© Paul Shambroom

Issues and Opportunities in Nuclear Arms Control and Disarmament Verification

Alexander Glaser

Woodrow Wilson School of Public and International Affairs and
Department of Mechanical and Aerospace Engineering
Princeton University

James Martin Center for Nonproliferation Studies
Washington, DC, July 17, 2014

Revision 1

Two Ways of Looking at the Problem

"Mission-focused" vs "Technology-focused"

Verification Challenges for Existing and Next-generation Arms Control Treaties

Comprehensive Test Ban Treaty

Fissile Material Cutoff Treaty

Next-generation Nuclear Disarmament Treaties

Emerging Technologies

Quasi Real-time Satellite Imagery "for Everyone"

New Media and Crowdsourcing

PART I

Verification Challenges for Existing and Next-generation Arms Control Treaties

Nuclear Arms Control Treaties

(and their Verification)

Comprehensive Test Ban Treaty (CTBT)

Bans all nuclear explosions in all environments
and would be verified by extensive verification mechanisms

Fissile Material Cutoff Treaty (FMCT)

At a minimum, treaty would ban fissile material production for weapons purposes
(Issue about treaty scope: Would it also cover existing stocks?)

Next-generation Nuclear Disarmament

Agreements that place limits on total number of nuclear warheads in arsenal
would pose qualitatively new verification challenges

Verifying the Comprehensive Test Ban Treaty

Comprehensive Test Ban Treaty (CTBT)

and the International Monitoring System (IMS)

The CTBT bans all nuclear explosions in all environments

Adopted by the UN General Assembly in 1996

Signed by 183 states, ratified by 161 states (as of February 2014)

Enters into force when 44 “nuclear capable” states have ratified the treaty

Missing: China, Egypt, India, Iran, Israel, North Korea, Pakistan, and the United States

The CTBT envisions extensive verification mechanisms

Dedicated international organization: Comprehensive Test Ban Treaty Organization (CTBTO)

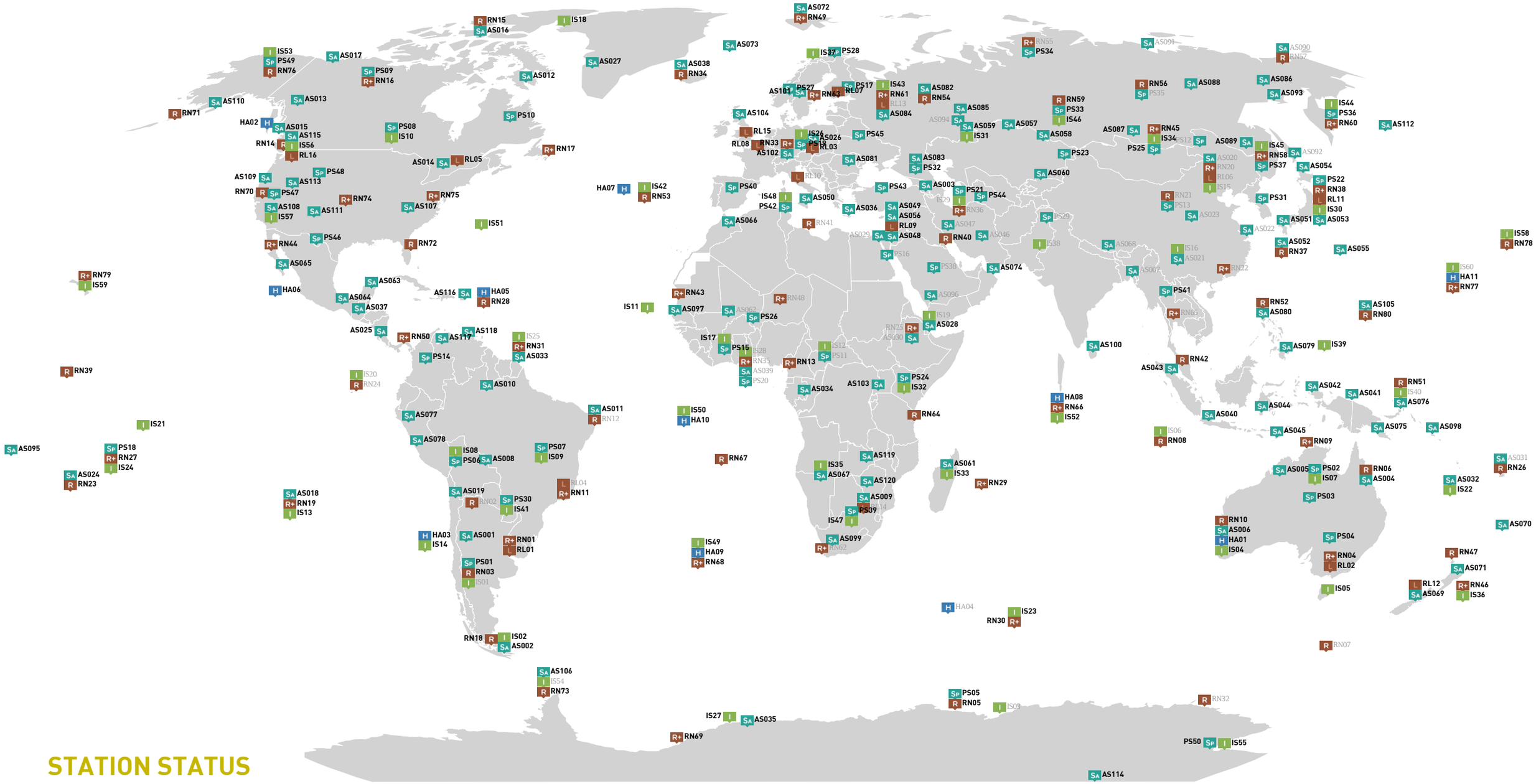
www.ctbto.org

INTERNATIONAL MONITORING SYSTEM

GLOBAL OVERVIEW - CERTIFIED STATIONS AND NON-CERTIFIED STATIONS

15 JUNE 2014

CTBTO PREPARATORY COMMISSION | preparatory commission for the comprehensive nuclear-test-ban treaty organization



STATION STATUS

DATE	15 Jun 2014
TOTAL STATIONS	337
CERTIFIED	273
NOT CERTIFIED	64

Primary Seismic | Auxiliary Seismic | Infrasound | Hydroacoustic | Radionuclide | Radionuclide w/ Noble Gas | Radionuclide Lab

WWW.CTBTO.ORG

The IMS Has Already Proven More Powerful Than Originally Anticipated

At the time of signature, it was assumed that the IMS would achieve a detection probability of 90% for a 1-kiloton (well-coupled) test

In the early 2000s, detection limit revised to about 0.1-kilotons

Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty
Committee on International Security and Arms Control, National Academy of Sciences, Washington, DC, 2002

Three North Korean tests confirmed the performance of the International Monitoring System

9 October 2006, 0.6–0.9 kt, detected by 22 IMS stations

25 May 2009, 2.5–4.6 kt, detected by 61 IMS stations

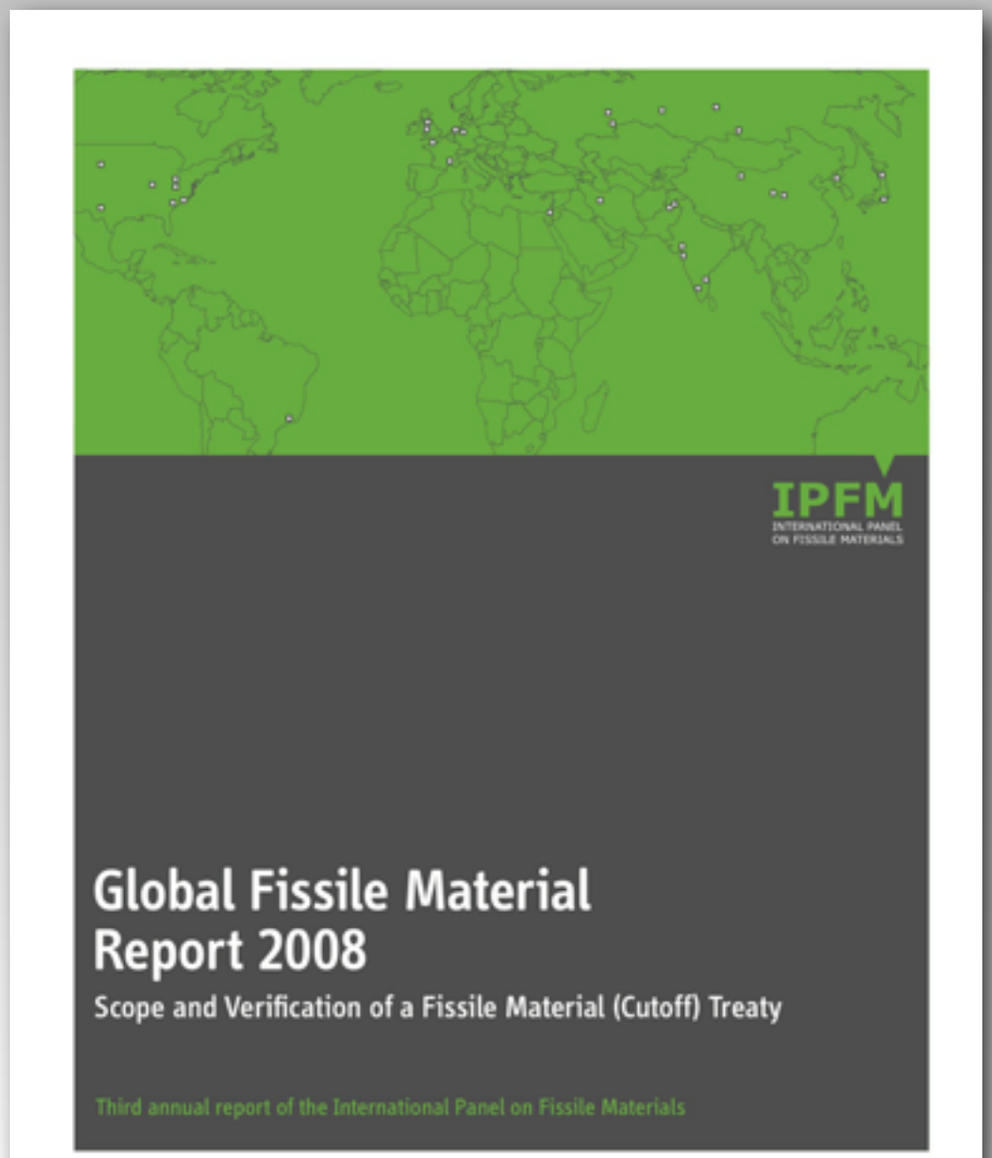
12 February 2013, 6.0–8.0 kt, detected by 94 (seismic) IMS stations

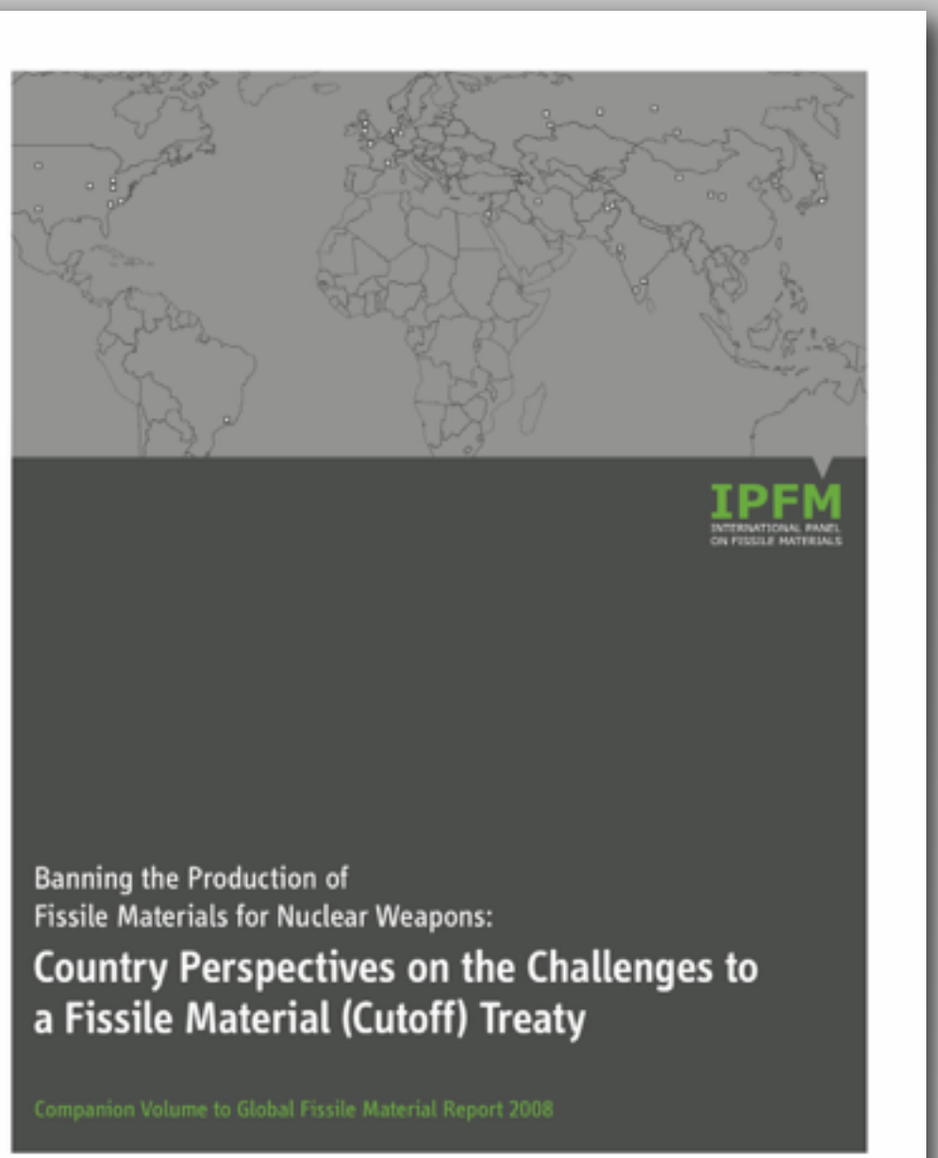
O. Dahlman, J. Mackby, S. Mykkeltveit, and H. Haak
Detect and Deter: Can Countries Verify the Nuclear Test Ban?, Springer, 2011

Verifying the Fissile Material Cutoff Treaty

Global Fissile Material Report 2008

www.ipfmlibrary.org/gfmr08.pdf and www.ipfmlibrary.org/gfmr08cv.pdf





Verification Challenges

1. Shutdown facilities
2. Operational (legacy) enrichment plants
3. Operational (legacy) reprocessing plants
4. Challenge inspections at military nuclear sites

---

depending on scope of FMCT

5. Naval-reactor fuel cycle
6. Weapon-origin fissile material

Precedents for verification exist in NPT safeguards
in non-weapon states, but some (important) differences

Verifying Nuclear Disarmament

Going “Beyond New-START”

“While the new START treaty is an important step forward, it is just one step on a longer journey. As I said last year in Prague, this treaty will set the stage for further cuts. And going forward, we hope to pursue discussions with Russia on reducing both our strategic and tactical weapons, including non-deployed weapons.”

U.S. President Obama, upon signing the New START Treaty, April 2010

Thousands of Nuclear Weapons Are No Longer Deployed and Currently In Storage

W87/Mk-21 Reentry Vehicles in storage, Warren Air Force Base, Cheyenne, Wyoming

Photo courtesy of Paul Shambroom, www.paulshambroom.com

What Are We Worried About?

(The Challenges of Nuclear Disarmament Verification)

Main Cheating Scenarios and Associated Verification Challenges

Verification Challenge 1

Party offers hoax or tampered devices instead of authentic treaty accountable items (TAI) so that real warheads, warhead components, or fissile material can be "diverted" to a secret stockpile of nuclear weapons

⇝ Authenticating (and verifying the dismantlement of) nuclear warheads

Verification Challenge 2

Party provides incomplete baseline declarations so that some treaty accountable items (e.g. warheads) are never part of the verification regime

⇝ Verifying the completeness of declarations

Verified Warhead Dismantlement

Warhead Dismantlement Verification

Some Precedents Exist and Future Work Can Build on Them

Inspection System developed as part of the 1996–2002 Trilateral Initiative during a demonstration at Sarov
Source: Tom Shea

Visual contact with a mockup nuclear weapon during a UK-Norway Initiative Dismantlement Exercise
Source: UK Norway Initiative, David Keir

Rationale behind verifying warhead dismantlement is to provide confidence that actual warheads are destroyed and that the fissile material they contained is recovered and accounted for

Many Challenges for Verified Warhead Dismantlement Remain

Development and Demonstration of Practical Inspection Systems

that assure the inspecting party that instrument works as described
and assure the host state that sensitive information is not leaked during the inspection

Trilateral Initiative developed focused only on plutonium

Demonstrate Viability of Cooperation Between Nuclear and Non-nuclear Weapon States

UK Norway Initiative has broken new ground in this area

but secrecy issues tend to make research and development outside the weapons labs difficult

Verifying the Completeness of Declarations

What About the Secret Nuclear Weapons Stockpile Stashed Away on that Remote Island?

Verifying the Completeness of Nuclear Warhead Declarations May Be Impractical

Warheads Fabricated, 1945–2010	
United States	70,000
Russia	55,000
United Kingdom	1,200
France	1,260
China	600
TOTAL	128,000

Instead, establish confidence in the completeness of fissile material declarations

(to assure that no covert warheads exist outside the verification regime)

Left: Dismantlement of the last 10-Megaton B53 bomb, October 25, 2011, www.energy.gov/articles/dismantling-final-b53-bomb

Right: Estimates from R. S. Norris and H. M. Kristensen, "Global nuclear weapons inventories, 1945–2010" *Bulletin of the Atomic Scientists*, July/August 2010, bos.sagepub.com/content/66/4/77

How Much Fissile Material is There?

Most weapon states have not yet made public their fissile material holdings

(United States and Britain are the exceptions)

Independent stockpile estimates carry significant uncertainties

(up to 20%, ton quantities in the case of Russia)

A Two-Step Process

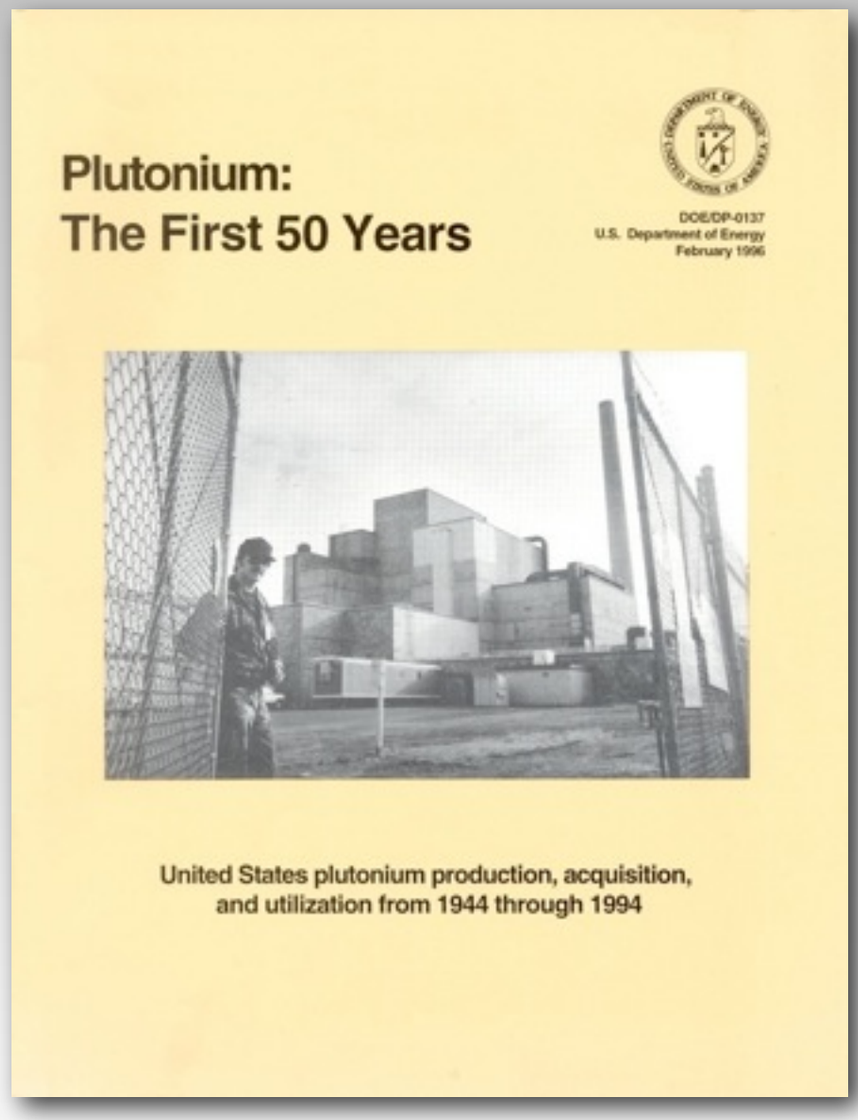
Baseline declarations of fissile material stocks (Transparency)

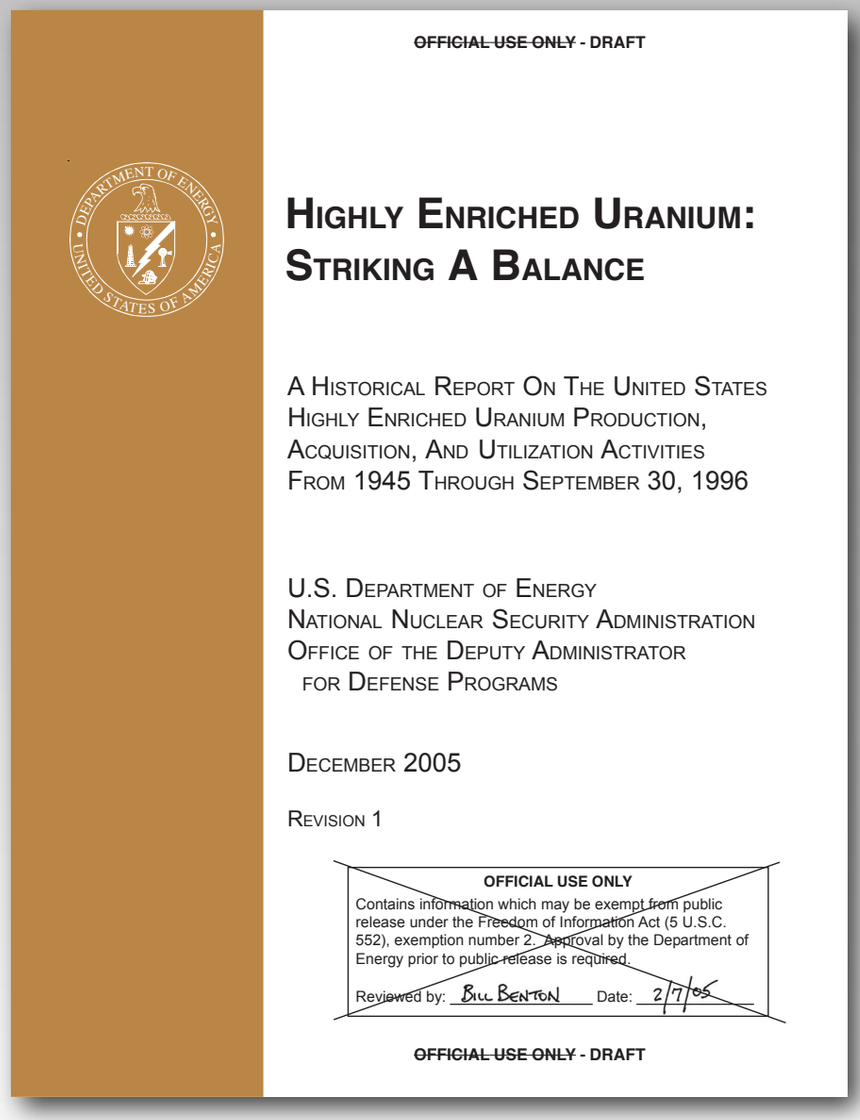
Establishing confidence in the completeness of declarations (Verification)

(Some similarity with "initial reports" required by INFCIRC/153, §62)

Supporting Declarations Put Data in Context

and can help lay the basis for verification of fissile material production and stocks



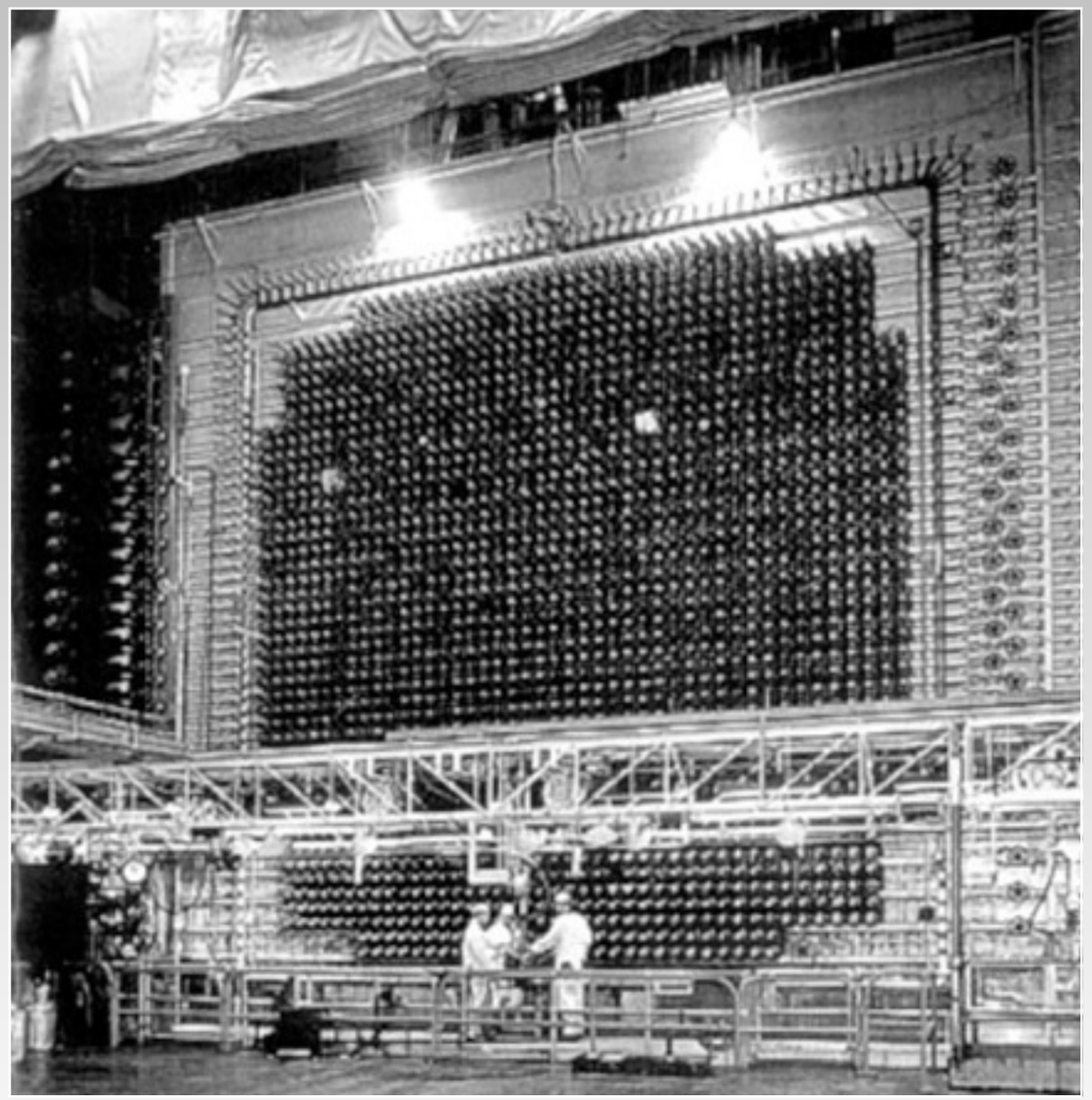


1996 and 2001 U.S. Declarations on Plutonium and HEU (and plutonium update in 2012)

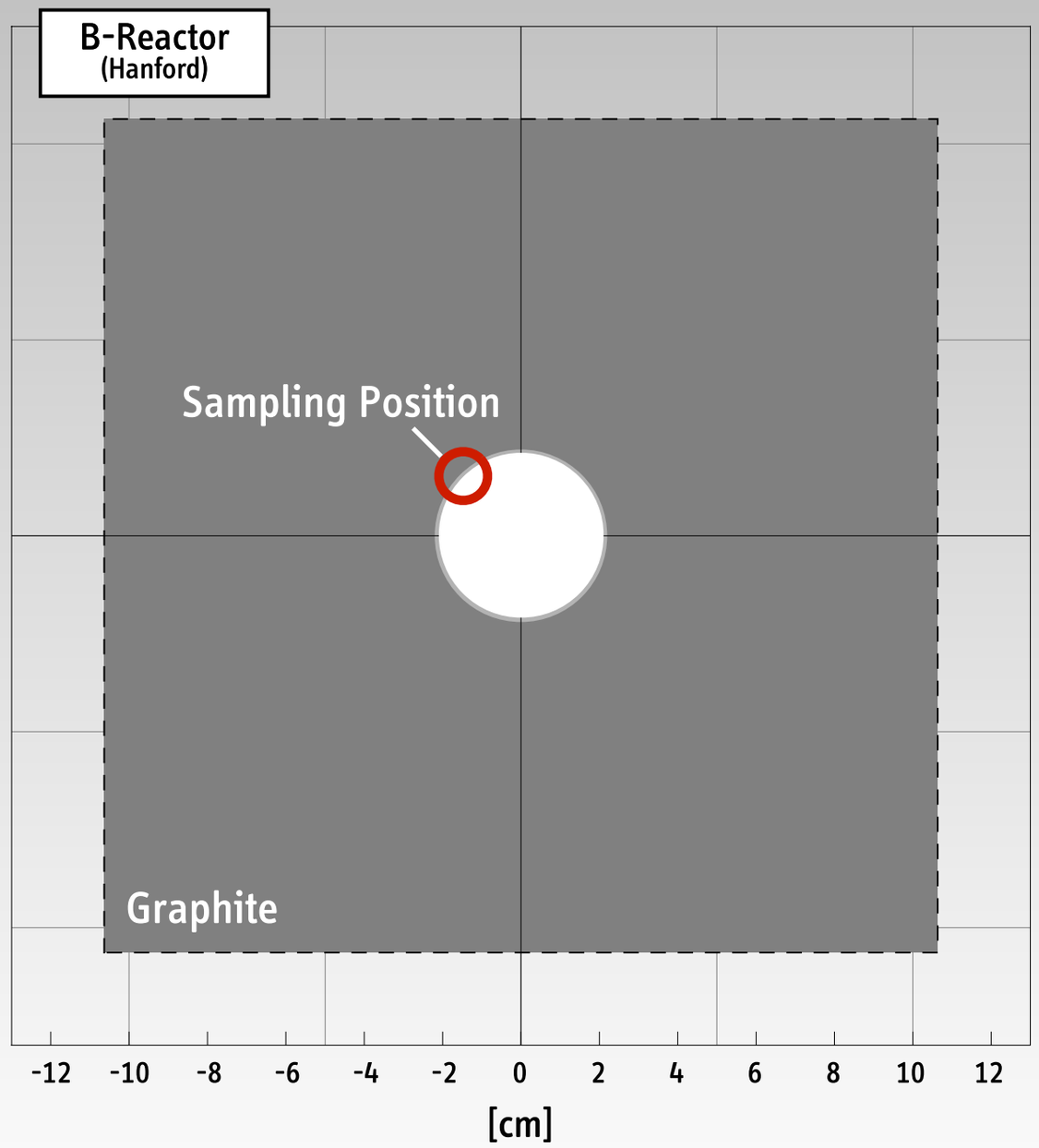
Will We Ever Be Able to Verify the Completeness of Such Declarations?

Nuclear Archaeology

Using Nuclear Forensic Techniques to Reconstruct Historic Fissile Material Production



U.S. Hanford B Reactor, 1944–1968



North Korea's Yongbyon Reactor, 2008

Nuclear archaeology would have been used to verify North Korea's plutonium declaration

The banner reads: "Let's protect Dear General Kim Jong Il desperately!"

Credit: CNN/Brian Rokus

“The Clock is Ticking”

Shutdown production reactors and enrichment plants are being decommissioned

Shutdown of the last Russian plutonium production reactor ADE-2 in Zheleznogorsk, 2010
Source: U.S. Department of Energy

Demolition of the K-25 uranium enrichment plant began in December 2008 and has been completed in 2012
Source: Bechtel Jacobs

**In many cases, facilities have been temporarily preserved;
but in other cases, environmental concerns (or site stewardship decisions)
have led to the demolition of former production sites**

Offer Test Beds for Nuclear Archaeology

To begin countries could offer single sites or facilities as test beds and invite partners with similar production facilities to engage in "site-to-site exercises" to jointly demonstrate verification approaches and measurement techniques

Left: Windscale Piles, www.sellafieldsites.com
Right: G2/G3, Marcoule, www.francetnp.fr

PART II

Emerging Technologies

Example 1

Quasi Real-time Satellite Imagery

with Access for "Everyone"

March 14, 2011 - DigitalGlobe

Quasi Real-time Imagery from Space

Posted in February 2014, www.youtube.com/watch?v=BsW6IGc4tt0 see also www.skyboximaging.com

Is There a Role for Real-time Imagery for Verification Purposes?

Characteristics and Constraints

Satellites can "stare" at selected site for about 60–80 seconds at a time

Revisit time for an arbitrary point on earth on the order of 1–3 times per day
(assuming appropriate satellite constellation)

Several applications (going beyond standard satellite imagery) imaginable

Preparations for a nuclear test; shipping activities; plumes from operating reactor

Challenges

Costs: Will international organizations (e.g. IAEA/CTBTO) be able to afford such a tool?

Countermeasures: How relevant and effective?

Example 2

New Media and Crowdsourcing

The 2009 DARPA Red Balloon Challenge

(The Classic Example; sponsored by the Defense Advanced Research Projects Agency)

December 2009, ten numbered eight-foot weather balloons
were deployed at public locations across the continental United States

Challenge: Find and submit the coordinates of all ten balloons as quickly as possible

Reward: $40,000 – Winning team identified all locations in just under 9 hours

"Arms Control in the Information Age"

"Today, any event, anywhere on the planet, could be broadcast globally in seconds. That means it is harder to hide things. When it is harder to hide things, it is easier to be caught. The neighborhood gaze is a powerful tool, and it can help us make sure that countries are following the rules of arms control treaties and agreements."

Remarks by Rose Gottemoeller
Under Secretary for Arms Control and International Security
Moscow State Institute of International Relations (MGIMO)
Moscow, Russia, March 30, 2012

https://geneva.usmission.gov/2012/04/02/rose-gottemoeller-arms-control-in-the-information-age/

“Inspection By the People”

The idea goes back to the late 1950s

“The [arms control or disarmament] treaty could make it a duty of each citizen with knowledge of any treaty violation to report it to the international inspectorate. Failure to report could be made punishable.”

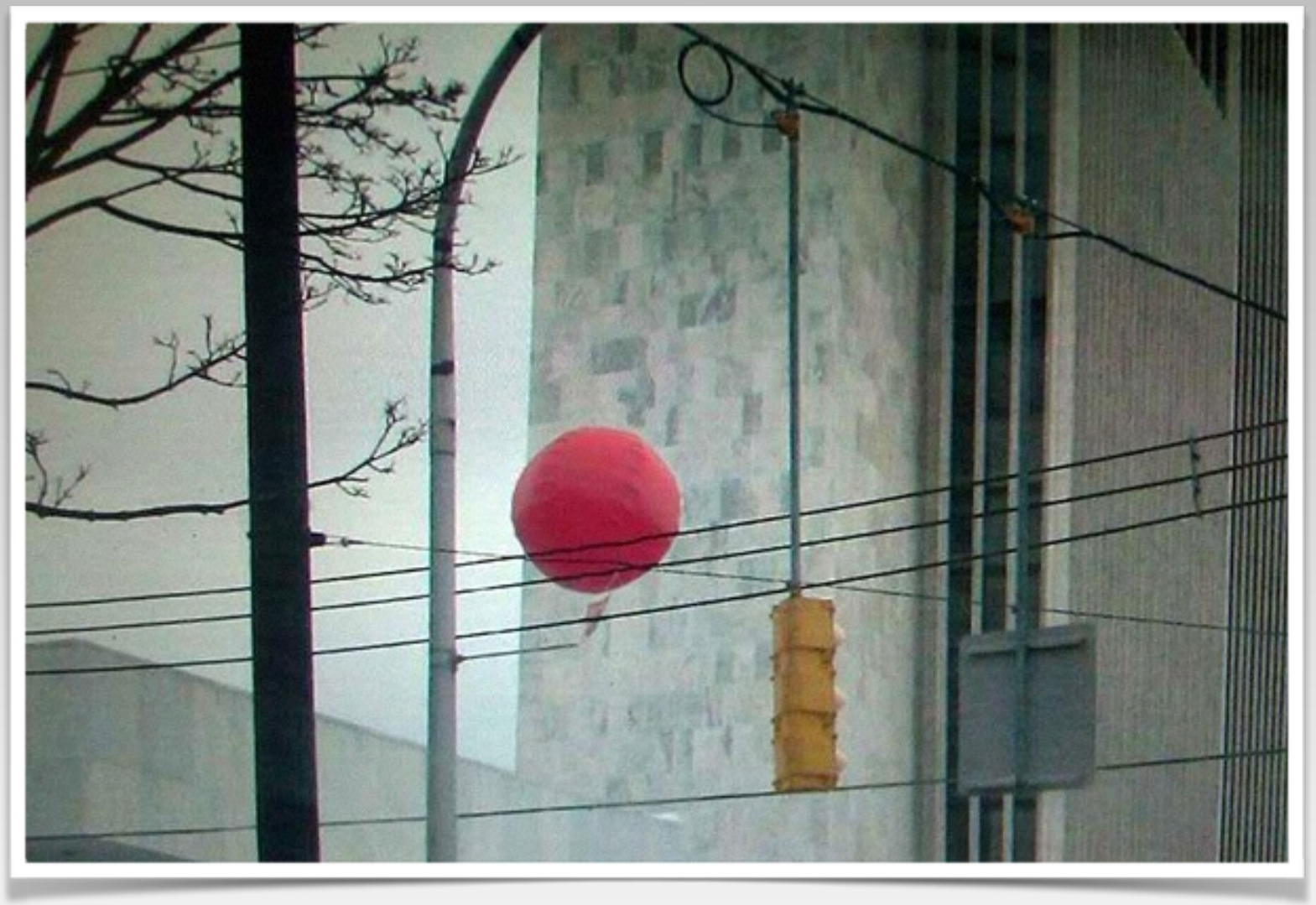
Jerome B. Wiesner, ”Inspection for Disarmament”
Chapter 4 in *Arms Control: Issues for the Public*
Prentice-Hall, Englewood Cliffs, NJ, 1961

What is different today compared to the 1950s/1960s … or the 2000s

(Almost) everything/everyone is connected, ubiquitous sensors
Reach and speed of (digital) networks; possibility of two-way communications

World population online: ~16% in 2005, ~30% in 2010, ~40% in 2013/2014
Estimate for the end of this decade: 6 billion (~75%) online, 30 billion devices connected to internet

Sabotage is Often Easy and Effective



Fabricated picture posted during the challenge showing balloon in Albany, NY, www.twitpic.com/s9kun

J. C. Tang et al., "Reflecting on the DARPA Red Balloon Challenge, *Communications of the ACM*, 54 (4), April 2011, pp. 78–85

“Old School Crowdsourcing”

THE FBI FEDERAL BUREAU OF INVESTIGATION

REPORT THREATS • A-Z INDEX • SITE MAP

Search Site SEARCH

CONTACT US | ABOUT US | MOST WANTED | NEWS | STATS & SERVICES | SCAMS & SAFETY | JOBS | FUN & GAMES

Wanted by the FBI

Select Language | Get FBI Updates

Home • Most Wanted • Ten Most Wanted

Ten Most Wanted

The FBI is offering rewards for information leading to the apprehension of the Ten Most Wanted Fugitives. Select the images of suspects to display more information.

Facts on the Program | Historical Photos of Each Top Tenner | 60th Anniversary Booklet


ROBERT WILLIAM FISHER


WILLIAM BRADFORD BISHOP, JR.


JASON DEREK BROWN


ALEXIS FLORES


FIDEL URBINA


GLEN STEWART GODWIN


EDUARDO RAVELO


VICTOR MANUEL GERENA


JOSE MANUEL GARCIA GUEVARA


SEMION MOGILEVICH

www.fbi.gov/wanted/topten

Note: Over the decades, more than 90% of “Most Wanteds” captured, but less than 30% as a result of direct public cooperation

JASON DEREK BROWN

Unlawful Flight to Avoid Prosecution - First Degree Murder, Armed Robbery

REWARD: The FBI is offering a reward of up to $200,000 for information leading directly to the arrest of Jason Derek Brown.

Jason Derek Brown is wanted for murder and armed robbery in Phoenix, Arizona. During November of 2004, Brown allegedly shot and killed an armored car guard outside a movie theater and then fled with the money.

Brown speaks fluent French and has a Masters Degree in International Business. He is an avid golfer, snowboarder, skier, and dirt biker. Brown enjoys being the center of attention and has been known to frequent nightclubs where he enjoys showing off his high-priced vehicles, boats, and other toys. Brown was a member of The Church of Jesus Christ of Latter-Day Saints, and completed his Mormon mission near Paris, France.

Brown has ties to California, Arizona, and Utah. In the past, he has traveled to France and Mexico. Additionally, he may be in the possession of a Glock 9mm and a .45 caliber handgun.

SUMMARY
SCARS & MARKS
ALIASES
DESCRIPTION
MORE PHOTOS

GET POSTER
EN FRANÇAIS
SUBMIT A TIP

Is There a Role for Crowdsourcing for Verification Purposes?

Successful precedents for emergency response, humanitarian relief, disease control
BUT deception efforts and sabotage are largely irrelevant in these cases

Experience so far with more relevant cases is mixed (false reports typically dominate)

Example: Red Balloon Challenge

MIT team recruited 5,000 participants, 200 submissions, fewer than 40 accurate

Validation of crowdsourced data is (very) costly

Encouraging the crowd to help you … and then keeping the crowd interested

V. Naroditskiy, I. Rahwan, M. Cebrian, N. R. Jennings, "Verification in Referral-Based Crowdsourcing," *PLOS ONE*, 7 (10), October 2012, 1–7

Wrapping Up

Summary

New Verification Technologies for Arms Control and Disarmament

Requirements for Existing or Next-generation Arms Control Treaties

Technology gaps for CTBT/FMCT verification small

BUT: Nuclear disarmament verification requires new approaches and techniques

Important opportunities to initiate new development and demonstration projects

Nuclear Warhead Authentication and Verified Dismantlement

Develop and demonstrate practical inspection systems
Demonstrate viability of cooperation between nuclear and non-nuclear weapon states

Nuclear Archaeology

Agree on most important types of operating records and infrastructure to be preserved
Develop and demonstrate the required forensic techniques