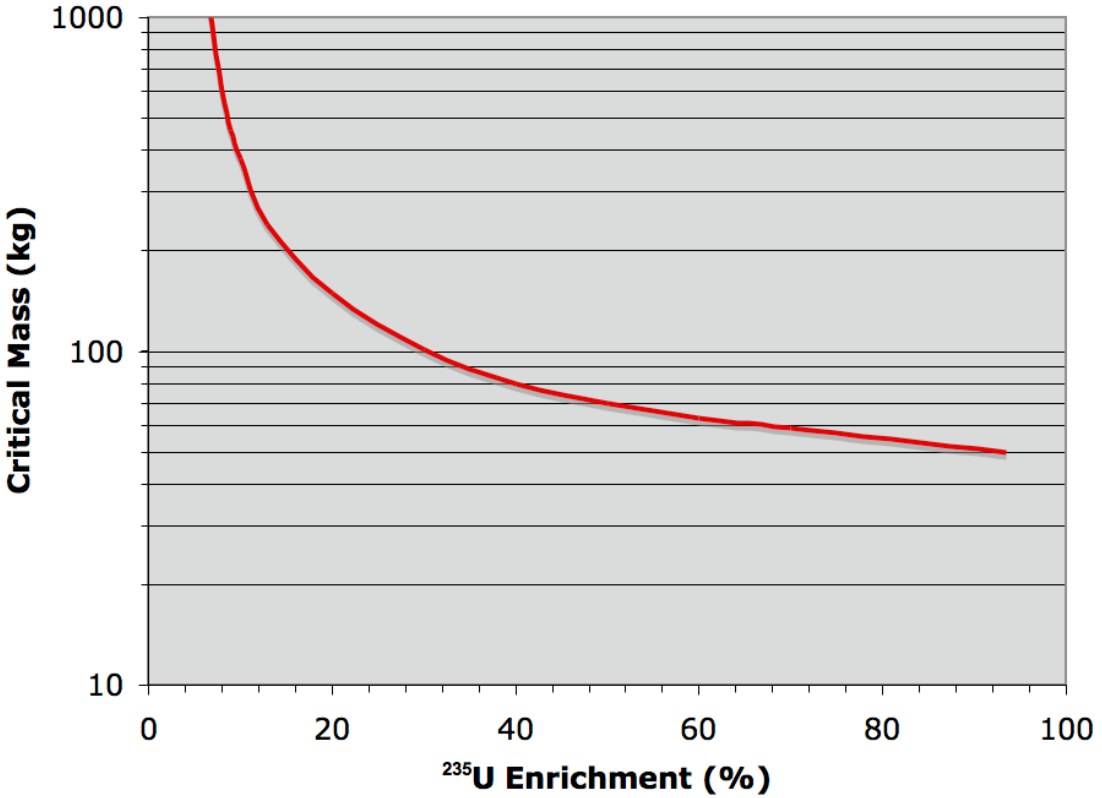


Fission Chain Reaction

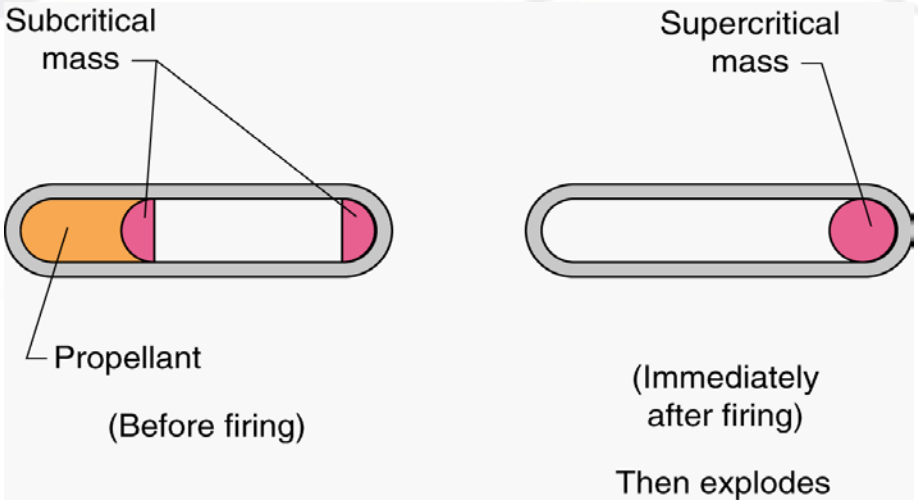


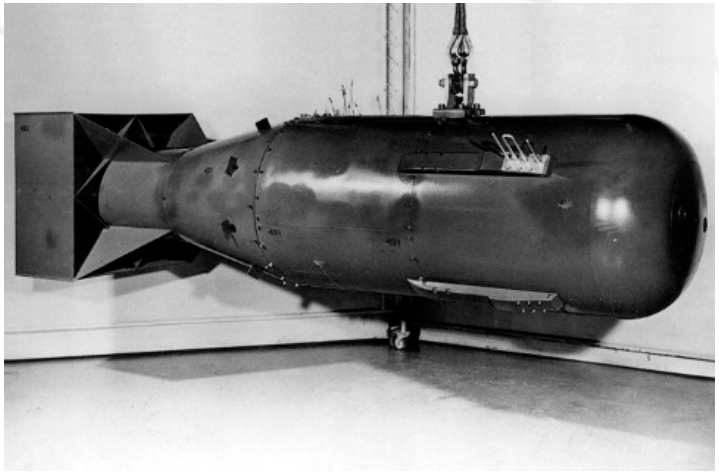
Material - materials enriched with higher concentrations of isotopes "more favorable" for fission have smaller critical mass

Higher enrichment in ^{235}U results in smaller critical mass



Critical Dimensions…, Paxton and Pruvost, LA-10860-MS (1986)





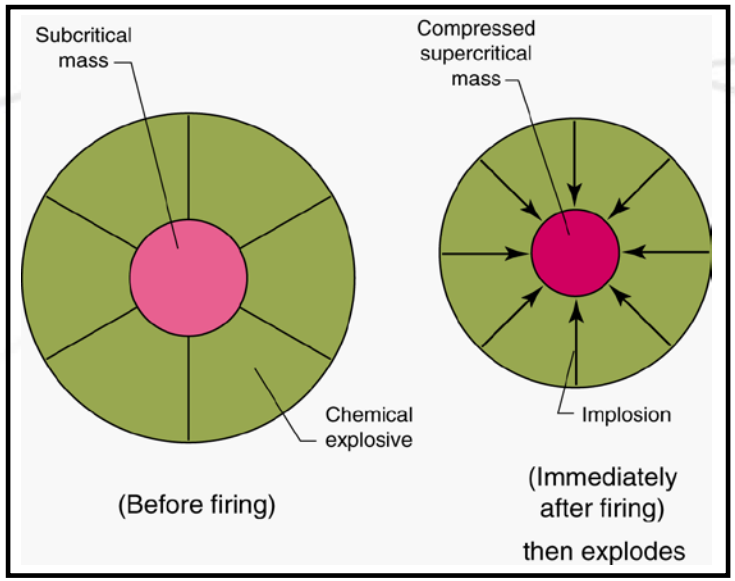
Gun-Assembled Weapons

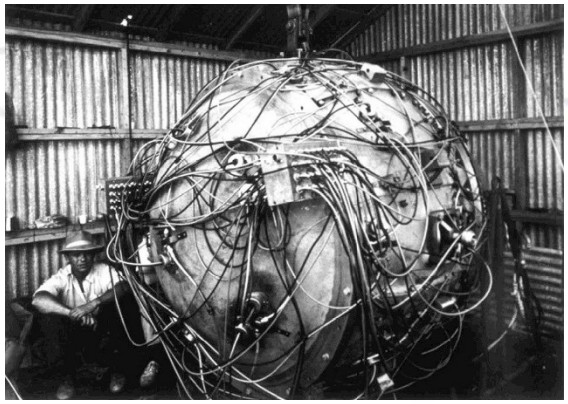
Advantages:

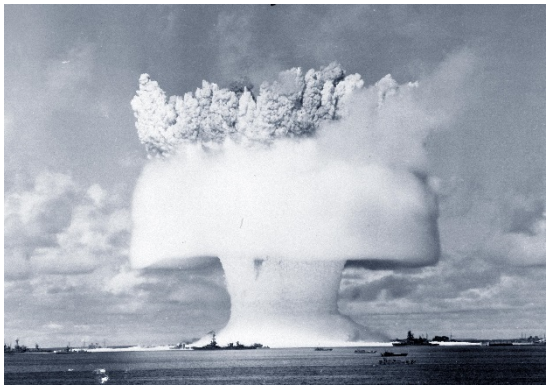
- Simple to design and construct – we used it in combat without first testing it.
- Very mechanically robust – good for penetrators and artillery shells.

Disadvantages:

- Very inefficient because it is uncompressed.
- Cannot be made inherently safe against unintended detonation.
- Due to slow speed of assembly, Pu cannot be used without a significant chance of preinitiation.







Implosion-Assembled Weapons

Fat Man design first tested at Trinity and used at Nagasaki. Further tested in Operation Crossroads.

Advantages:

- More efficient, due to compression of material.
- Speed of implosion allows use of plutonium.

Disadvantages:

- More difficult to design.
- Amount of nuclear material in solid pack is limited by criticality.

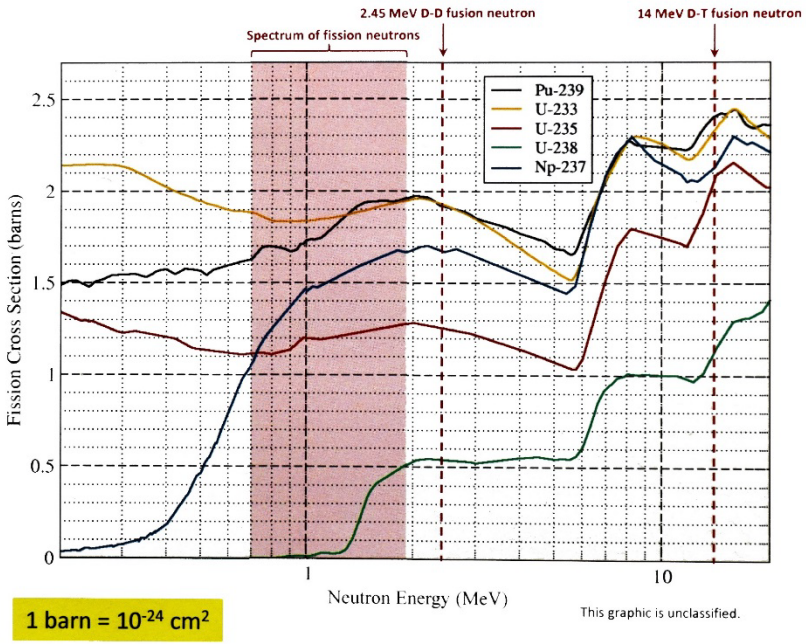
Boosting

Deuterium and tritium gas is compressed and heated to fusion conditions.

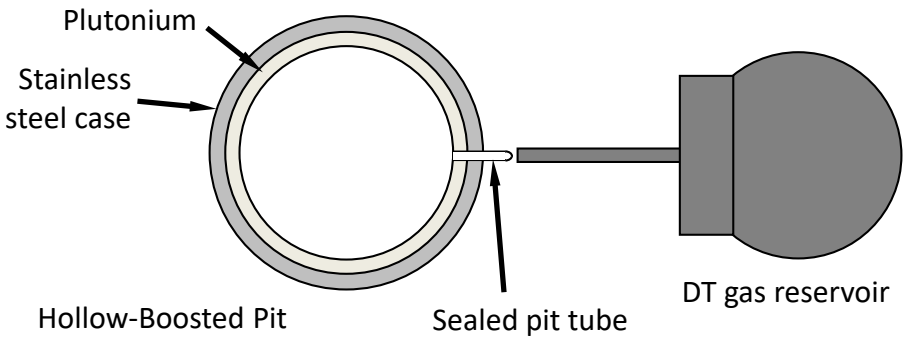
Produces a flood of high-energy (14 MeV) neutrons that boost subsequent fission of Pu or HEU, increasing yield.

Boosted yield of weapon degrades with time due to radioactive decay of tritium (12.3 year half-life).

This degradation requires that the boost gas reservoir be replaced periodically.

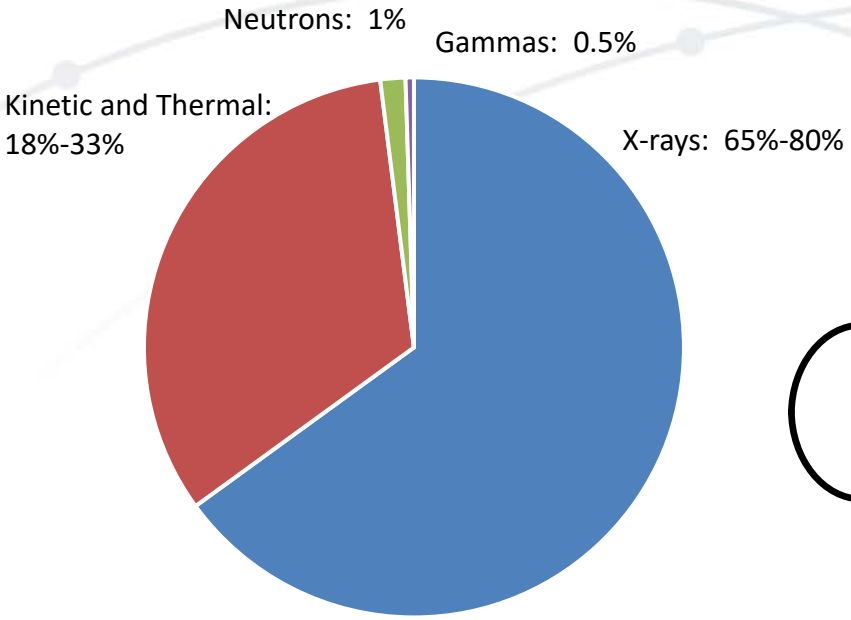


1 barn = 10^{-24} cm^2

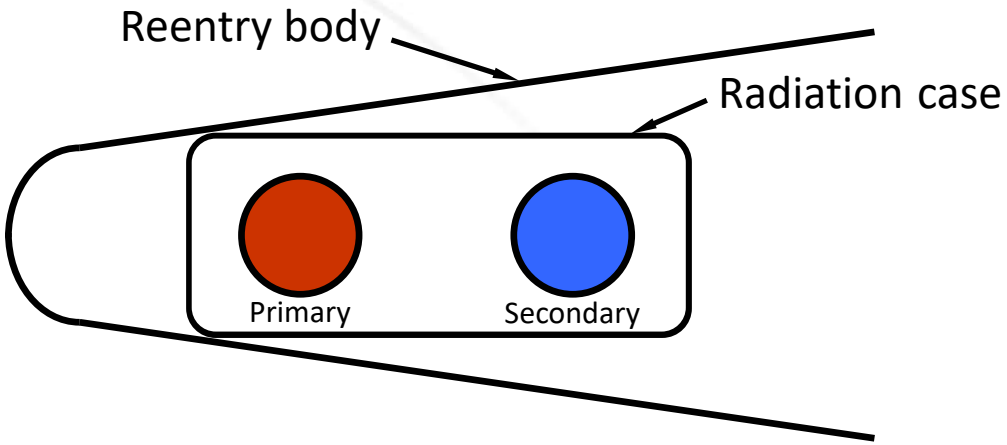


Boosting helps because:

- Fission cross-section is larger for 14 MeV neutrons.
- Nu-bar is higher for fissions caused by 14 MeV neutrons.
- It increases the neutron population by a factor of hundreds in the time that it would only double for fission-only.



Nuclear Weapon Outputs



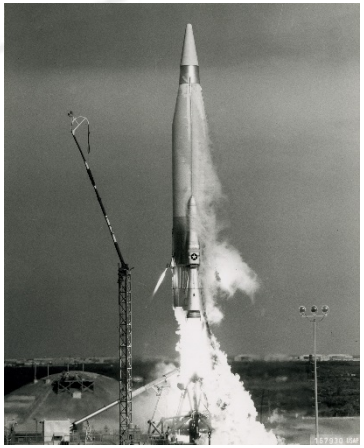
Two-Stage Thermonuclear Weapons

Energy from primary stage drives secondary stage

- X-rays from primary is contained by radiation case, and implodes the secondary.
- Most of weapon yield comes from secondary.
- All weapons currently in the US stockpile are variations of this basic design.

The early US manned space program used nuclear weapon missiles

Redstone SRBM



Atlas ICBM

Titan ICBM

Saturn 1B launching Apollo
1st stage was effectively
8 x Redstone SRBM

Redstone launching Mercury

Atlas launching Mercury

Titan launching Gemini

1945-1975: The development of computer technology was driven by the nuclear weapons program

- The U.S. acquired increasingly larger single-processor “supercomputers”.
- The Soviets developed both indigenous computer technology and copied U.S. designs, lagging the U.S. by 3-5 years.
- All features of modern nuclear weapons and many of the U.S. stockpile devices were designed in this timeframe.
- **This was possible because we could test designs.**

IBM 7090, early-1960s

Cray-1, late-1970s

Soviet BESM-6, 1970s

CDC 6600, late-1960s