CONFRONTING THE PERPETUAL MENACE

CAN WE HAVE NUCLEAR DISARMAMENT WITHOUT NUCLEAR TRANSPARENCY?

Alex Glaser
Princeton University

Copenhagen, December 11, 2020

Painting by Helen Audrey Schrayer, Acrylic on Canvas, 2017
Revision 4b
OUTLINE

BACKGROUND
(How we got here)

DEALING WITH SECRETS
(Nuclear weapons and arms control)

WHAT SCIENTISTS & ENGINEERS CAN DO
(Elements of a research agenda)

OUTLOOK
(Next steps for nuclear arms control & verification)
BACKGROUND

(How we got here)
A modern nuclear weapon has a destructive power tens to hundreds of times greater than the Hiroshima bomb.

Even a “limited” nuclear war would have global environmental consequences

Smoke from a regional nuclear war between India and Pakistan

Alan Robock and Luke Oman, climate.envsci.rutgers.edu/nuclear and www.atmos-chem-phys.net/7/2003/2007; see also, Toon et al., Science Advances, October 2019
There remain about 13,300 nuclear weapons in the world today.
With the aim of inhibiting the other side's recovery, Russia and NATO each target the other's 30 most populated cities and economic centers, using 5–10 warheads on each city depending on population size. Immediate casualties: 85.3 million over 45 minutes. The countervalue plan: 91.5 million. Number of immediate casualties, including fatalities (34.1 million) and injuries (57.4 million), resulting from the series of nuclear exchanges. Deaths from nuclear fallout and other long-term effects would significantly increase this estimate.

Watch the four-minute video: https://youtu.be/2jy3JU-ORpo

There never has been a moment's justification for having the capability to destroy humanity.

Daniel Ellsberg
75 YEARS OF NUCLEAR WEAPONS

(CAN YOU SPOT THE DIFFERENCES IN THESE PICTURES?)

U.S. W80-4 cruise missile warhead
Source: NNSA/Sandia National Laboratory

North Korean two-stage weapon
Source: KCNA
BOHR ON THE NUCLEAR CHALLENGE

“A PERPETUAL MENACE TO HUMAN SECURITY”

FROM THE 1944 MEMORANDUM TO PRESIDENT ROOSEVELT

“Unless ... some agreement about the control of the use of the new active materials can be obtained in due time, any temporary advantage, however great, may be outweighed by a perpetual menace to human security.”

www.atomicarchive.com/resources/documents/manhattan-project/bohr-memo.html

FROM THE 1950 OPEN LETTER TO THE UNITED NATIONS

“Free access to information and unhampered opportunity for exchange of ideas must be granted everywhere. [...] It must be realized that full mutual openness, only, can effectively promote confidence and guarantee common security.”

THE TURNING POINT
(1989/1990)
ENERGY SECRETARY UNVEILS
OPENNESS INITIATIVE

Secretary of Energy Hazel R. O'Leary today launched a comprehensive initiative to lift the veil of Cold War secrecy and move the Department of Energy (DOE) into a new era of government openness.

As a beginning to the process, O'Leary released information about the nation's nuclear weapons program that has been kept secret for 50 years.

"Secretary O'Leary's bold new initiative will allow a more informed group of stakeholders to work with the Department of Energy to solve the problems that face our Nation," said President Bill Clinton, who has directed federal agencies to dramatically increase the public's access to information about its government. "This new policy will ensure maximum disclosure of information and technologies critical to the Nation's economic and global interests."

Examples of previously classified information being disclosed for the first time include:  

www.osti.gov/includes/opennet/reports/r93254.pdf
A New Approach. The breakup of the former Soviet Union, the end of the Cold War, and other national and international events of recent history have enabled our national leadership to reconsider the constraints placed on both classified and unclassified Government information. The Department of Energy (DOE) remains committed to a policy of responsible openness, and will continue ... to declassify and release information to the public consistent with the requirements of national security” (p. i).

- Hypothetically, a mass of 4 kilograms of plutonium or uranium-233 is sufficient for one nuclear explosive device. (94-1)

- Fact that all U.S. weapon pits that contain plutonium have at least 500 grams of plutonium, no elaboration. (99-4)
U.S. FISSION MATERIAL DECLARATIONS

There is enough nuclear explosive material worldwide to make over 200,000 nuclear weapons

- 1340 tons of highly enriched uranium (HEU)
- 520 tons of separated plutonium

Each block corresponds to 12 kg of HEU, the amount necessary to make a fission bomb; about 111,670 bombs-worth total

Each block corresponds to 4 kg of plutonium, the amount necessary to make a fission bomb; about 130,000 bombs-worth total

Graphic/concept by Alex Wellerstein
# Transparency Scorecard 2020

**Information on Nuclear Warhead & Fissile Material Inventories and Status**

<table>
<thead>
<tr>
<th>Category</th>
<th>United States</th>
<th>Russia</th>
<th>Britain</th>
<th>France</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of total warheads</strong></td>
<td>Approximate</td>
<td>No</td>
<td>Yes (upper limit)</td>
<td>Yes (upper limit)</td>
<td>Relative (out of date)</td>
</tr>
<tr>
<td></td>
<td>Yes (strategic only)</td>
<td>Yes (strategic only)</td>
<td>Yes (planned)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Dismantlements</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes (no details)</td>
<td>Yes (no details)</td>
<td>No</td>
</tr>
<tr>
<td><strong>Verification</strong></td>
<td>Partial</td>
<td>Partial</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Fissile material stockpiles</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes (no details)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Production histories</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Excess/Disposal</strong></td>
<td>Yes (nothing new)</td>
<td>Yes (nothing new)</td>
<td>Yes (nothing new)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Verification</strong></td>
<td>Partial</td>
<td>Partial</td>
<td>Partial (but no longer)</td>
<td>Partial (some plutonium)</td>
<td>No</td>
</tr>
</tbody>
</table>
DEALING WITH SECRETS

How do you regulate & eliminate nuclear weapons (when you cannot “talk about” them?)

(Why does this matter now?)
GLOBAL NUCLEAR WEAPON STOCKPILE

Based on the Nuclear Notebook, maintained by Hans M. Kristensen and Matt Korda, thebulletin.org/nuclear-notebook/
BEYOND NEW START

OBAMA/BIDEN ADMINISTRATION (2009–2016)

“I've determined that we can ensure the security of America and our allies, and maintain a strong and credible strategic deterrent, while reducing our deployed strategic nuclear weapons by up to one-third.”

Remarks by President Obama at the Brandenburg Gate, Berlin, June 19, 2013

TRUMP ADMINISTRATION (2017–2020)

U.S. Special Presidential Envoy for Arms Control (Marshall S. Billingslea) has threatened to increase the U.S. nuclear arsenal if Russia does not agree to U.S. conditions for New START extension, i.e., to begin negotiations on a multilateral “all-warhead” agreement with strengthened verification provisions.

Source: DPA (top) and NNSA (bottom)

fas.org/blogs/security/2020/10/new-start-2020_aggregate-data/
PROJECT CLOUD GAP, 1963–1969
(WITH FIELD TEST 34 IN SUMMER/FALL 1967)

fas.org/nuke/guide/usa/cloudgap
FIELD TEST 34

TAKE AWAYS BY THE U.S. ATOMIC ENERGY COMMISSION

“Permitting the inspectors a degree of access to the weapons which included x-ray photography did not always result in their correctly identifying real and fake weapons. Thus, even though a great deal of weapon design information was revealed through x-ray photography, it did not provide assurance that actual weapons were being examined.”

NUCLEAR WEAPONS HAVE UNIQUE SIGNATURES

BUT THEY ARE SENSITIVE AND CANNOT BE REVEALED TO INSPECTORS
NUCLEAR WARHEAD VERIFICATION

KEY CONCEPTS OF (PROPOSED) INSPECTION SYSTEMS

**ATTRIBUTE APPROACH**
Confirming selected characteristics of an object in classified form (for example, the presence/mass of plutonium)

**TEMPLATE APPROACH**
Comparing the radiation signature from the inspected item with a reference item (“golden warhead”) of the same type

**INFORMATION BARRIERS**
Technologies (and procedures) that prevent the release of sensitive nuclear information
EARLY INFORMATION BARRIERS
(RESEMBLED RUBE-GOLDBERG MACHINES)

Fissile Material Transparency Technology Demonstration (FMTTD), Los Alamos, August 2000
“All I see is a green LED with a battery connected to it.”

Russian nuclear weapons expert during technology demonstration at a U.S. national laboratory in the early 2000s
HOW INSPECTIONS MAY LOOK LIKE

(NO REAL PRECEDENTS EXIST)

Source: U.S. Department of Energy (left) and ukni.info (right)
HOW NOT TO GIVE AWAY A SECRET

CONTINUE IMPROVING TECHNOLOGIES AND APPROACHES
Work on information barriers with a particular focus on certification and authentication; in particular, identify joint hardware and software development platforms.

REINVENT THE PROBLEM: NEVER ACQUIRE SENSITIVE INFORMATION TO BEGIN WITH
Explore radically different verification approaches; for example, consider non-electronic measurements or develop alternatives to direct inspections of nuclear weapons altogether.

REVEAL THE SECRET
Requirement to protect sensitive information is typically the main reason for complexity of verification approaches; for example, mass of fissile material in a nuclear weapon.

Source: Author (top and bottom), altave.com.br (middle)
REINVENTING THE PROBLEM

(Some examples)
TAKING ELECTRONICS OUT OF THE PICTURE
(WHERE IT MATTERS MOST, FOR DETECTION AND DATA STORAGE)

Superheated C-318 fluorocarbon (C$_4$F$_8$)
droplets suspended in aqueous gel
Tailor-made by d’Errico Research Group, Yale University

Sensitive to neutrons with $E_n > E_{\text{min}}$
Designed to be insensitive to $\gamma$-radiation

Active volume ........... : 6.0 cm$^3$
Droplet density .......... : 3500 cm$^{-3}$
Droplet diameter ...... : $\sim$100 µm
Absolute Efficiency ... : $4 \times 10^{-4}$
ZERO-KNOWLEDGE NEUTRON RADIOGRAPHY
WITH PRELOADED, NON-ELECTRONIC (BUBBLE) DETECTORS

Perhaps we shouldn't even bother about directly accessing nuclear warheads (at least, for now)
SEPARATING THE “ITEM” AND ITS “TAG”
(BUDDY-TAG INSPECTIONS WITHOUT DIRECT ACCESS TO WARHEADS)

A. Glaser and Yan Jie, Minimally Intrusive Approaches to Nuclear Warhead Verification, Irmgard Niemeyer, Mona Dreicer, Gotthard Stein (eds.), Nuclear Non-proliferation and Arms Control Verification, Springer, 2020
CONFIRMING WARHEAD LIMITS WITH ABSENCE MEASUREMENTS

Building on the experience with New START, confirming compliance with all-warhead agreements could primarily rely on absence measurements with minimum access to treaty accountable items.

Source: Sandia National Laboratories, Randy Montoya
INSPECTIONS FROM A DISTANCE

THAT DO NOT REQUIRE TRUSTED SENSORS

Apparatus with RF antennas/receivers and 20 independently movable mirrors ("Death Star")

Joint project with
U. Rührmair (LMU Munich)
J. Tobisch, C. Paar, C. Zenger (Ruhr University Bochum)
S. Philippe, A. Glaser (Princeton University)
B. Barak (Harvard University)
Using Virtual Reality to develop and demonstrate new verification approaches
CAN WE HAVE NUCLEAR DISARMAMENT WITHOUT NUCLEAR TRANSPARENCY?
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NO NEED FOR REVEALING NUCLEAR SECRETS

Inspection protocols and measurement equipment for non-intrusive approaches for confirming numerical limits and for monitoring nuclear warheads in long-term storage could be developed quickly.

Focus initially on basic approaches that can accommodate “upgrades” later on.

MEANWHILE …

Dismantlements continue to be unverified, and almost 90% of all nuclear weapons do no longer exist today.

Weapon states ought to begin now to document dismantlements in ways that international inspectors will find credible at a later time.

Source: U.S. DOE (top and bottom)
Georgetown students shed light on China’s tunnel system for nuclear weapons

China is rapidly building up its nuclear forces, including the expansion of plutonium and uranium plants as part of a secretive, crash program to add warheads to its growing missile and bomber forces, according to declassified U.S. briefing slides obtained by The Washington Times.

The four slides were part of a recent briefing for NATO allies in the past month on Chinese nuclear forces and show three facilities that appear to have sharply increased in size since 2010.
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Graphic/concept by Alex Wellerstein
U.S. plutonium production reactor at the Savannah River Site, i.imgur.com/CPrBoCK.jpg
A U.S. delegation led by State Department official Sung Kim crosses the military demarcation line between North and South Korea on May 10, 2008. North Korea shared 18,000 pages of operating records to confirm the correctness of its declared plutonium stockpile. Credit: Chung Sung-Jun
REFOCUSSING TRANSPARENCY
ON FISSILE MATERIALS & THE HISTORY OF THEIR PRODUCTION

ESTABLISHING THE BASELINES

- Confirming the end of fissile material production for military purposes
- Declaring historic production to establish baselines

These efforts could be followed by declarations of excess materials, international safeguards on these materials, and their disposition/elimination

CONFIRMING WHAT’S THERE: NUCLEAR ARCHAEOLOGY

- Preserving operating records
- Developing relevant (nuclear forensic) techniques

Joint exercises could envision data exchanges (e.g. sharing of operating records) and measurement campaigns at selected “test beds”

Source: U.S. DOE (top) and www.francetnp.gouv.fr
THE BAN TREATY

WILL ENTER INTO FORCE IN JANUARY 2021

Tim Wright and Ray Acheson
with Ban Treaty

Setsuko Thurlow and Beatrice Fihn
with Berit Reiss-Andersen
Nuclear Weapons
We built them.
We can take them apart.

@NuclearAnthro