

Putting the Genie Back in the Bottle: The Science of Nuclear Non-Proliferation

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- 
- A large, glowing orange and yellow mushroom cloud from a nuclear explosion, rising from the ocean surface. The cloud has a thick, vertical column of smoke and fire in the center, topped by a wide, flat, glowing disc. The background is a dark, overcast sky.
- Outline:
1. Nuclear Weapons 101.
 2. The Comprehensive Test Ban Treaty.
 3. North Korean Nuclear Tests.
 4. Why should you care?
 5. More Reasons to Care.
 6. Some Conclusions.

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 - Many components of the Soviet nuclear arsenal left behind in the former Soviet Union (FSU).
 - Collapse of Russian ruble in 1998 leaves even Russian arsenal with limited funds for maintenance and security of nuclear materials.

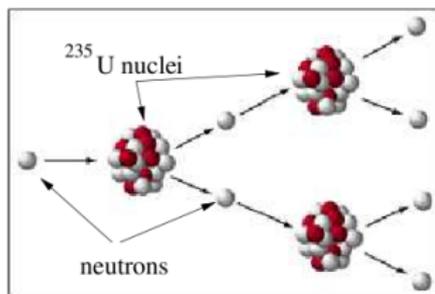
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 - Many components of the Soviet nuclear arsenal left behind in the former Soviet Union (FSU).
 - Collapse of Russian ruble in 1998 leaves even Russian arsenal with limited funds for maintenance and security of nuclear materials.
- Return (?) to Great Power competition in 2015.

Nuclear Weapons 101

- Fissile materials (^{235}U , ^{239}Pu) release enormous energies.
- As each nucleus splits, it emits 2 or so neutrons plus lots of energy ($\approx 180\text{ MeV}$).
- If density is high, a 'chain reaction' will cause other fissions in a self-propagating process.

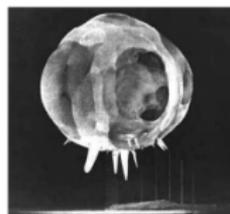
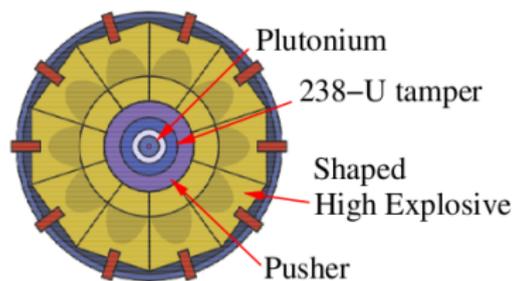
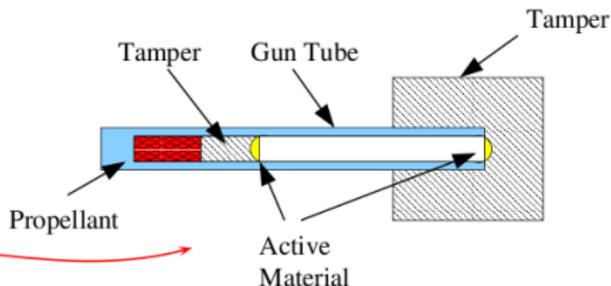
A Chain Reaction



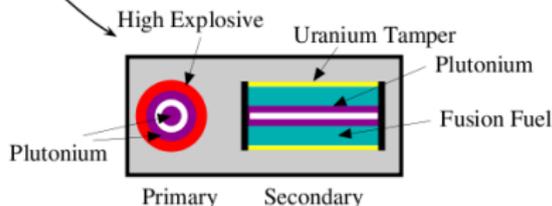
- Only about 8 kg of plutonium or 25 kg of highly-enriched uranium (HEU) is needed to produce a weapon.

Nuclear Weapons 101

- Uranium, gun-type weapon - High explosive fires highly-enriched uranium slug down the gun tube and into the uranium target. The density increases enough to sustain the chain reaction.
- Plutonium implosion device - High explosive crushes the plutonium primary to a density where fission can occur.
- Two-stage, thermonuclear weapon - Fission weapon crushes secondary containing deuterium and tritium gas and/or a fission 'spark plug'.

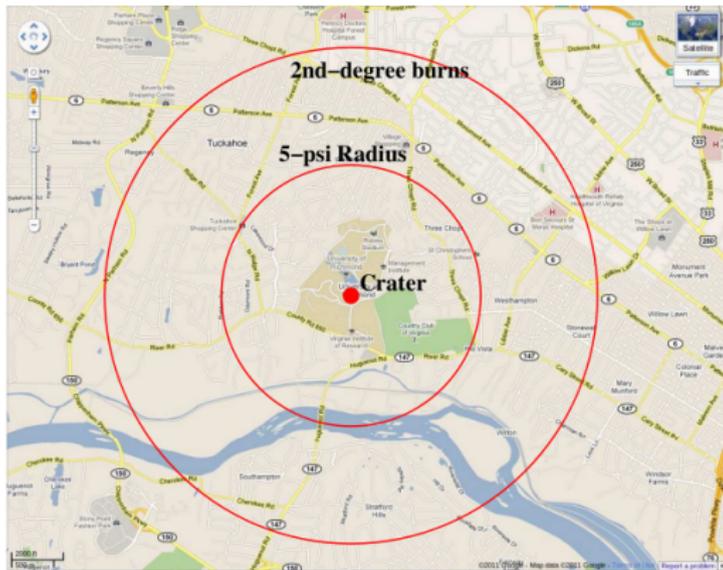


Nuclear fireball 1 ms after detonation (Tumbler Snapper); it is about 20 m across.



Nuclear Weapons 101

- Energy released in the form of light, heat and blast.
- Blast \approx 40-50% of total energy.
- Thermal radiation \approx 30-50% of total energy.
- Ionizing radiation \approx 5% of total energy.
- Residual radiation \approx 5-10% of total energy.
- Figure shows effect of a 15 kiloton bomb (about the size of the Hiroshima bomb) exploded over the Gottwald Science Center.



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The Comprehensive Test Ban Treaty (CTBT)

- The CTBT bans all nuclear explosions to limit the proliferation of nuclear weapons.
- A network of seismological, hydroacoustic, infrasound, and radionuclide sensors will monitor compliance.
- On-site inspection to check compliance.
- The US has signed the CTBT (1996), but has not ratified it.

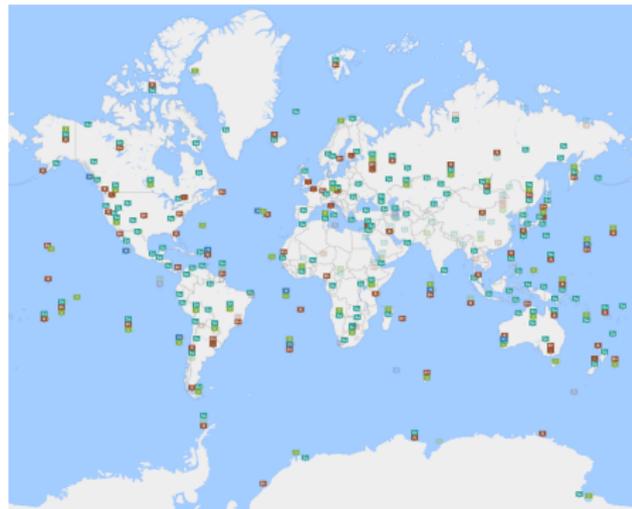


Green - ratified
Blue - signed
Red - outside treaty

The CTBT Verification Regime

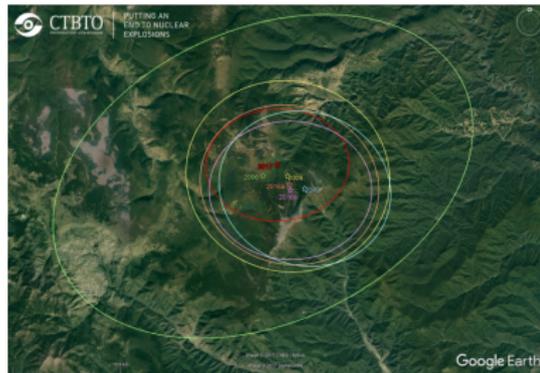
- The International Monitoring System (IMS), consists of 337 facilities that constantly monitor for signs of nuclear explosions. Over 70% are already collecting data.
- Detection technologies:
 - Seismic: 50 primary and 120 auxiliary seismic stations monitor shock waves.
 - Hydroacoustic: 11 hydrophone stations 'listen' for sound waves in the oceans.
 - Infrasound: 60 stations on the surface can detect ultra-low frequency sound waves (inaudible to the human ear) that are emitted by large explosions.
 - Radionuclide: 80 stations measure radioactive particles in the atmosphere, 40 also pick up noble gases.
- On-site-Inspection: If IMS data from the IMS show a nuclear test has occurred, a Member State can request an on-site-inspection subject to a vote .

	Primary Seismic
	Auxiliary Seismic
	Infrasound
	Hydroacoustic
	Radionuclide
	Radionuclide with Noble Gas *
	Radionuclide Laboratories



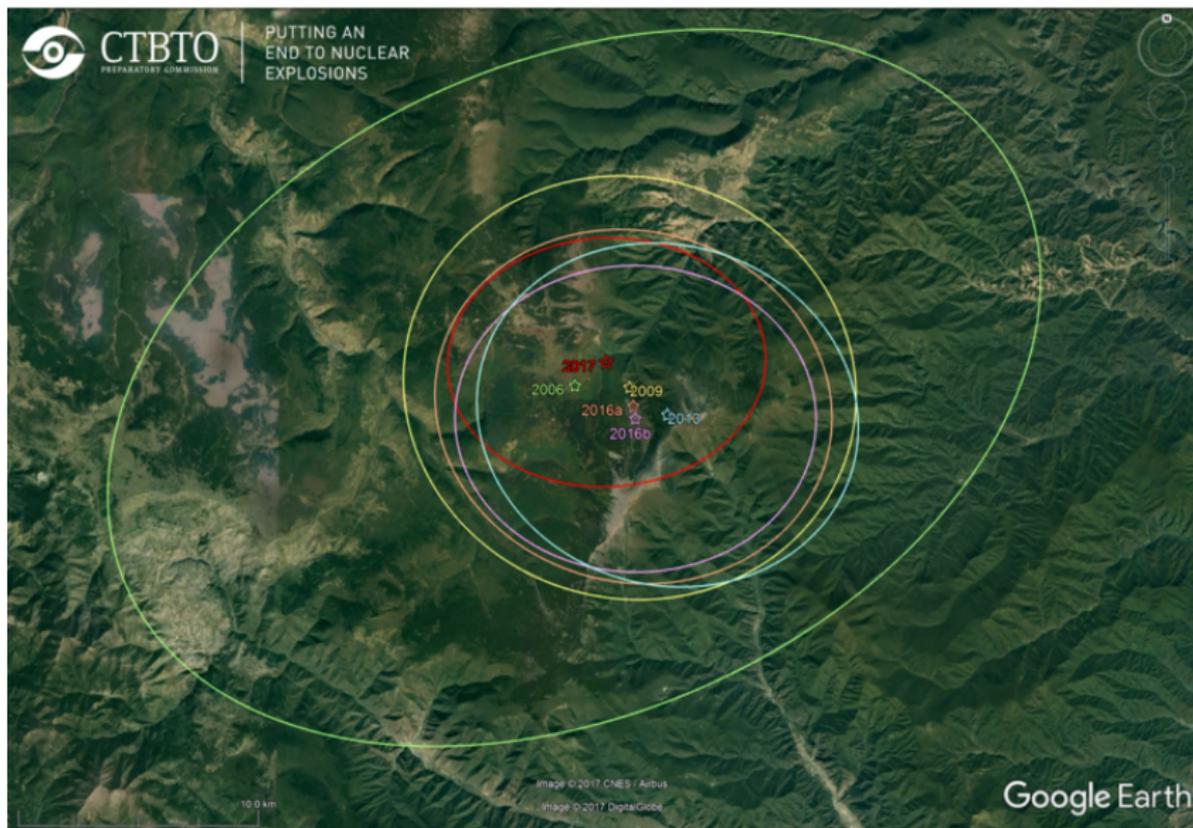
Testing the Testers

- North Korean tests a nuclear bomb October 9, 2006.
 - Over 20 CTBTO seismic stations detect it.
 - Radionuclides detected two weeks and 4700 miles away (!) in the Yukon.
 - Yield: **0.7 - 2.0 kt.**
- They do it again on May 25, 2009
 - 61 CTBTO seismic stations detect blast.
 - No radionuclides are found!!?? Epic fail?
 - Yield: **2 - 5.4 kt.**
- February 12, 2013 Test
 - 94 seismic, 2 infrasound stations.
 - Radionuclides found again!
 - Yield: **6 - 16 kt.**
- January 6, 2016 Test
 - NK claims a hydrogen bomb, but data consistent with previous test.
 - Yield: **7 - 10 kt.**
 - Radionuclide evidence inconclusive due to background.



- September 9, 2016 Test
 - Yield: **20-30 kt.**
 - No radionuclides detected.
- September 3, 2017 Test.
 - Yield is large - **70-280 kt.**
 - Hydrogen bomb or boosted fission.
 - error ellipse = $\pm 6.7 \text{ km}$.

Testing the Testers



What is Happening?

- Geologists detect the shaking induced by the blast and pinpoint the site of the explosion within 100 meters - first sign of a test. And then estimate the yield (**geology**).
- A few special nuclei made in the blast (xenon) are chemically inert and find their way through a kilometer of rock to reach the atmosphere (**geology, nuclear physics**).
- Calculations of the weather enables meteorologists to predict the spread of the plume from the blast (**meteorology, physics, computer science**).
- Air monitoring stations process huge amounts of air to capture the xenon atoms (**chemistry**).
- Nuclear physics detectors make the final identification of the decay of the xenon nuclei (**nuclear physics**).
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- Calculations of the weather enables meteorologists to predict the spread of the plume from the blast (**meteorology, physics, computer science**).
- Air monitoring stations around the world are alerted to measure the concentration of the plume.
- Nuclear physics detectors make the identification of the decay of the xenon nuclei (**nuclear physics**).
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Detecting the nuclear test requires sophisticated science that draws on many people in many disciplines!

International response is driven by the scientific results - scientists have to get it right!

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 - There is abundant, public information on containing gases from nuclear blasts.
 - Higher yield bomb could have sealed the rock from venting.
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The American Geophysical Union and the Seismological Society of America have stated the IMS will detect all explosions down to 1 kiloton (and much less in some areas) and within a radius of 35 km (October, 2009).

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Why Should You Care?

- ... clandestine nuclear tests could not be verified (by the IMS). ... even when Pyongyang declared that it would conduct a nuclear-weapons test and announced where and when it would occur, this monitoring system failed to collect necessary radioactive gases and particulates to prove that a test had occurred.

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- The worst-case scenario under a no-CTBT regime poses far bigger threats to U.S. security - sophisticated nuclear weapons in the hands of many more adversaries - than the worst-case scenario of clandestine testing in a CTBT regime, within the constraints posed by the monitoring system.

National Academy of Sciences (NAS), *Technical Issues Related to the Comprehensive Nuclear-Test-Ban Treaty*, Washington, D.C., National Academy Press, 2002, pp. 10.

Why Should You Care?

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115TH CONGRESS
1ST SESSION

H. R. _____

(Original Signature of Reader)

To restrict funding for the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

Mr. WILSON of South Carolina introduced the following bill, which was referred to the Committee on _____

A BILL

To restrict funding for the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 **SECTION 1. RESTRICTION ON FUNDING FOR THE PRE-**
4 **PARATORY COMMISSION FOR THE COM-**
5 **PREHENSIVE NUCLEAR-TEST-BAN TREATY**
6 **ORGANIZATION.**

7 (a) STATEMENT OF POLICY.—Congress declares that
8 United Nations Security Council Resolution 2310 (Sep-

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January 31, 2017 (12:44 p.m.)

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1 tember 23, 2016) does not obligate the United States nor
2 does it impose an obligation on the United States to re-
3 frain from actions that would run counter to the object
4 and purpose of the Comprehensive Nuclear-Test-Ban
5 Treaty.

6 (b) RESTRICTION ON FUNDING.—

7 (1) IN GENERAL.—No United States funds may
8 be made available to the Preparatory Commission
9 for the Comprehensive Nuclear-Test-Ban Treaty Or-
10 ganization.

11 (2) EXCEPTION.—The restriction under para-
12 graph (1) shall not apply with respect to the avail-
13 ability of United States funds for the Comprehensive
14 Nuclear-Test-Ban Treaty Organization's Inter-
15 national Monitoring System.

Sponsored by Joseph Wilson of South Carolina,
February 7, 2017

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Status of the CTBT in the Trump Administration

- 1 The Trump administration has yet to comment publicly about the CTBT.
- 2 Commended the CTBTO IMS for detecting nuclear test explosions.
- 3 Requested full funding for the CTBTO though some Republicans in Congress are aiming to restrict that funding.
- 4 Ordered the Department of Energy to be ready to conduct a short-notice nuclear test in as little as six months.²
- 5 The yet-to-be-released Nuclear Posture Review (NPR) notes the return to Great Power competition with Russia, China, and Iran.³
 - 1 Broadens the circumstances for a nuclear response to non-nuclear attacks on populations, infrastructure, and U.S. nuclear forces.
 - 2 It calls for new low-yield weapons and the re-introduction of submarine-launched cruise missiles.
- 6 US and Russia are still maintaining compliance with the 2010 START Agreement.⁴

² W.J. Hennigan, Time, February 1, 2018, <http://time.com/5128394/donald-trump-nuclear-poker/>

³ Steven Pifer, Brookings Institute, Monday, February 5, 2018,

<https://www.brookings.edu/blog/order-from-chaos/2018/02/05/questions-about-the-nuclear-posture-review>

⁴ Felicia Schwartz and Michael R. Gordon, Wall Street Journal, Feb. 5, 2018,

<https://www.wsj.com/articles/u-s-says-it-has-met-nuke-reduction-target-under-treaty-with-russia-1517828668>

Another Reason To Care - Timeline of North Korean Nuclear Program

- 1960's - First NK reactor built at Yongbong with Soviet help.
- 1970's - Plutonium reprocessing starts with Soviet help.
- 1980's - NK develops nuclear weapons infrastructure with significant outside help.
- 1990's
 - US President G.H.W. Bush announces US withdrawal of all nuclear weapons from S. Korea.
 - US, SK, and NK agree to nuclear-free Korean peninsula, but mutual inspections fail.
 - Agreed Framework "freezes" NK nuclear program and allows inspections in exchange for building power reactors and fuel oil.
- 2000's
 - US President G.W. Bush names NK in the axis of evil.
 - Agreed Framework collapses over delays in inspections (US) and construction of reactors (NK).
 - NK starts reprocessing spent fuel, gets technical support for nuclear weapons from Pakistan in exchange for missile technology.
 - First nuclear tests.
- 2010's
 - NK nuclear tests show increasing yield and technical prowess.
 - Rapid growth in missile technology.

Another Reason To Care - Timeline of North Korean Nuclear Program

- 1 US Defense Intelligence Agency finds that North Korea has produced a miniaturized nuclear warhead for mounting on an ICBM and could have up to 60 nuclear warheads.⁵
- 2 Rapid development of intercontinental ballistic missile capabilities (17 tests in 2017) leading to the Hwasong-15 tested on November 28, 2017 with a potential range of - 13,000km range.
- 3 The population of Seoul, South Korea area is about 25 million and is located 40 km from the Demilitarized Zone. Seven hundred artillery pieces and rockets (out of an arsenal of about 14,000 guns and rockets) can reach Seoul. Twenty-three thousand US troops are stationed in South Korea.

North Korea's missile range



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How do we respond to a nuclear North Korea?

The Nukes are Loose. - NTI Threat Index 2016

The Nuclear Threat Initiative (NTI) is a nonpartisan, nonprofit organization that works to prevent catastrophic attacks and accidents with weapons of mass destruction and disruption. Its threat index ranks the nuclear security practices of 176 countries.

OVERALL SCORE				
Rank / 24	Country	Score / 100	Change since	
			2014	2012
1	Australia	93	0	+3
2	Switzerland	91	+2	+4
3	Canada	87	+2	+8
4	Poland	84	+3	+7
=5	Belgium	83	+3	+13
=5	Germany	83	+1	+6
=5	Norway	83	+2	+5
=8	Belarus	81	0	+7
=8	France	81	+1	+3
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Without a comprehensive and effective global system in place, states approaches to nuclear security continue to vary widely, thereby creating dangerous weak links that terrorists could exploit as they seek the easiest path to weapons-usable nuclear materials.

Conclusions

- Do we live in a safer world than during the Cold War? **Yes, sort of.**
 - The threat of nuclear Armageddon has receded with the lowering of tensions between Russia and the US.
- Has the threat of a nuclear conflict increased? **Yes, sort of.**
 - While the threat of a large-scale nuclear war between Russia and the US is smaller, the proliferation of nuclear weapons technology has increased the risk of nuclear weapons being used.
- What can be done? **Lots, but it will take time, money (Opps! There goes my tax cut!) and leadership from the US (CTBT, NPT, ABM, BWC, CTR).**
- What can I do?
 - Learn! Cut through the hype.
 - Vote! Write to Congress.
 - The US and other countries are in desperate need of technical expertise.



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② It's expensive!

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- 4 Production of trained scientists, engineers, technicians. all from basic science research.
About 200 doctoral theses have come out of JLab.



Why Should You Pay For It (basic science, that is)?

In Paris in 1783 Benjamin Franklin watched with amazement one of the first hot-air balloon flights. The following exchange was said to occur.

Questioner to Franklin: Sir, what's the use of flying in the air?

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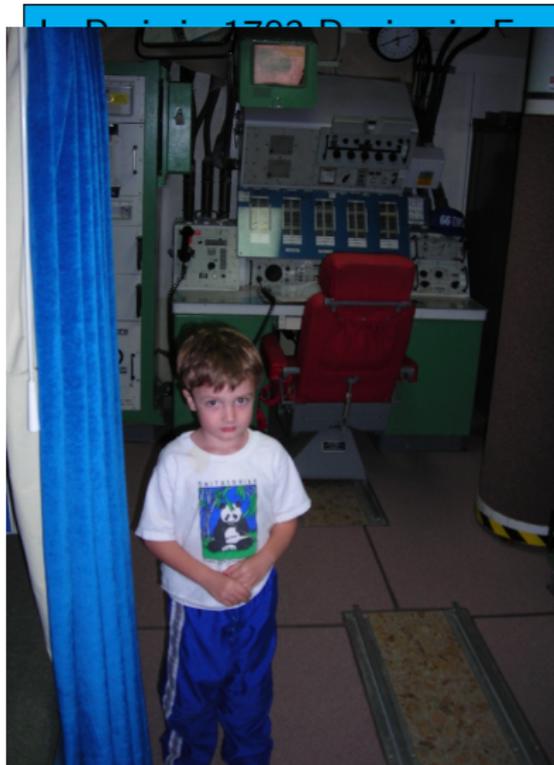
Ben Franklin's answer: Sir, what's the use of a newborn baby?

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... Franklin watched with amazement one of the following exchange was said to occur.
what's the use of flying in the air?
what's the use of a newborn baby?



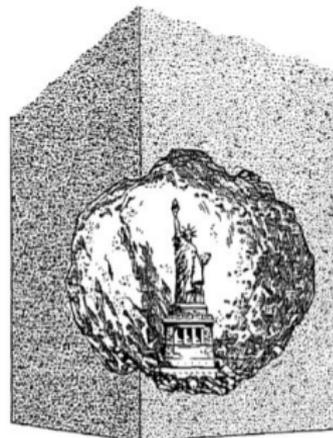
Additional Slides

Can an Opponent Cheat on the CTBT?

- U.S. and Russian experiments have demonstrated that seismic signals can be muffled, or decoupled, for a nuclear explosion detonated in a large underground cavity.
- Such technical scenarios are credible only for yields of at most a few kilotons.
- Other scenarios require mine-masking, multiple explosions, hide-in-an-earthquake.
- The IMS is expected to detect all seismic events of about magnitude 4 or larger corresponds to an explosive yield of approximately 1 kiloton (the explosive yield of 1,000 tons of TNT).

What can be learned from low-yield, surreptitious blasts?

Can it extrapolated to full-up tests?



Demonstration of size of cavity needed to decouple a 5 kT blast.

US Congress, Office of Technological Assessment, *Verification of Nuclear Testing Treaties*, OTA-ISC-361, (Washington, DC; US Government Printing Office; May, 1988).

"All the News
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Late Edition
New York: Today, cloudy with some light snow, high 35. Tonight, early snow, low 27. Tomorrow, becoming partly sunny, high 38. Yesterday, high 34, low 25. Weather map, Page D8.

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NEW YORK, FRIDAY, JANUARY 5, 2001

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REPORT TO CLINTON ASKS U.S. TO RATIFY TEST-BAN TREATY

A LAST-DITCH CAMPAIGN

Retired Head of Joint Chiefs
Seeks to Assuage Critics of
Pact Announced by Bush

By MICHAEL R. GORDON

A former chairman of the Joint Chiefs of Staff who conducted a comprehensive study of the nuclear test ban treaty at the request of President Clinton has concluded that the United States must ratify it in order to mount an effective campaign against the spread of nuclear weapons.

The assessment by Gen. John M. Shalikashvili, who was chairman of the Joint Chiefs from 1993 to 1997, is part of a last-ditch attempt by Mr. Clinton to build support for the treaty, which Senate Republicans rejected in 1999 and on which President-elect George W. Bush's own top aides have sharply disagreed.

General Shalikashvili's report outlines measures intended to assuage critics of the treaty, including increased spending on verification, greater efforts to maintain the United States nuclear arsenal and a joint review by the Senate and administration every 10 years to determine whether the treaty is still in American interests.

President-elect Bush assailed the treaty as unverifiable and unenforce-

Road Ban Set For One-Third Of U.S. Forests

Clinton Order Will Put
Logging Off Limits

By DOUGLAS JEHL

WASHINGTON, Jan. 4 — In the biggest land conservation act in decades, President Clinton will approve an order on Friday putting nearly a third of the national forest land permanently off limits to road building and logging.

The move, covering more than 38 million acres in 39 states, is to be cast by the White House as a capstone in the president's efforts to protect public lands from development. It would effectively prohibit not only commercial logging but also oil and gas development across an area larger than the nation's current national parks. And while not specifically banned, off-road vehicle activity would probably be severely limited in the roadless areas because of their inaccessibility.

The president's order, a strengthened version of an October 1999 administration proposal, is likely to set off furious challenges from Western states and Republican lawmakers who have called the plan hasty and irresponsible.

Among those who plan to head almost immediately to federal court to try to block the sweeping effort is the governor of Idaho, who with other Westerners has denounced the action as an unwelcome intrusion into land-use decisions better made at a local level.

In the presidential campaign,

Three Who Are Losing Their Old Chairmanships . . .



Associated Press

Bud Shuster of Pennsylvania
Former chairman of the Transportation and Infrastructure Committee announced yesterday that he was resigning.



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. . . and Three New Chairmen of Powerful Committees



Associated Press

Bill Thomas of California
Ways and Means



Seneca East

Billy Tauzin of Louisiana
Energy and Commerce



Seneca East for The New York Times

Michael G. Oxley of Ohio
Financial Services

HONORING '95 VOW, HOUSE REPUBLICANS REPLACE 13 CHIEFS

FIGHT FOR COVERED POSTS

In the Evenly Divided Senate,
Democrats Move Toward
a Deal to Share Power

By LIZETTE ALVARIZ

WASHINGTON, Jan. 4 — Six years after promising to change the ways of Washington fundamentally, House Republicans today made good on their pledge to curtail the power of committee barons and replaced 13 of their most senior chairmen.

The newly created selection process created fierce competition among members who sought the positions, intensified party fund-raising by the members seeking to demonstrate loyalty and led to the creation of a new committee.

Representative Bill Thomas, a California known for his sharp intellect and temper, was named as the chairman of the Ways and Means Committee, which oversees tax policy, Medicare and Social Security, defeating a more senior and more conservative competitor. And Representative Henry J. Hyde of Illinois, who as chairman of the Judiciary Committee handled President Clinton's impeachments, will now head the International Relations Committee.

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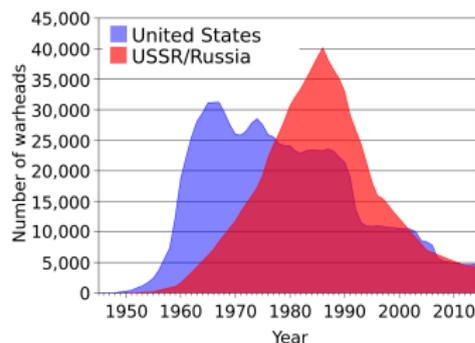
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In an institution where change usually comes slowly and against great

The Soviet and US Nuclear Arsenals

- By the end of the Cold War the US and USSR had nuclear arsenals containing about 64,000 warheads on various delivery vehicles.
- US and Soviet military stockpiles contained about 1600 tons of highly-enriched uranium (HEU) and about 200 tons of plutonium.



- An unforeseen consequence of the end of the Cold War was the disposition of nuclear weapons materials.

Fissile Material Security in Russia Declines

- The economic situation in Russia left few funds for maintaining the security of now-unused nuclear materials.
- Reports by the National Research Council in 1994, 1997 and 1999 have revealed the extent of the decline of security.



Building at the Kurchatov Institute housing enough HEU for a nuclear bomb. It had no motion sensors, detectors, or portal monitors.

- In the 1990's there have been numerous instances of smugglers apprehended with nuclear materials.
- In late 1998 the Russian FSB (successor to the KGB) reports stopping an attempt to steal 18.5 kg of weapons-usable material.

Why Should You Care?

- The US and most other nations have a long-standing policy of nuclear nonproliferation.
- A nuclear blast would have horrific consequences; loss of life, property, and security.
- Even acquisition of a nuclear weapon by an adversary could have a devastating influence on US security and non-proliferation.
- **One of the highest hurdles to obtaining a nuclear weapon is acquiring enough weapons-grade fissile material to produce a bomb.** Iraq spent \$5-\$10 billion in the 1980's to produce a few grams of plutonium.
- Smuggling fissile material is a 'short-cut' to acquiring nuclear weapons; it lowers the acquisition hurdle.
- Prevention (*i.e.*, security) is critical especially against an 'insider' threat.

What Can an Opponent Do?

- What can a terrorist organization do?
 - Acquiring the necessary technology to enrich uranium or plutonium is beyond the capabilities of most terrorists.
 - Stealing the necessary fissile material is NOT!
 - A gun-type, uranium weapon of low yield is still a difficult endeavor, but could be done.
 - There are other alternatives for terrorists like a 'dirty bomb'.
 - **The likeliest terrorist weapons are still guns and bombs.**
- All of the above can be negated if one of the current nuclear powers gives one away. This is unlikely.
- There is continued smuggling activity for nuclear materials.
- The ITBD includes three incidents involving HEU and three involving plutonium during the period 1992-2015.

Confirmed incidents involving unauthorized possession and related criminal activities, 1993-2015

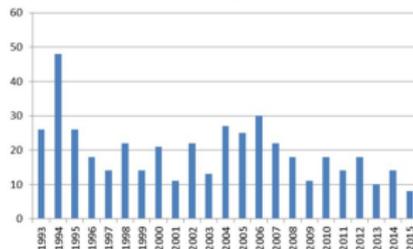


Figure 1 Incidents reported to the ITBD involving unauthorized possession and related criminal activities, 1993-2015.

IAEA Incident and Trafficking Database (2016 Fact Sheet)

The US Response

- In 1991 the US Congress passes the Nunn-Lugar Act. The US pays to improve security of fissile materials and to dismantle the Russian nuclear complex (cooperative threat reduction).
 - The US spent about \$700 million a year to reduce this threat.
 - The Fissile Material Storage Facility (FMSF) securely stores plutonium and uranium from dismantled weapons.
 - HEU Purchase Agreement downblended about 500 metric tons of HEU to reactor fuel (not usable in a nuclear weapon) for \$20 billion.

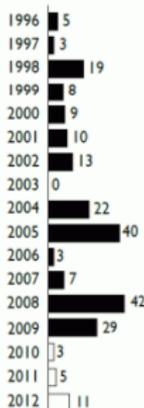


Fissile Material Storage Facility at Mayak financed by the US Cooperative Threat Reduction program.

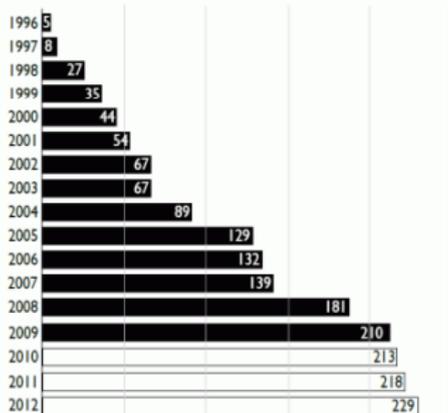
- Most of these cooperative programs ended by December, 2014 due to the conflict over Russian actions in the Ukraine.

How Loose are the Nukes?

Number of Building Upgrades Completed During the Fiscal Year



■ Cumulative Buildings with Comprehensive Upgrades
□ DOE Projections



There exists a publicly unknown number of buildings containing weapon-usable nuclear material in Russia on which the United States and Russia have never agreed to cooperate.

Country

Year

Iraq	1992
Colombia	1996
Spain	1997
Denmark	1998
Georgia	1998
Philippines	1999
Thailand	1999
Slovenia	1999
Brazil	1999
Sweden	2002
Greece	2005
South Korea	2007
Latvia	2008
Bulgaria	2008
Portugal	2008
Romania	2009
Libya	2009
Taiwan	2009
Turkey	2010

Countries that have eliminated all weapons-usable fissile material.

Reproduced from M. Bunn, *Securing the Bomb 2010*, Harvard University and the Nuclear Threat

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1996 ■ 5

1996 ■ 8

Country

Year

Iraq

1992

Colombia

1996

Action Taken	Completed	% of 2017 Goal	Action Taken	Completed	% of 2017 Goal
Warheads Deactivated	7616	82.2%	SLBM Launchers Eliminated	492	80.4%
ICBMs Destroyed	914	87.8%	Nuclear Air-to-Surface Missiles Destroyed	906	100%
ICBM Silos Eliminated	498	76.4%	Bombers Eliminated	155	100%
ICBM Mobile Launchers Destroyed	197	54.9%	Nuclear Test Tunnels/Holes Sealed	194	100%
Nuclear Weapons-Carrying Submarines Destroyed	33	84.6%	Nuclear Weapons Transport Train Shipments	611	73.7%
Submarine-Launched Ballistic Missiles (SLBMs) Destroyed	695	95.3%	Nuclear Weapons Storage Facility Upgrades	24	100%
Cooperative Biological Engagement Laboratories Secured	47	57.3%	Declared CW Agent Destroyed (Metric Tons)	4018.6	73.4%

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Public Policy Opportunities

If you want to get paid (jobs):

- The National Academies (NAS, NAE, NRC, IOM) hire Senior Project Assistants and Research Assistants.
- The scientific societies (AIP, APS, AGU, AGI, ACS, AAAS or AAS) hire science policy researchers.
- Other organizations like the Center for Science, Policy, and Outcomes, the Federation of American Scientists, and the Union of Concerned Scientists sometimes hire researchers.
- The General Accounting Office hires researchers.
- The Congressional Research Service (CRS) produces an annual guide of policy jobs in Washington, DC.

- Policy-makers are in dire need of technical expertise in writing laws to evaluate national security threats, handle privacy, and regulate medical diagnostic testing.
- People are hungry for information.
- An educated electorate is essential.
- Training the populace could save lives in the event of an attack.
 - Panic will amplify the effect of an attack.
 - Panic is greatly diminished when people receive training.

Assessing Risk

What should you stay awake worrying about at night?

Deaths in 2014*	Cause
2,626,418	All causes
614,348	Heart disease
33,736	Vehicle accidents
55,227	Influenza/Pneumonia
42,826	Suicide

Deaths in 2014*	Cause
11,019	Homicide
42,032	Poisoning
31,959	Falling
3,406	Drowning
2,701	Fire

*National Vital Statistics Reports, **65**, no. 4, June 30, 2016.