CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

# *Fissile Material Restrictions in Nuclear Weapon States: Treaties and Transparency*

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PROLIFERATION PREVENTION PROGRAM

# Starting point of this workshop

- FM(C)T has languished for decades
  - Impasse at the Conference on Disarmament
  - But, production of fissile material for weapons halted long ago by 5 NPT nuclear weapon states
  - Significant increases in production by India, Pakistan and North Korea – non-NPT nuclear weapon states.
- Three developments suggest it might be time to take another look at FM(C)T and approaches to it.
  - Nuclear Security Summits (2010, 2012, 2014, 2016) have raised awareness of risks of HEU/Pu stockpiles, focused on HEU, but not achieved much on Pu and certainly not with respect to military stockpiles
  - NPT Revcons have called for increased transparency
  - Iran Deal (JCPOA) suggests not enough to limit ENR, but also stockpiles

# Some alternative angles

- Fissile Material Control Initiative-like effort
  - Voluntary efforts on stockpile issues
- Approach through fuel cycle limits
  - “ban” on national enrichment and reprocessing
  - limit uranium enrichment globally to 6%
  - limit spent fuel reprocessing
  - declare fissile material stocks

# Structure of the workshop

- Covering some old ground
  - FMCT history, process
  - Status of current efforts
  - Political and technical challenges
- Can we be creatively disruptive?
  - Is the disarmament/nonproliferation framework too confining?
  - Can we get beyond the stocks/no-stocks stumbling block?
  - Are there fuel-cycle related approaches we might consider outside of a treaty framework that may now make sense?

# Ground rules

- Speakers vs. participants
  - Somewhat artificial divide in a brainstorming effort
- Best outcome
  - Future collaboration among participants
  - Injection/infection of new ideas
  - Cross-fertilization between NGO/government
- Chatham-House rules
  - In this case, better to ask permission (to cite) than forgiveness

# “The FMCT and the CD: An Abusive Relationship”

Remarks by Paul Meyer at CSIS workshop, June 27, 2016, Washington D.C.

One has to go back over a generation to appreciate the manner in which the Conference on Disarmament (CD) has first embraced and then spurned a treaty to ban the production of fissile material for nuclear weapons. At the instigation of the UN General Assembly the CD agreed in 1993 to take on the task of negotiating such a treaty. The development of a mandate for the Ad Hoc Committee in question was entrusted to a Canadian Ambassador, the late Gerald Shannon, who after a year of consultation was able to put before the CD in March 1995 a report containing the sought after mandate. It was an exercise in “constructive ambiguity” that recognized the continuing differences amongst CD members over the scope of the treaty, but finessed this by affirming the right of any delegation to raise this or any issue of concern during the negotiation itself.

This mandate formally contained in CD document 1299 is familiarly referred to as the Shannon mandate. At its core is the direction to negotiate “a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices”. The CD adopted the Shannon mandate (in one of its rare decisions given its strict consensus procedures) and it was actually operationalized briefly in the summer of 1998 via a dedicated AHC. This two-week wonder of official activity in August however was soon terminated never to be re-instated. The fizzban treaty like all of the so-called four core issues of the CD fell victim to the inability of the 65 member Conference to agree upon a Program of Work. Thus no subsidiary bodies have been established to work on the fizzban or anything else on the CD’s agenda and this state of paralysis has continued for twenty years.

Yes the fizzban is occasionally referenced in statements made in the weekly plenary sessions of the CD when it is in session. Yes there have been a dozen or so working papers related to the fizzban submitted by a handful of CD members over the intervening years. And there have been a few days of “informal discussions” of a fizzban presided over by a CD ambassador acting in his/her personal capacity. The most recent documented account was prepared by German Ambassador Michael Biontino regarding two informal meetings held in June 2014. The fact remains however that no official work on a fizzban has been undertaken by the CD since the stillborn session of August 1998.

This prolonged neglect of the fizzban occurs despite the sustained support for commencing negotiations on it regularly expressed by the international community. Last year the UN General Assembly adopted the annual resolution on the fizzban that called for the CD to begin its negotiation. The resolution was passed with 179 positive votes and only one opposing vote (that of Pakistan). The fizzban is routinely endorsed as an objective and within the NPT context has long been agreed as a top priority.

Given this widely supported priority status and in light of the CD's protracted deadlock, a casual observer of the diplomatic arena might well ask why hasn't the fizzban been entrusted to another multilateral forum for its negotiation? Like the dominant partner in an abusive relationship the CD doesn't want to release its hold on a fizzban negotiation even while it continues year after year to neglect to do anything about it. The only thing more shocking than this display of dysfunctionality has been the willingness of leading states to abet it. Thus one has had the ritualistic repetition by the Non Aligned Movement of its willingness to begin negotiation of a fizzban, but only in the CD. Leading Western states frankly are no better. When G7 Foreign Ministers met this April in Hiroshima their communiqué reference to the fizzban read as follows: "As a priority, we call upon the Conference on Disarmament to immediately begin negotiations on a treaty banning the production of fissile material for use in nuclear weapons…" Given that this same Conference has been moribund for twenty years, for G7 Foreign Ministers to assign a key negotiation to it seems the height of folly or cynicism or both.

I found it especially disappointing that Canada's Foreign Minister, Stéphane Dion, was one of the seven foreign ministers having recourse to such stale and discredited formulations on the fizzban. After all he (and the new government of Prime Minister Justin Trudeau) has designated the fizzban as a priority for Canada. Dion has described the fizzban as "a realistic, achievable step and one that Canada believes must move forward without further delay". Since the days of Ambassaddor Shannon Canada has historically taken a leadership role on the fizzban. This sense of responsibility for realizing a fizzban motivated the ingenious Canadian-led initiative in 2012 to establish a UN Group of Governmental Experts (GGE) via UNGA authorization to study the substantive issues raised by the envisaged treaty. The subsequent report of this GGE agreed to by consensus and issued in May 2015 (A/70/81) is one of the few tangible achievements that the international community can refer to on the FMCT file. Pavel Podvig will address the GGE and its implications, but I will only flag here that this progress came about only because states were prepared to use the authorizing power of the General Assembly and thus escape the dead hand of the CD.

Elissa Golberg, the Canadian chair of the GGE in her forward to the report makes it clear that negotiation is the intended goal of the collective effort represented by the GGE: "We can only hope that the renewed interest and momentum generated by the work of the Group….will translate into action and the commencement of negotiations without further delay".

It will take more than heart-felt hopes to overcome the impasse the fizzban faces. It requires a display of leadership to liberate the treaty from the prison of the CD and make it the subject of a UNGA-mandated negotiation that it is not vulnerable to a veto. In recent years Pakistan has been most adamant in using the veto-power inherent in the CD's consensus-based decision making to deny any work proceeding on this file, although no doubt other CD members are quietly supportive of Pakistan's sabotage from the shadows.

Pakistan has proclaimed repeatedly (cf. Minister of State for Foreign Affairs Syed Fatemi's May 17 address at the CD) that a treaty that did not address "asymmetries in fissile material stocks would adversely affect Pakistan's vital security interests" and is not acceptable. Pakistan has also decided to reject the Shannon mandate and its provisions to raise scope issues as insufficient to protect Pakistan's security interests as in its opinion such a mandate fails to provide for the negotiation of "a treaty that genuinely advances nuclear disarmament and contributes to regional and international stability and security" (CD/2036 August 2015).

Although the US has at times signaled that its patience was coming to an end with regard to the CD and a fizzban it has not yet supported non-CD options for a negotiation. At the start of this year at the CD the US did seem to float a more neutral formula than the Shannon mandate for work at the CD on a fizzban, but this gambit has not succeeded in bringing the key opponent, Pakistan, onboard. In a rapid rejection Ambassador Janjua of Pakistan in her January 26 speech inaugurating the 2016 CD session pointedly said the proposal for a revised mandate fails to meet Pakistan's conditions and thus is unacceptable to her delegation.

Given the blocking position adopted by Pakistan and sustained for years despite the frequent if feckless assurances by some P5 states that they will persuade Pakistan to accept negotiations, it is clear that the only solution is to move negotiations outside of the CD. It is worth recalling here that even the French when submitting last spring their draft FMCT treaty refrained from specifying that its negotiation needed to take place at the CD.

As noted earlier Canada is becoming increasingly explicit about the need to get serious on fizzban diplomacy. At last May's NPT Review Conference the Canadian representative in Main Committee I stated: "Canada believes that the CD is the best venue in which to negotiate a treaty, it is not the only one in which to do so. The time has perhaps come for NPT states parties to decide if support for negotiations exclusively in the CD is worth the price of an indefinite delay in starting those negotiations". In my view Ottawa is increasingly convinced that it is not. Moreover Canada was able to convince its partners in the 12 member state Nonproliferation and Disarmament Initiative (NPDI) to indicate that they are also open to non-CD options. The NPDI working paper submitted to the 2015 NPT RevCon in its espousal of commencing FMCT negotiations employed the phrase "preferably in the CD" leaving a clear opening for other forums to take on this task.

Having built up a certain head of steam with the GGE and buoyed by domestic political support for a revitalization of multilateral ACD efforts Canada seems poised to take further steps to initiate negotiations.

The logical next step would be to submit at UNGA a resolution authorizing the commencement of negotiations of a Fizzban in line with the Shannon mandate or some modified version of it. The Open Ended Working Group approach that has been effectively employed for the negotiation of the Arms Trade Treaty could equally be applied to the fizzban objective.

In my expectation by this fall's UNGA, Canada in concert with like-minded states will introduce some new proposal for extracting states from the CD rut and putting into motion a process to commence negotiations of a fizzban. I would suggest that civil society and concerned think tanks be supportive of such efforts. If state and non-state actors are serious about commencing negotiation of a fizzban they will need to abandon the charade of pretending that such a treaty negotiation can be conducted in the CD and support productive alternatives.

# China and FM(C)T

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**Presentation for Workshop on Fissile Material Restrictions in Nuclear Weapon States: Treaties and Transparency, Center for Strategic and International Studies, Washington, D.C. 2016, June 27-28, 2016**

# Operating history of China's military fissile-material-production facilities

| Facility | Start up | Shutdown |
|---|---|---|
| Enrichment plants | | |
| Lanzhou Gaseous Diffusion Plant | 1964 | Stopped HEU production in 1979 |
| Heping Gaseous Diffusion Plant | 1970 | Stopped HEU production in 1987 |
| Plutonium production Reactors | | |
| Jiuquan reactor | 1966 | Closed in 1987 |
| Guangyuan reactor | 1973 | Closed in 1987 |
| Reprocessing facilities | | |
| Jiuquan military pilot plant | 1968 | Closed down in early 1970s |
| Jiuquan reprocessing plant | 1970 | closed around 1987 |
| Guangyuan reprocessing plant | 1976 | closed around 1987 |

# Jiuquan Plutonium Production Complex

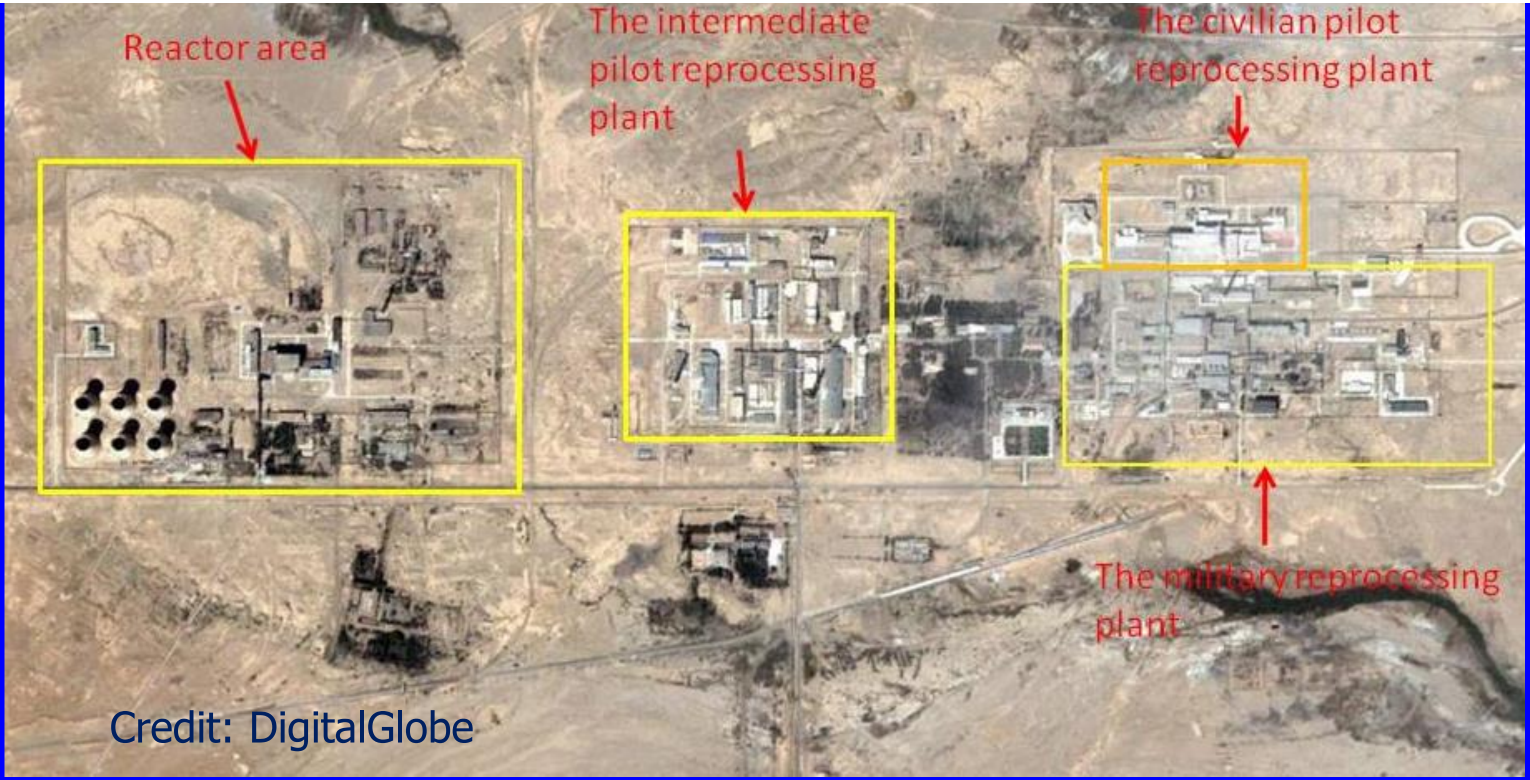
**--1978 "military to civilian conversion" policy**
**--1984 began work on reactor conversion to dual use**
**--Aug.1987 the government required "closed reactor and reprocessing"**
**--1990 began decommissioning**

**Collocated site for:**

**--the processing of plutonium and HEU produced in the past into metal,**
**--the fabrication of weapons components; final assembly of weapons.**
**--civilian pilot plant**

**Concerned about on-site sampling?**

**Some sensitive information, e.g., chemical composition, etc.**



# The Guangyuan  Plutonium Complex

--Under  “military to civilian conversion” policy, mid-1980s worked on reactor conversion to dual use
--In 1987 the government required cessation of Pu production;
--since 1990, decommissioning.

Collocated site for:
-- the processing of plutonium and HEU produced in the past into metal
-- the fabrication of weapons components;
--the final assembly of weapons.

Concerned on-site sampling ?
Some sensitive information, e.g., chemical composition,  etc.

# Civilian reprocessing programs

**In the mid-1980s, China selected a closed fuel cycle strategy to reprocess spent fuel and has recently sped up development of this strategy.**

## The reprocessing pilot plant

**--Capacity: 50 tHM/year; Jiuquan nuclear complex, Gansu;**

**--Project approved July 1986; construction commenced July 1997;**

**--Successful hot test Dec 21, 2010, operating about 10 days, producing 13.8kg Pu. Later: 25.4 kg**

**--problem: MUF ; high waste volume;**

**--Capital cost : about 3.2 billion RMB in 2014; several times more than earlier estimates.**

**--Long delay: from projected approval to hot test =14 year, then operating only 10 days.**

**--Operation resumed around early 2016.**

## 200 tHM/yr reprocessing plant

-- approved July 2015, site preparation at Jinta, Gansu province.

--operational 2020?

## 800 tHM/yr reprocessing plant

--Since 2007 negotiation with AREVA – disputes over price,
--Finished first stage (technical) and second stage (business) since 2015
-- CNNC plans to start construction 2020

## Limiting SF reprocessing?

--Submits annual INFCIR/549 report of civilian plutonium
--concerned about large Japanese Pu stock, China may be interested.
--But the collocated pilot plant at plant 404 could affect China's willingness (if verification needed).

## The pilot MOX fuel fabrication facility (0.5 tons/year) at plant 404

--built near the pilot reprocessing plant, its purpose is to supply fuel for China's Experimental Fast Reactor.

--loading of CEFR with MOX fuel is expected before 2020. Several research projects about pellets, cladding, rod and subassembly were approved. The testing rods would be put into CEFR for irradiation before 2017.

Source: CIAE

# China's fast neutron reactor projects

## China's experimental fast reactor

--Construction started May 2000
--Completed in July 2010
--Design capacity: 25 Mwe
--Located: CIAE, Beijing

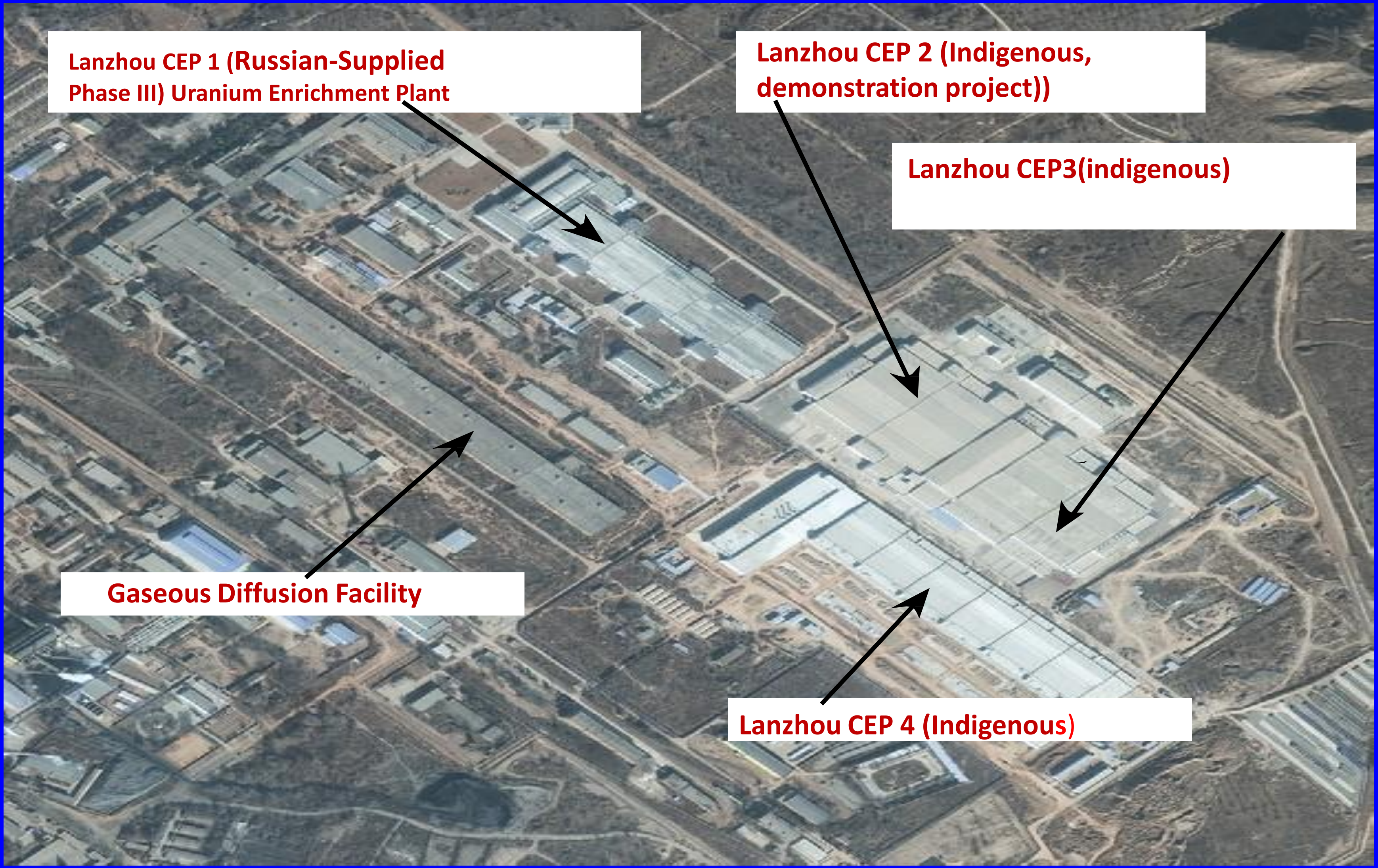
--Operations:
- ✓ 1st criticality 7/2010, 40% power;
- ✓ 26 hours in 2011,
- ✓ no operation 2012 &13;
- ✓ 72 hours Dec. 2014 (100% power)
- ✓ since then for R&D

## CFR-600 demonstration fast reactor
--design power: 600 MWe
--location: Xiapu, Fujian province
--Dec. 2015, Concept design;
--by end 2016, preliminary design
--to start construction in 2017
--commission in 2023.

## Commercial fast reactor
--a 1000 MWe CFR-1000 in 2030s.

## Others
--to buy Russian BN-800?

# Lanzhou Uranium Enrichment Plant




**Satellite image from 18 January 2015**
**Coordinates: $36^{0}$08′53.30″ N/$103^{0}$31′24.49″ E). Credit: DigitalGlobe**

# Lanzhou facilities

| Project | Capacity (million SWU/year) | Comments |
|---|---|---|
| Lanzhou GDP | 0.2 (pre-1979), 0.3 (post-1979) | Began operation in 1964; stopped HEU production in 1979; Closed in 2000. |
| Lanzhou CEP 1 (Russia-supplied phase III) | 0.5 | Began operation in 2001. |
| Lanzhou CEP2 (demonstration project, domestic) | 0.5 | On July 4,2008 started construction; began operation in 2010. |
| Lanzhou CEP3 (domestic) | 0.5 | Construction almost finished in 2010. Began operation in 2013. |
| Lanzhou CEP4 (domestic): Phase I , II | 0.6+0.6 | Phase I: Began construction in 2013. Trial tests in April 2016. Phase II: significantly delayed? |

# Plant 814: Dual/military use

**Plant 814: Heping GDP at Jinkouhe**

--25 June 1970—1987 HEU for weapons.

--capacity: around 0.23 million SWY /year

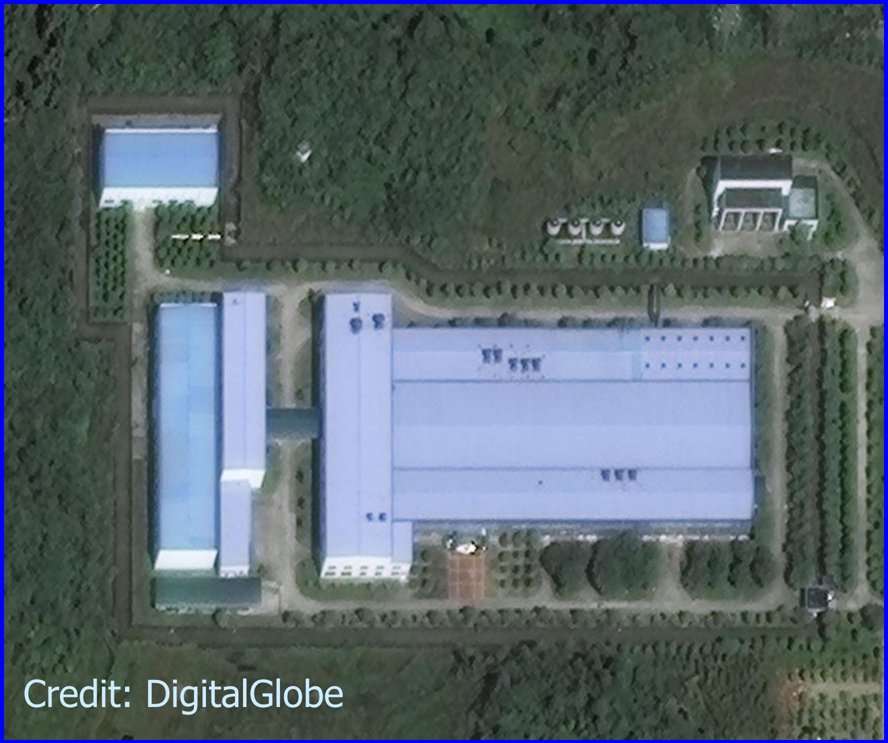
--since 1987 continues operation for non-weapons purpose.

**Plant 814 : Dual/military CEP near Emeishan ?**

----In 2007 started operation

--capacity around 0.25 million SWU/year.

--dual/military CEP? Eg., isolated, secured location, etc.

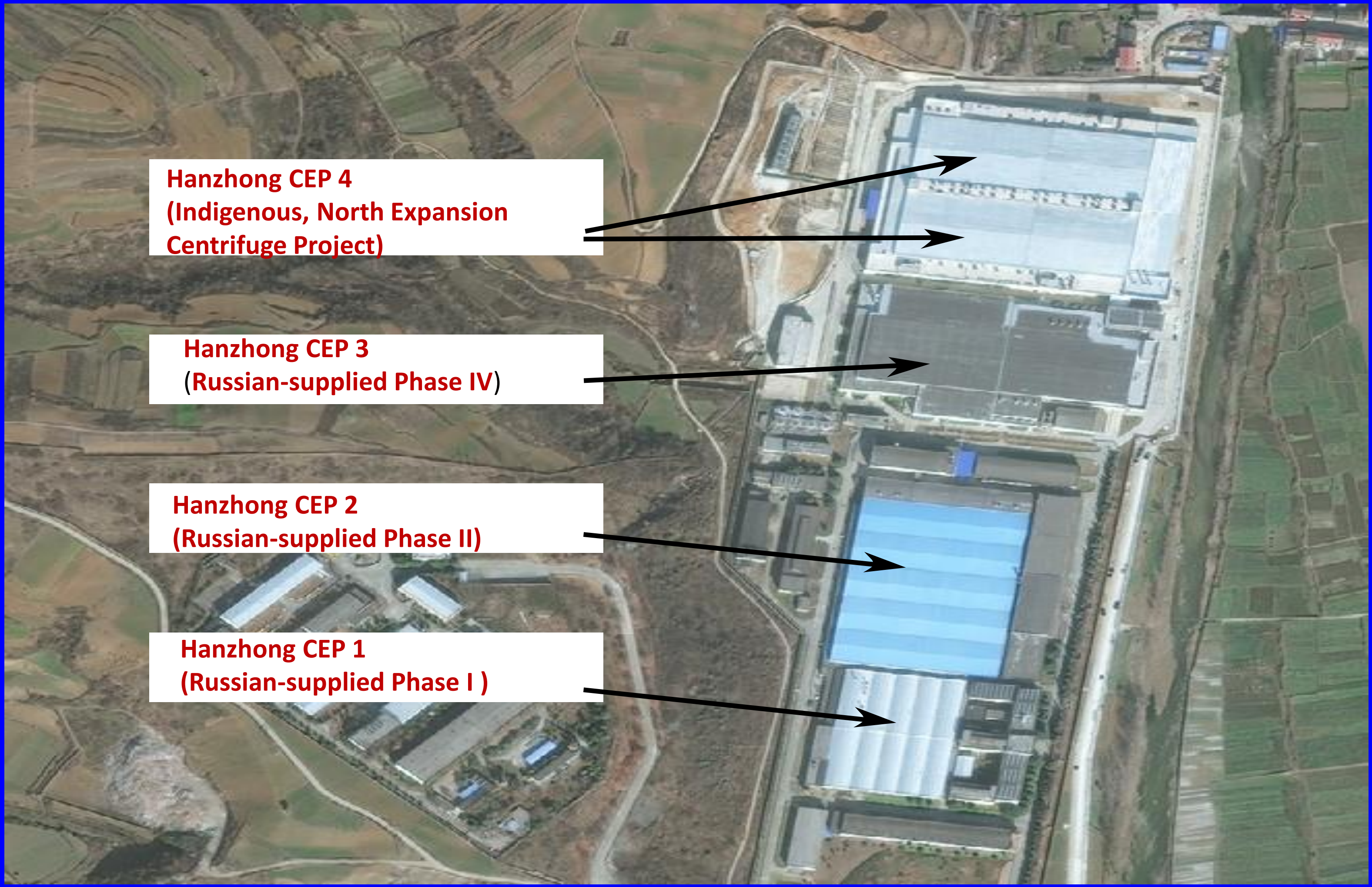
# Plant 814 : Commercial CEPs near Emeishan city

--**CEP1**: local government planned to start the project in 2008
--Construction around 2011, and operation around 2013
---around 0.8 million SWU/year

--**CEP2**: recently completed construction, around 0.8 million SWU/year


Satellite image from October 5, 2014 (Coordinates: 29°40’38.33’’ N/103°32’04.65’’ E). The image shows CEP2 under construction. Source: DigitalGlobe

# Hanzhong  Uranium Enrichment Plant (Plant405)




Satellite image from January 27, 2013
Coordinates: 33°15′47.70″ N/107°25′52.74″ E. Source: DigitalGlobe.

# Hanzhong centrifuge facilities

| Project | Capacity (million SWU/year) | Comments |
|---|---|---|
| Hanzhong CEP1 (Russian-supplied phase I) | 0.2 | Began operation in February 1997, under IAEA Safeguards |
| Hanzhong CEP2 (Russian-supplied phase II) | 0.3 | Began operation in January 1999, under IAEA Safeguards |
| Hanzhong CEP 3 (Russian-supplied phase IV) | 0.5 | Construction started in 2009; conducted trials in 2011. Began normal operation in 2013. |
| Hanzhong CEP 4 (domestic) Phase I &II | 1.2 (0.6+0.6) | Construction permit on January 4, 2012. Phase I:. Began operation in 2014. Phase II: installment and adjustment |

- **Chinese non-weapon uses of HEU are very limited**
- **Nuclear-power submarines fueled with LEU (from first generation to current)**
- **Only a few research reactors with HEU**

  **--most converted to LEU fuels.**

  **--CEFR: HEU to be replaced by MOX before 2020.**

  **--Zero Power Fast Critical Reactor (NPIC, Chengdu)**
- **Tritium production reactor**

  **--Produced by Jiuquan and Guangyuan reactors in the past. Should use power reactors?**

## Support HEU phase-out proposals?

**--Xi Jinping addressed at 2016 NSS: "We support all countries in minimizing the use of HEU according to their needs as long as it is economically and technologically viable."**

| Research Reactor | Operator | Characteristics | Status |
|---|---|---|---|
| China Experimental Fast Reactor (CEFR) | China Institute of Atomic Energy (CIAE), Beijing | FBR, 64.4% HEU, 65 MWt/25MWe | Operational Loading MoX before 2020 |
| Zero Power Fast Critical Reactor | Nuclear Power Institute of China (NPIC)， Chengdu, Sichuan | Critical fast, 90%HEU, 0.05 kWt | Operational |
| PPR Pulsing Reactor | NPIC, Chengdu | Pool, 20% HEU, 1 MWt | Operational |
| MNSR-SZ | Shenzhen University, Guangdong | Tank in pool, LW, 90% HEU, 30 kWt | Operational (converting) |
| MNSR-IAE | CIAE, Beijng | Tank in pool, LW, 90% HEU, 27 kWt | Operational (converted, March2016) |
| HFETR | NPIC, Chengdu | Tank , LW, 90% HEU, 125 MWt | Converted in 2007, Operational |
| MJTR | NPIC, Chengdu | Pool, LW, 90% HEU, 5 MWt | Converted in 2007, Operational |
| MNSR-SD | Research Institute of Geological Science, Jinan, Shandong | Tank in pool, LW, 90% HEU, 33 kWt | Shut down |
| MNSR-SH | Shanghai Institute for Measurement and Testing Technology, Shanghai | Tank in pool, LW, 90% HEU, 30 kWt | Shut down in 2007 |
| HFETR Critical Assembly | NPIC, Chengdu | Critical assembly, LW, 90% HEU, 0 KWt | Converted in 2007, reported shut down later |
| Fast Neutron Critical Assembly | CIAE, Beijing | 0 kWt | Shutdown |
| HWRR | CIAE, Beijing | LEU, 15 MWt | Operational |
| SPR | CIAE, Beijing | Pool, LEU, 3.5 MW | Operational |
| China Advanced Research Reactor (CARR) | CIAE, Beijing | Tank in pool, LW, 19.75% LEU, 60 MWt | First Critical in May 2010 |
| NHR-5 | Tsinghua University, Beijing | Heating supply reactor, LEU, 5 MWt | Operational |
| HTR-10 | Tsinghua University, Beijing | High Temperature Gas-Cooled Reactor, coated particle fuels, LEU, 10 MWt | Operational |
| ESR-901 | Tsinghua University, Beijing | Pool, 2-cores, 19.75% LEU, 1 MWt | Critical in 1964, operational |

# China’s policy

- On October 4, 1994, U.S. Secretary of State Christopher and Chinese Foreign Minister Qian issued a joint statement in which they promoted the “earliest possible achievement” of a treaty prohibiting the production of fissile material for use in nuclear weapons.
- Supported Shannon Mandate, 1995
- A linkage with PAROS, around 2000

--- “the Conference on Disarmament in Geneva should not emphasize the importance of only the FMCT negotiations to the neglect of the issues of nuclear disarmament and the prevention of an arms race in outer space, and should, at the minimum, give equal attention to all three issues by carrying out its substantive work in a balanced manner.” --- In 2000 China’s defense white paper

- China agreed to FMCT negotiation without linkage in 2003; however, US proposed an unverified FMCT in 2004, blocked a restart.

## China’s current position

**Such a treaty would be “conducive to preventing nuclear weapons proliferation and promoting nuclear disarmament.” China has advocated negotiations to “conclude at an early date a multilateral, non-discriminatory and internationally and effectively verifiable FMCT, based on a comprehensive and balanced program of work acceptable to all.”**

# China’s position on an FM(C))T negotiation

- Ban “future production,” not including past stocks
- Wants an *verifiable* FMCT
- Prefers to a focus on verification approach
- Less intrusive approach at former military nuclear facilities
- Against abuse of on-site challenge inspection

# China’s major concerns

- **China’s serious concerns on US space weapons and missile defense programs**

- **Could neutralize China’s strategic nuclear deterrent; More freedom to encroach on China’s sovereignty (including Taiwan affair).**
- **Would damage nuclear arms control and disarmament regimes, damage strategic stability and international security.**
- **U.S. missile defense and space weapons plans will affect China’s willingness to participate in an FMCT negotiation.**

**--Although China supports an FMCT negotiations, the reference to ‘‘a comprehensive and balanced program of work acceptable to all’’ could mean a consideration of space weapons issues.**

- **In practice, driven by US missile defense programs, recently China deploys MIRVs.**

## ❑ The past shows China is sensitive to international security environment

- In 1950s, the Korean War and US nuclear threat motivated China to develop its nuclear weapon program, and began to build its first set of nuclear facilities ( Lanzhou GDP and Jiuquan Pu complex).

- Since 1964, given worsening Chinese-Soviet relations, Vietnam war, and US threats, China started construction of "third line" nuclear materials production facilities as "back-up" ( Heping GDP, Fuling Pu complex (project 816)—gave up construction in early 1980s).

- In late 1960s, given border conflicts with Soviet Union and a perception of coming war between two countries, China began a rush construction of the third set of nuclear facilities (Guanyuan Pu complex, Hanzhong enrichment plant—military facility never completed and civilian CEP since 1980s, and Project 827 including a production reactor—once again gave up constructions in early 1980s).

## ❑ China's "military to civilian conversion" is a de facto moratorium on fissile material production

- Since late 1980s, given an improved external security situation (e.g. normalization of diplomatic relations between China and US), Deng Xiaoping judged "no large world wars within next twenty years" (instead of Mao Zedong's "war preparation" strategy). Thus China has pursued "military to civilian conversion" policy, ending construction of nuclear facilities (project 816 and 827); converting or closing all production facilities by 1987.

❖ **The past may suggest international security situation (e.g. US-China strategic security) would affect China's attitude to an FMCT negotiation.**


Fuling plutonium production complex--816 Underground Nuclear Project, started construction in 1967 and ended in 1984 (never finished) based on international security situation. Part of the site was opened as a domestic tourist attraction in 2010.

# *Verification of fissile material restrictions*

Center for Strategic and International Studies
Washington, D.C., 28 June 2016

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# Overview

<u>The fuel cycle</u>

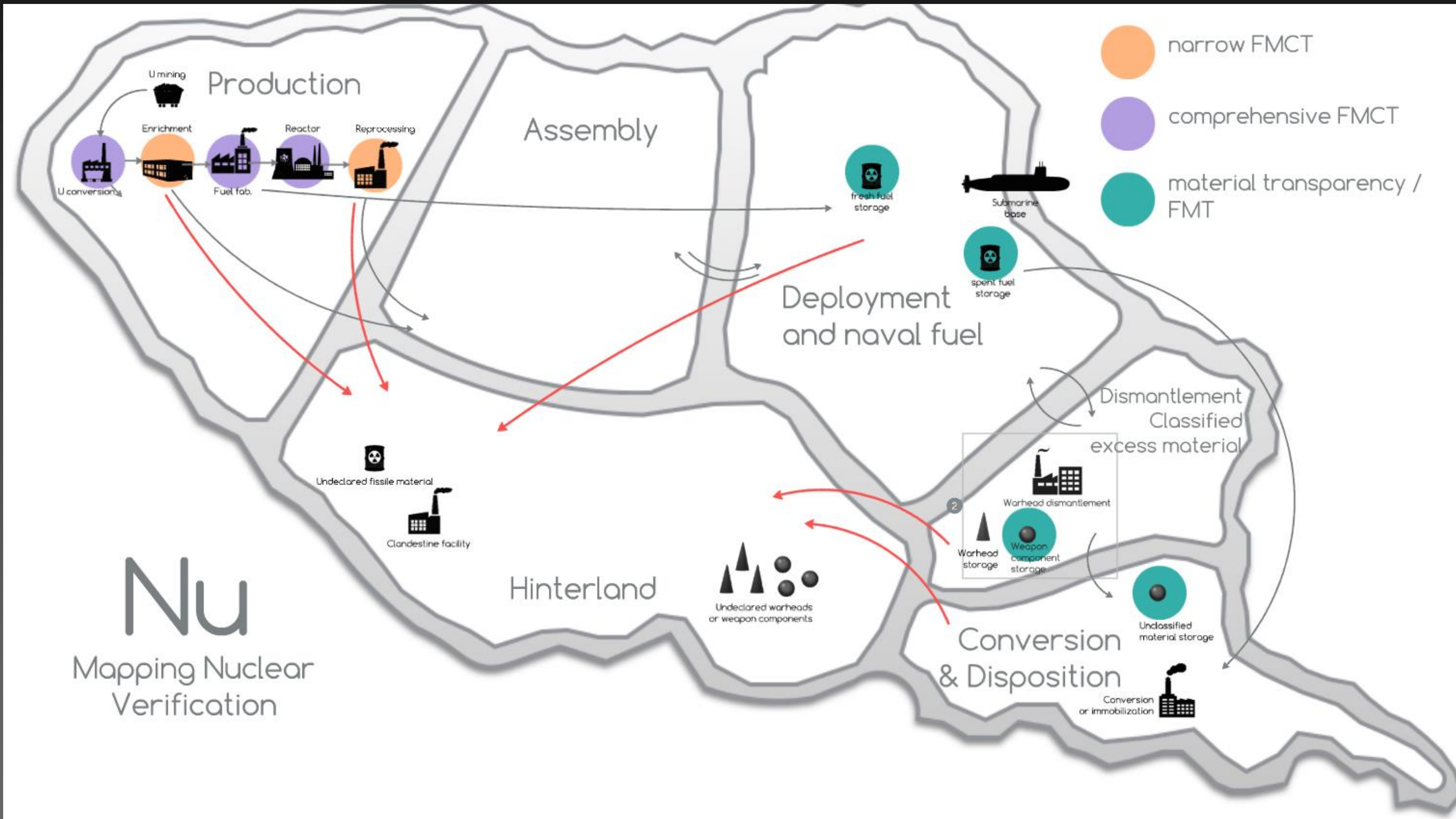
Declared production facilities

Undeclared production facilities

<u>The military material side</u>

Verification scenarios for excess stocks (unclassified/classified) and naval fuel

Undeclared stocks

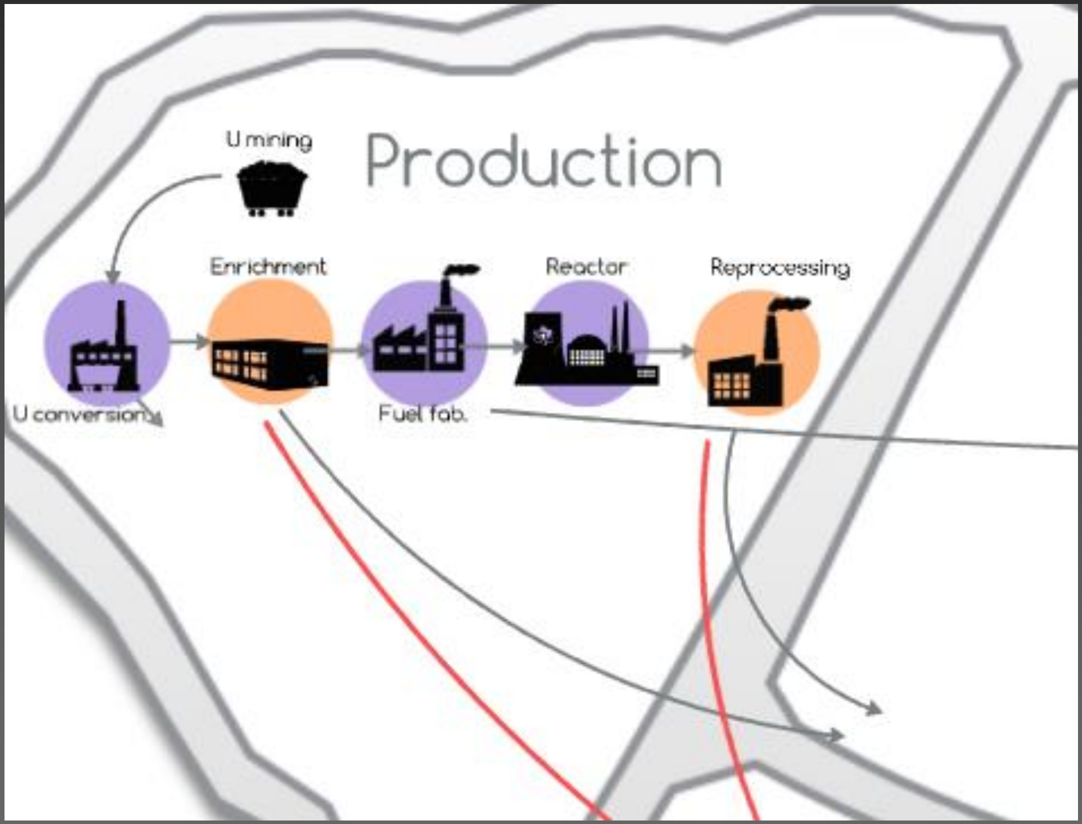


narrow FMCT
comprehensive FMCT
material transparency / FMT
U mining
Production
Enrichment
Reactor
Reprocessing
U conversion
Fuel fab.
Assembly
fresh fuel storage
Submarine base
spent fuel storage
Deployment and naval fuel
Dismantlement
Classified excess material
Warhead dismantlement
Warhead storage
Weapon component storage
Unclassified material storage
Undeclared fissile material
Clandestine facility
Hinterland
Undeclared warheads or weapon components
Conversion & Disposition
Conversion or immobilization
Nu
Mapping Nuclear Verification

# Workshop: Nuclear Verification At Low Numbers

Princeton, December 2015

# *The fuel cycle*



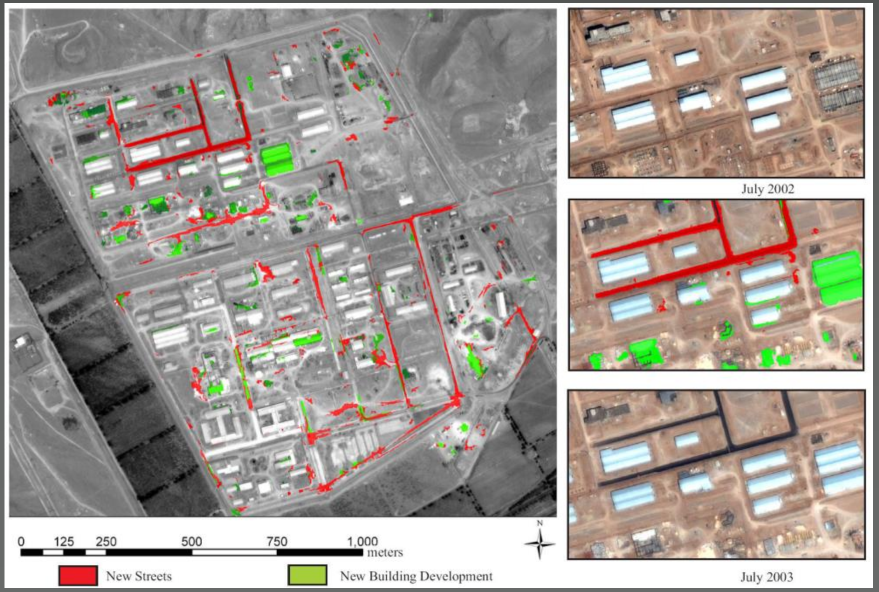

to large extent parallel to IAEA Safeguards

# Declared production facilities (limited FMCT)

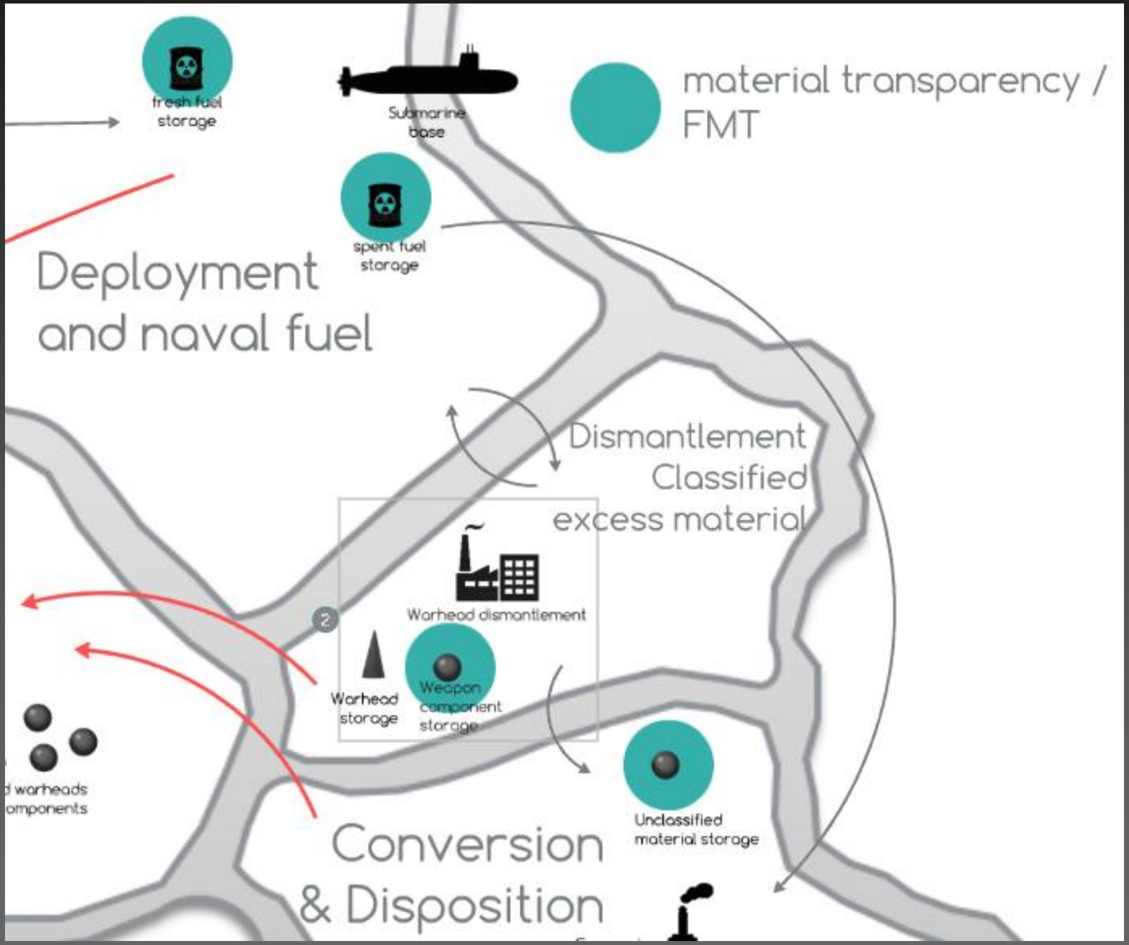
- HEU instead of LEU production
  - Unattended monitoring
  - Swiping
- Diversion of HEU for non-proscribed activities to weapons use
  - Continuity of knowledge, material accountancy
- Diversion of Pu to weapons use
  - Process monitoring, Continuity of knowledge
- Operation of “shutdown” facilities
  - Satellite imagery
  - Environmental signatures
- Capability limits
  - Design Information Verification

# Undeclared production facilities

- comprehensive FMCT (IAEA Safeguards equivalent)
  - Diversion of natural U
  - Diversion of LEU
  - Diversion of spent fuel
- Wide-area environmental sampling
- On-site inspections (short notice, high threshold)
  - Swiping
- Open source information
  - Satellite imagery
  - News and New media
  - Research publications
- Intelligence



# *The military material side*




Under current NWS sensitivity concerns

# Designated excess stocks (unclassified)

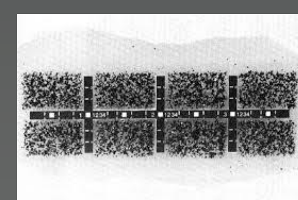
On-site inspections (planned and short notice), remote monitoring

Non-destructive assay (NDA)


*material accountancy: isotopics and fissile mass*

Containment & surveillance

perimeter control

seals & tags

*unique identification, continuity of knowledge*

# Designated excess stocks (unclassified)

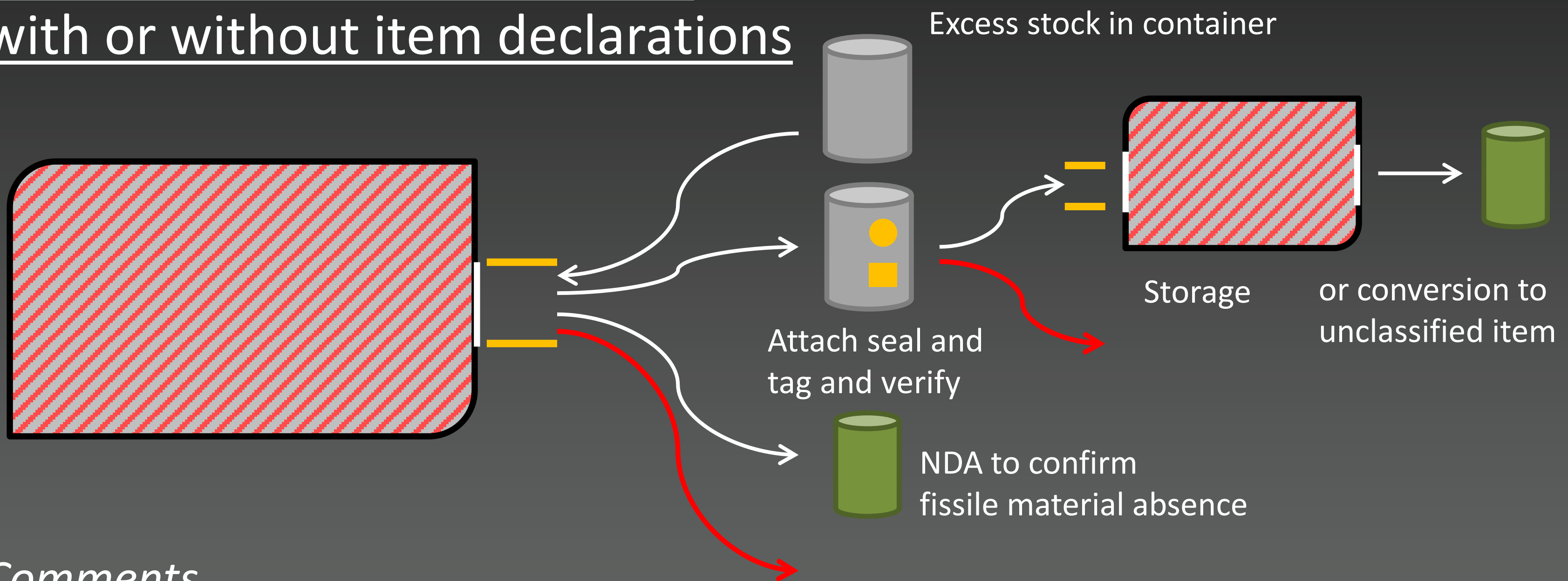
US Voluntary Offer Agreement at K-Area Material Storage (Savannah River):
3 tons military non-pit Pu stored in drums

- Monthly accounting reports
  (incl. container ID, chemical composition, mass and isotopics)
- NDA: Gamma spectrometry and neutron multiplicity counting
- Seals on containers and video surveillance

B. Smith, Y. Ferris, Cost Effective Measures for Meeting International Atomic Energy Agency Requirements in Storage of Surplus Plutonium
Waste Management Conference, Tucson 2/27 – 3/2 2000.

# Design. excess/naval stocks (classified): Detect diversion

Scenario A: Perimeter control with or without item declarations

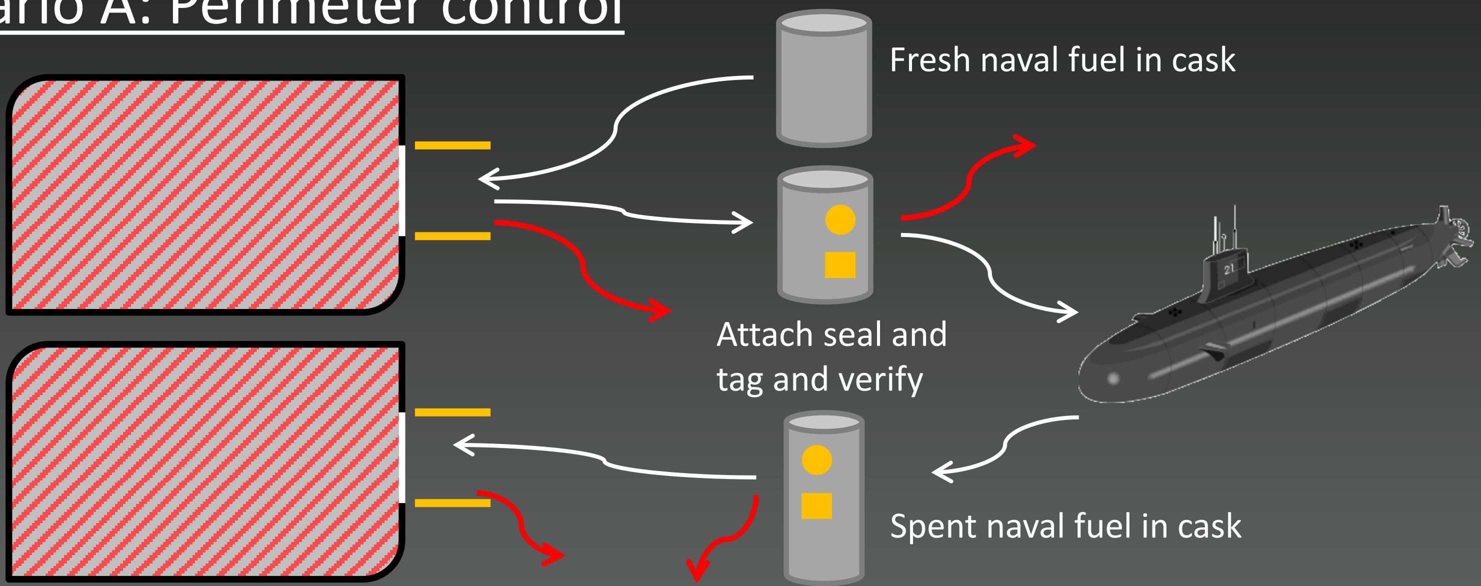



*Comments*

- Requires confidence in the absence of hidden access points
- Requires confidence in portal monitors, seals and tags
- Non-treaty accountable items, that are sensitive ?
  → limitations on NDA

# Design. excess/naval stocks (classified): Detect diversion

Scenario A: Perimeter control



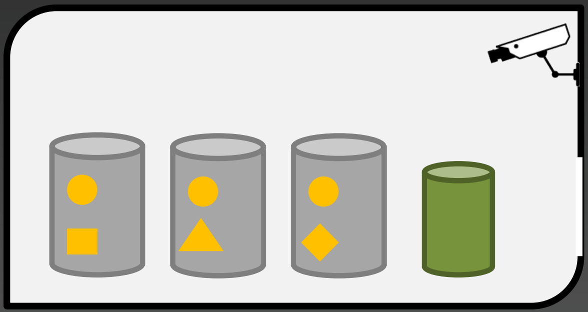

*Comments*

- In order to effectively detect diversion:
  Full continuity of knowledge through naval fuel cycle

S. Philippe, Safeguarding the Military Naval Fuel Cycle, *Journal of Nuclear Materials Management*, Vol. XLII, No.3, 2014, pp 40-52.

# Design. excess/naval stocks (classified): Detect diversion

Scenario B: Verifying item declarations



- Initial verification of inventory, applying seals and tags for *unique identification*
- Some combination of
  - Remote monitoring
  - Regular full Item inventory verification (complex for large designated inventories)
  - Verified transfers between areas (complex for large designated inventories)
  - Item-location-registers continuously updated, short-notice on-site verification at selected sites

*Comments*

- Managed access challenge, in particular for short-notice access requires negotiated protocols for all areas and situations, very hard to solve

# Designated excess stocks (classified): Verify isotopics or weapon origin

<u>Verify that material is of a certain type</u>

- Sensitive information from gamma spectrum or neutron measurements
- Attribute information barrier:
  verify attribute thresholds
  e.g. isotopics or fissile mass
- Template information barrier:
  verify that measured signature corresponds to recorded signature of an authentic item

# Designated excess stocks (classified): Verify isotopics or weapon origin

*Comments*

- Past projects: Trilateral Initiative, US-Russian lab-to-lab cooperation, US-UK cooperation, UK-Norway Initiative, academic research
- Readily usable information barriers do not exist yet
- Major challenge:
  How to have confidence in the correct functionality, absence of hidden features

- US-Russia HEU Purchase Agreement:
  Low-resolution gamma measurements to determine enrichment of shredded Russian HEU
  *without information barrier*

# Design. excess/naval stocks (classified): Verify fissile mass

Verify that a certain amount of material is monitored

- Assume the threshold mass of the attribute method
  → perhaps significant underestimation
- Information barrier releases cumulative mass after multiple measurements
  → not possible if there is one type
- Convert classified material to standard mass items
  - *Other item characteristics remain classified:*
    Use an information barrier
    which only outputs the fissile mass
  - *Item is unclassified*
    Measure directly

# Design. excess/naval stocks (classified): Verify fissile mass

On the conversion to standard masses

Plutonium Management and Disposition Agreement:

- US considers produced oxide unclassified
  (same isotopics as warhead component)
- Russia uses 2 kg Pu spheres and blends with up to 12% other plutonium after oxide conversion to declassify
  - inspect 2 kg Pu spheres with information barrier
  - measure directly after conversion

- If number of converted warhead components is known:
  Add unknown amount of blend stock and include it

P. Rexroth, L. Groves, L. Trost, S. Deland, C.D. Croessmann, An Integrated Systems Approach to the Monitoring and Inspection for the US/Russian Agreement on Management and Disposition of Excess Weapons Plutonium, 43rd INMM Annual Meeting, Orlando, 2002.

# Design. excess/naval stocks (classified): Verify fissile mass

- Sensitivities of naval fuel:
  geometry, cladding, matrix materials
- Perhaps less sensitive: U-235 mass,
  may require information barrier
- Conversion to standard masses:
  Only if fuel is reprocessed

S. Philippe, Safeguarding the Military Naval Fuel Cycle, *Journal of Nuclear Materials Management*, Vol. XLII, No.3, 2014, pp 40-52.

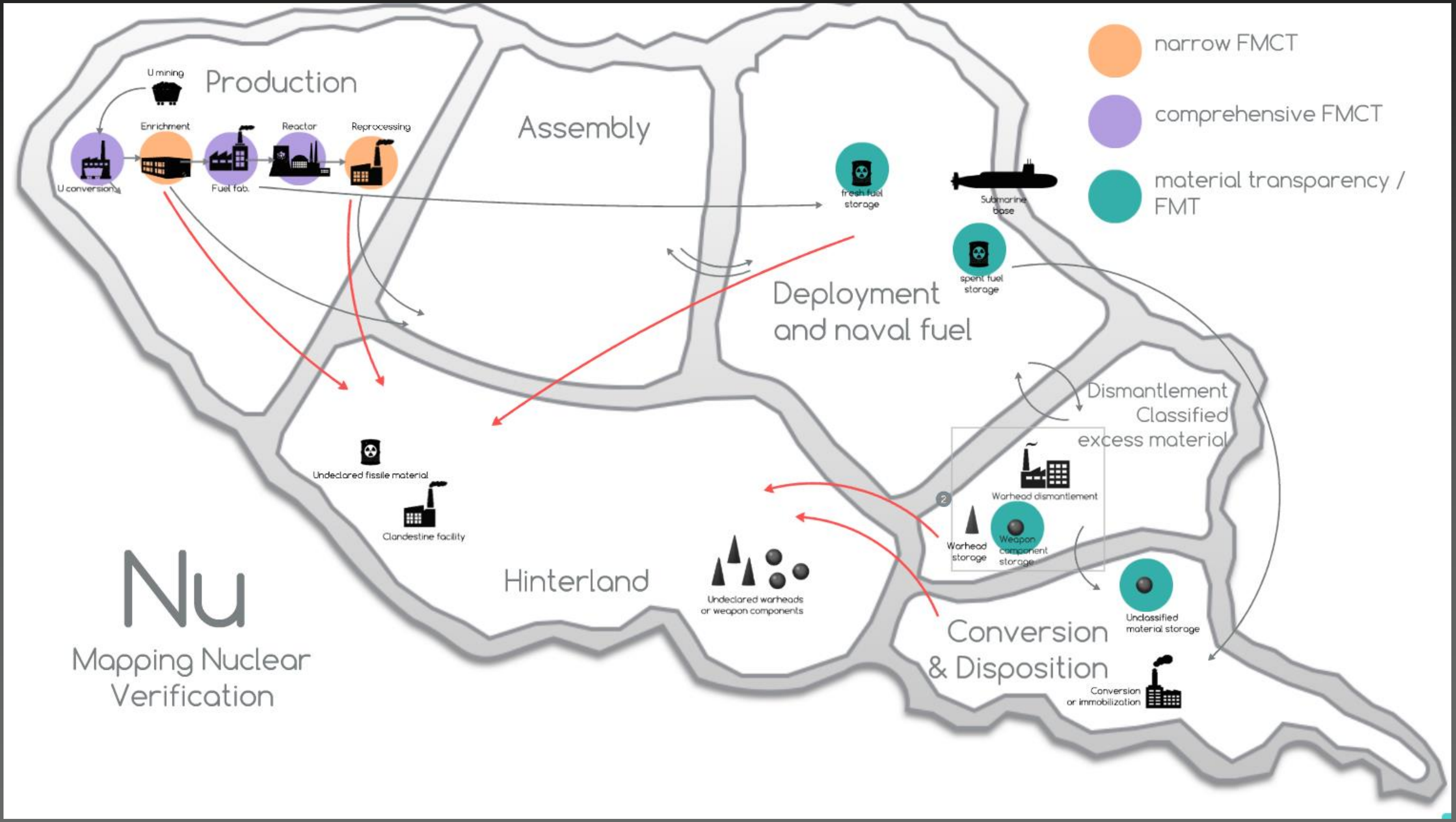
# Undeclared materials

- Open source information, possible signatures ?
  - Satellite imagery
  - News and New media
  - Research publications


- Short-notice inspections
  - How to overcome managed access issue?

- Nuclear archaeology
  - Analysis of trace elements, e.g. in graphite

# Conclusion and recommendations



# Conclusions and recommendations

<u>Fuel cycle and military material verification</u>

Large verification uncertainties remain

Sensitive information protection is a challenge

Significant more R&D necessary

Confidence under current sensitivity concerns very challenging

Cooperative research projects, joint exercises

# Ending production of HEU for *any* purpose

**Frank von Hippel**
Program on Science and Global Security
Princeton University

Workshop on Fissile Material Restrictions in Nuclear Weapon States:
Treaties and Transparency
Center for Strategic and International Studies
28 June 2016

# Outline

Global HEU stockpile has been falling because Russia and the U.S. stopped producing and have been blending down much more excess Cold War HEU to LEU than Pakistan, India, DPRK and (since 2012) Russia have been producing.

But remaining excess Cold War HEU stocks are large

At current rate of consumption, almost no need to produce more for at least 50 years. ("Almost" relates to India's naval use.)

Non-naval HEU use on the way out.

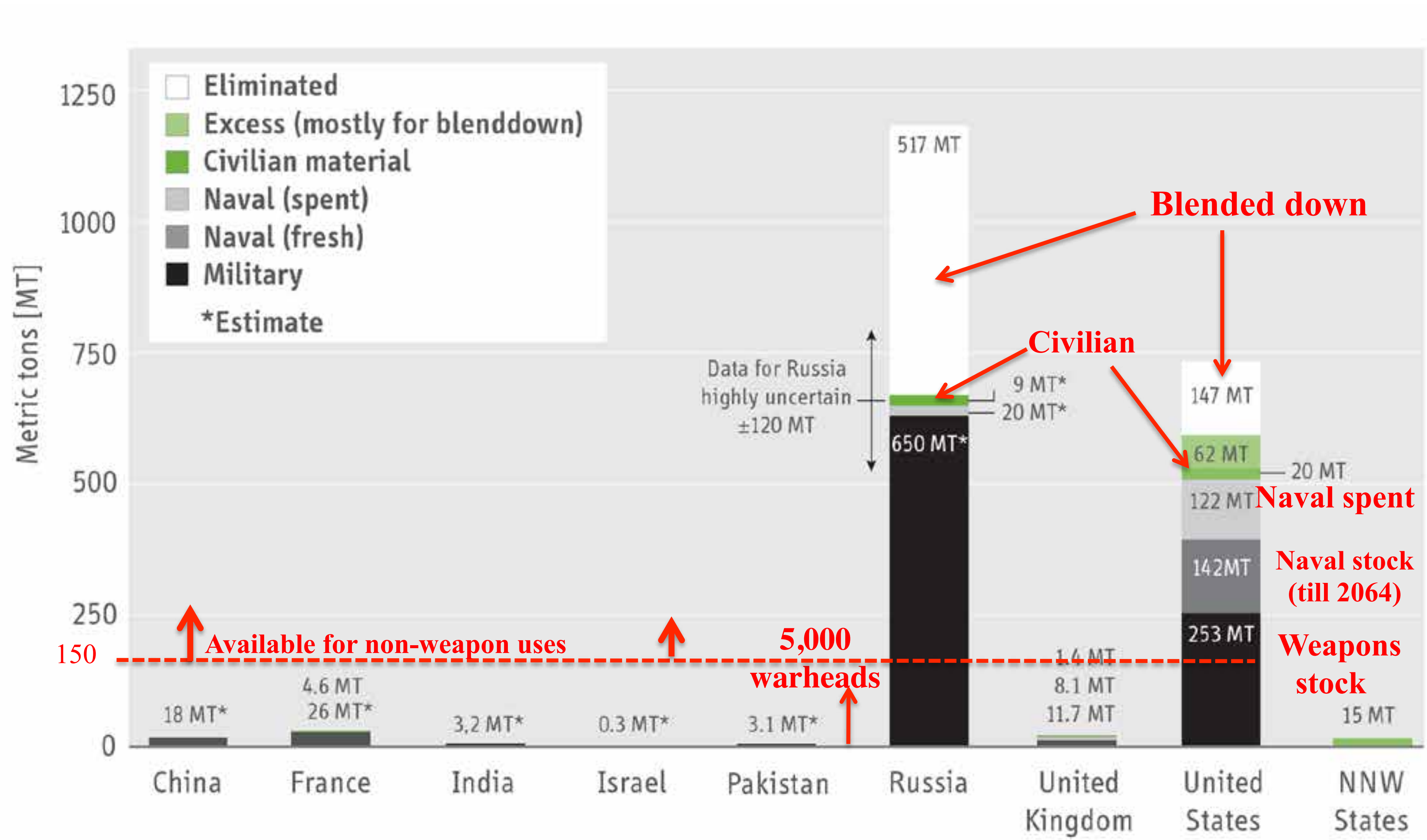
More than enough time to transitioning the HEU-fueled nuclear navies to LEU if a decision is made to do so.

Therefore, if we decided to transition the navies to LEU, we could expand the proposed FMCT to ban HEU production for *any* purpose.

# HEU Stocks, 2015: Huge, mostly Russian and U.S.

Only ~ 300 tons needed for ~10,000 warheads (incl. working stocks)

~700 tons available for other uses (enough for 100 years of current use)



# Non-weapon uses of HEU

| Use | **Estimated annual HEU use** (metric tons wge* per year) |
|---|---|
| Naval-reactor fuel | **4** (2.5 U.S/UK, 1.5 Russia) |
| Isotope-production reactor fuel (Russia) | **1** (until 2023) |
| Breeder-reactor fuel (Russia) | **1** (until 2020-25) |
| Research reactor fuel | **0.7** (being phased out) |
| Medical isotope production targets | **0.04** (being phased out) |
| **Total** | **~ 7 tons/year** |

*wge = weapon-grade equivalent

# U.S. HEU stockpile: More than adequate for 50 years*

| | |
|---|---|
| **Allocated** | |
| For naval fuel | 160→152 tons (enough till 2064) |
| For research reactors & Mo-99 (incl blend-down to 19.75%) | 43 tons (enough till ~2035) |
| | |
| **Requirements for remaining 253 tons** | |
| For 4500 warheads (@25 kg +10% working stocks) | ~123 tons |
| For blend down to 19.75% (2035-2064). (Alternatively, Urenco.) | ~37 tons |
| LEU for tritium-prod. (58 tons/year of 4.9% LEU, 2035-64) | ~90 tons |
| | |
| **Future availability**: HEU from further WH reductions | |

Russia has much more HEU.

U.S. and Russia supply their own and other countries' consumptive HEU requirements with the exception of India's naval reactors.

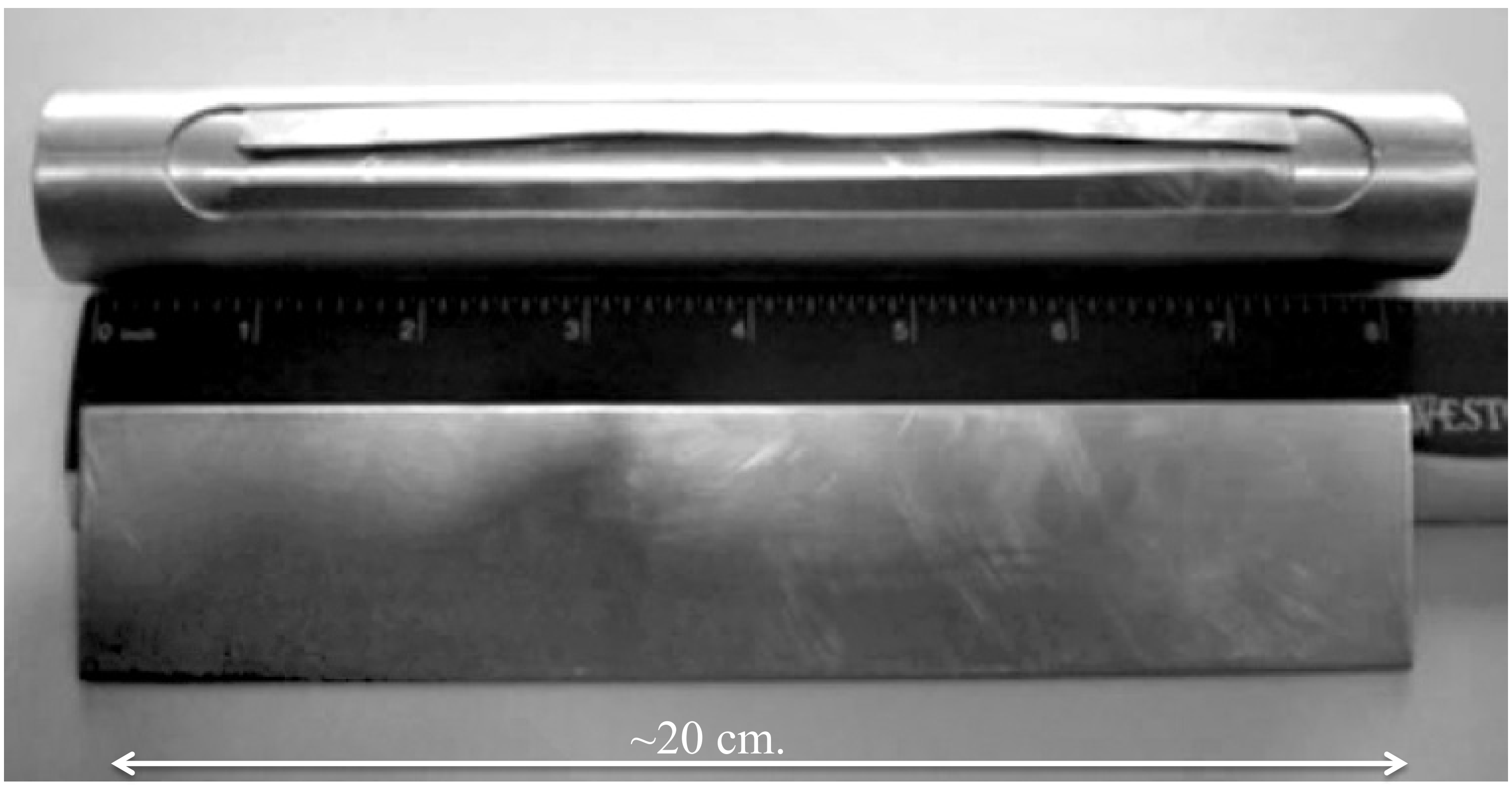
So, except for India, world could live off its HEU stocks for 50 years.

*Difference between these numbers and DOE's in its Report to Congress, *Tritium and Enriched Uranium Plan Through 2060* (2015), is that DOE assumes the blend-down of about 20 tons of unallocated HEU and I assume 127 tons.

# Non-naval HEU consumption on the way out

**Medical radioisotope production shifting rapidly to LEU because of U.S. pressure as primary consumer of Mo-99 and primary supplier of HEU for production "targets".**

Cutaway of nickel-coated LEU foil between two aluminum tubes on top of an old HEU dispersion target.



## Civilian uses of HEU (mostly research-reactor fuel) going down

HEU use in fuel has declined due to retirement (150) and conversion (65) of HEU-fueled research reactors since 1978.

But being replaced by a demand for 19.75% LEU.

## ~ 100 remaining HEU-fueled Research Reactors

***Russia has not given priority to converting its HEU-fueled domestic reactors but has been shutting down some.***

Most HEU-fueled high & low-power reactors can be converted but high-density fuel to convert 5 US high-power reactors and 3 in Europe has been delayed till late 2020s, by which time, most will be retired.

***Outside U.S., little attention thus far to critical and pulsed reactors.***

| | High-power reactors (>30 kWt) | Low-power reactors (≤30 kWt) | Critical and subcritical assemblies | Pulsed reactors | Total |
|---|---|---|---|---|---|
| **Russia** | 14 | 0 | 25 | 14 | **53** |
| **China** | | 2 | 1 | | **3** |
| **EU** | 4 | 2 | 4 | 2 | **12** |
| **USA** | 6 | 0 | 6 | 3 | **15** |
| **Others** | 3 | 8 | 4 | 1 | **16** |
| **Total** | **27** | **12** | **40** | **20** | **99** |

# Russia's tritium-production and breeder reactors

**Tritium-production** (for nuclear weapons)

Russia plans to replace its two tritium-production reactors with one dual-purpose tritium- and electric-power-production reactor in 2023. Will it be LEU fueled?

U.S. has already done this. Savannah River tritium and plutonium-production reactors shut down in 1988. Tritium being produced by TVA Watts Bar nuclear power plant, which is LEU fueled.

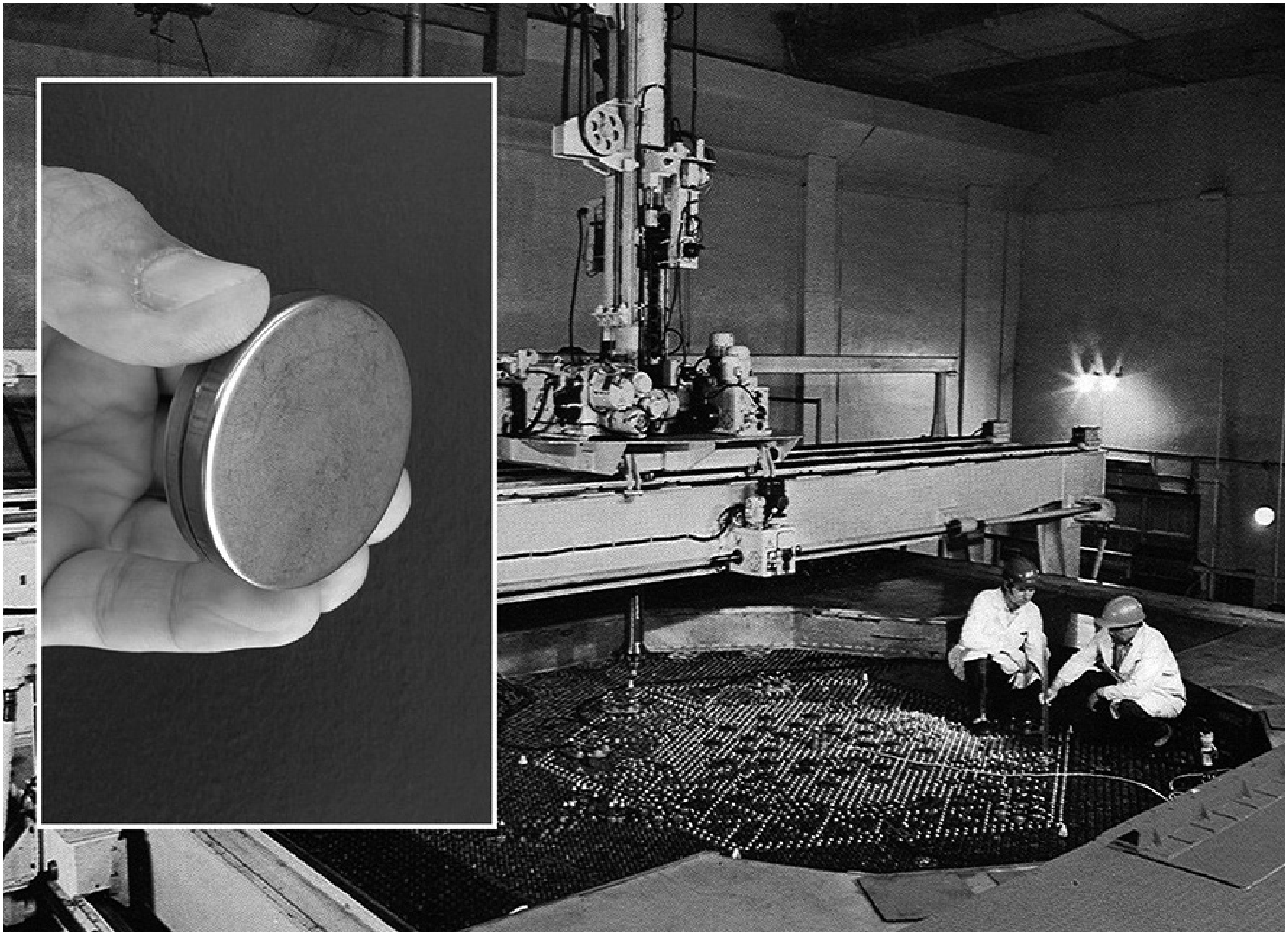
**Breeder reactors**

Until recently, Russia had no capacity to make plutonium fuel and fueled its breeder reactors with 20-30% enriched HEU.

Plan is to continue to fuel Russia's old breeder reactor (BN-600) with HEU until it shuts down (2020-2025?) but to fuel new BN-800 to mixed oxide (MOX, uranium-plutonium) fuel.

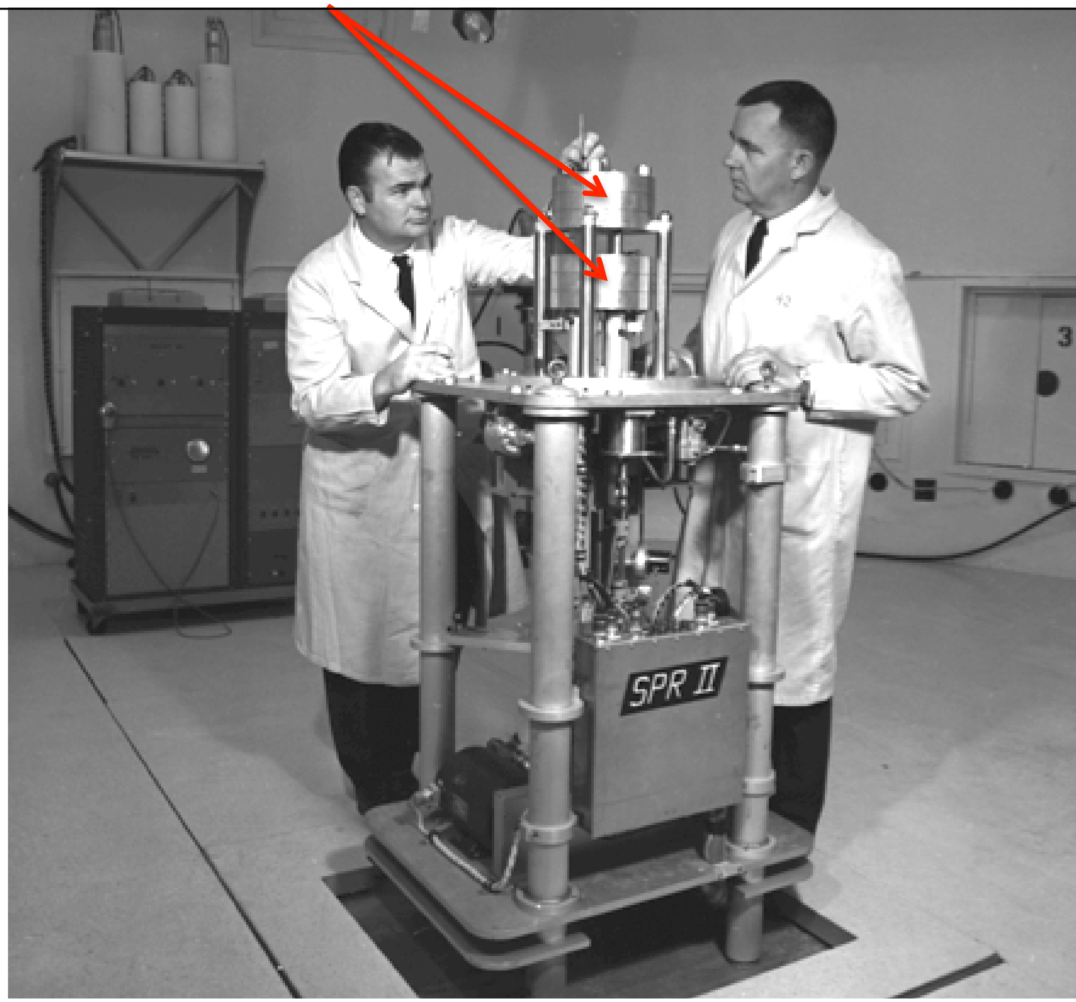
**Critical assemblies and pulsed reactors, like warheads, do not consume HEU but, like warheads, pose security risks.**

**Computer simulations could replace most critical assemblies.**
Russia's BSF has~ 9 tons of HEU – enough for ~100 Hiroshimas.



**U.S. retiring all but one HEU-fueled pulsed reactor because security is too costly. Twenty remain, mostly in Russia.**

Former Sandia Pulsed reactor used to simulate neutron pulse from a nearby nuclear explosion, 227 kg HEU, enough for 4 Hiroshima bombs. Russia’s BIGR is bigger (833 kg).



# Use of HEU in naval reactor fuel

# Naval-propulsion fuel

| Country | Nuclear ships and submarines | Fuel enrichment |
|---|---|---|
| **U.S.** | 10 aircraft carriers, 73 submarines | **93.5+%** |
| **U.K.** | 11 submarines | **93.5% from U.S.** |
| **Russia** | 49 submarines (7 research), 2 cruisers, 6 icebreakers | **21-90+%** |
| **India** | 1 submarine | **21-45%** |
| **China** | 14 submarines | **5%?** |
| **France** | 1 aircraft carrier, 10 submarines | **LEU (new sub will be 6%)** |
| **Brazil** | submarine under development | **<20%** |

## Supplies

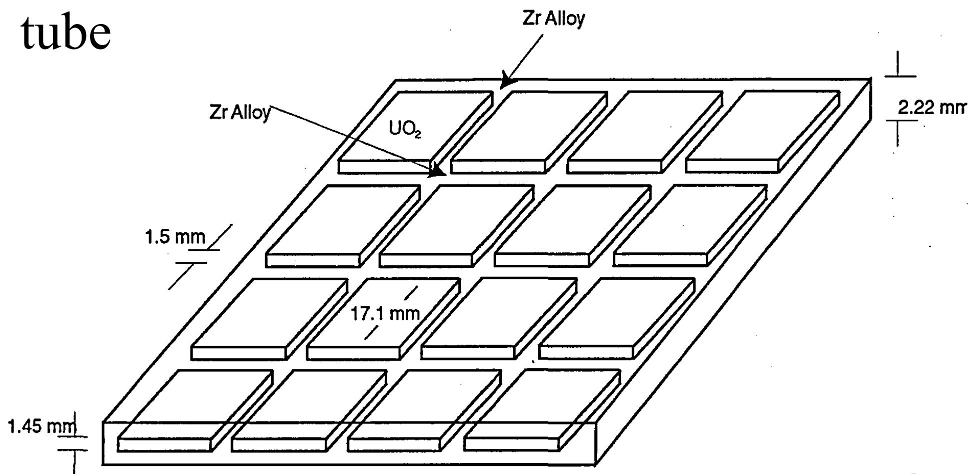
U.S. supplies HEU for UK naval reactors

Could Russia do the same for India if India joined a production ban? Perhaps, but India probably would rather convert to LEU than accept IAEA verification for its naval fuel cycle.

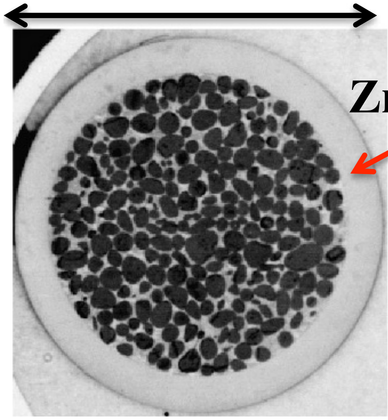
# *France* uses LEU →6% for naval reactors. *China* always used LEU. *Russia* plans to use LEU fuel in new nuclear icebreakers. All refuel regularly (~10 years). Easy for Russia/India to convert.

**Top: France's "caramel" fuel** (7 gU/cc)

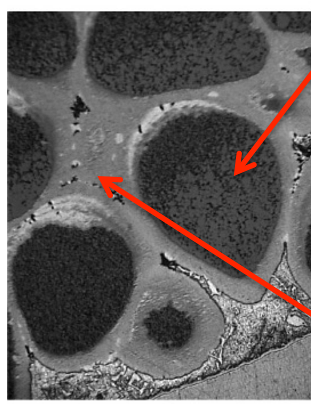
**Bottom: Russia's dispersion fuel,** $UO_2$ particles in aluminum (6gU/cc) in a zircaloy tube




**1 cm**



**Zr alloy**



**$UO_2$**

**Aluminum**

**Russia's *Sovetskiy Soyuz* icebreaker**

(HEU-fueled 1990-)

# Door to using LEU for U.S. naval fuel has opened a crack

***"recent work has shown that the potential exists to develop an advanced fuel system that could increase uranium loading beyond what is practical today while meeting the rigorous performance requirements for naval reactors."***

– Office of Naval Reactors [NR], *Report to Congress,* Jan. 2014

NR was to "***provide to the Committees on Appropriations…not later than March 31, 2016, a report that describes the key goals and milestones, timeline, and annual budget requirements to develop a LEU fuel system for naval reactor cores."*** – Defense Authorization, FY2016

Report about to emerge from internal Administration review?

Questions:

- ***NR says lifetime cores for submarines not achievable with LEU but I believe that, with some redesign, larger lifetime cores would fit in existing subs.***
- ***Which DOE budget should fund LEU fuel  development: Naval reactors or  nonproliferation?***

# Conclusions

Transitioning US/UK naval reactors to LEU fuel might be possible.

Transitioning Russian and Indian naval reactors would be much easier (lower HEU enrichment and non-lifetime cores).

Russia’s new tritium-production reactor could be designed to use LEU.

Within next 20 years, virtually all HEU-fueled research reactors will be converted or retired.

Within the next few years, virtually all neutron targets for medical radioisotope production will be LEU.

Existing Russian and U.S. HEU stocks could supply current non-weapons uses for >50 years.

***Pressing for a ban on further HEU production for any purpose would reinforce the movement away from HEU use.***

# Future HEU Requirements for U.S. Naval Propulsion

**Alan J. Kuperman, Ph.D.**
Associate Professor, LBJ School of Public Affairs
Coordinator, Nuclear Proliferation Prevention Project
(NPPP.org)
University of Texas at Austin

**Prepared for Workshop on**
**"Fissile Material Restrictions in Nuclear Weapon States: Treaties and Transparency"**
Center for Strategic and International Studies
Washington, D.C.
June 27-28, 2016

# Nuclear Proliferation Prevention Project (NPPP)



## Home

The NPPP engages in research, debate, and public education to ensure that civilian applications of nuclear technology do not foster the spread of nuclear weapons to states or terrorist groups.

**WHAT'S NEW:**

**White House Embraces NPPP Call to Replace Bomb-Grade Naval Fuel**

April 1, 2016

SEARCH THIS SITE:

To search, type and hit enter

HELPFUL LINKS

- Endowment (NPPE)
- Leventhal Fellowship
- NCI Paper Archive
- NCI Website Archive
- UT-Austin Courses

# Risks of Naval HEU Fuel

- Theft
- Proliferation
- Renewed HEU production

# Fresh HEU for Naval Propulsion Dwarfs Other Non-Weapons Uses & Previous Reductions

| Non-Weapons Uses of Fresh HEU (Globally) | Per Year (kg) |
|---|---|
| Research Reactors (RR) | 750 |
| Medical Isotope Targets | 50 |
| Icebreaker Ship Propulsion | 150 |
| Two Russian Isotope Production Reactors | 1,000 |
| **Subtotal (excluding Naval Propulsion)** | **1,950** |
| **Naval Propulsion** | **3,000** |
| **TOTAL** | **~5,000** |

| | |
|---|---|
| Previously Reduced by RR Conversion | 280 |
| Previously Reduced by RR Shutdown | 450 |
| **Total Previously Reduced by RERTR/GTRI** | **~700** |

Sources: Alan J. Kuperman, ed., *Nuclear Terrorism and Global Security: The Challenge of Phasing out Highly Enriched Uranium* (New York: Routledge, 2013). DOE, “Tritium and Enriched Uranium Management Plan Through 2060,” Report to Congress, October 2015. Frank von Hippel, personal communication, 2016.

**Note: Excludes Russian breeder reactor, whose fuel enrichment is barely higher than LEU.**

# When Will U.S. Navy Run Out of HEU?

- “According to DOE, the department’s current HEU inventory allocations are sufficient to meet national security demands through 2064.”
  - – U.S. GAO-15-123, October 2014

- But some ambiguity . . .

Table 8. Naval Reactors HEU Deliveries Through 2060

| Time Period | Annual Requirement (MTU) | Total Requirement (MTU) |
|---|---|---|
| FY 2012–FY 2020 | 3.6 | 32.3 |
| FY 2021–FY 2030 | 2.8 | 28.0 |
| FY 2031–FY 2040 | 2.5 | 25.0 |
| FY 2041–FY 2060 | 2.15 | 43.0 |
| **Total** | | **128.3** |

Source: DOE, "Tritium and Enriched Uranium Management Plan Through 2060," Report to Congress, October 2015.

# Naval HEU Will Not Last Much Beyond 2064
## (unless change in supply or demand)

- Jan 2001: Of ~100 tons HEU previously assigned to Navy, DOE says "The majority . . . is already in or has been used in naval reactor cores. The remainder will be fabricated into fuel in the near future."
  - **So, probably < 20 tons HEU were leftover by 2005.**
- 2005: 160 more tons of excess weapons HEU were assigned to the Navy, which rejected 8 tons as off-spec, leaving the Navy 152 tons of new HEU + less than 20 tons of leftover HEU, so **< 172 tons HEU supply in 2005.**
- **How much fresh Naval HEU required from 2005 to 2064?**

  2005 - 2011: 18 tons (assuming 2.6 tons/yr)
  2012 - 2060: 128 tons (DOE 2015 report to Congress)
  2061 - 2064: 10 tons (assuming 2.6 tons/yr)
  **~156 tons HEU demand 2005 - 2064**

# Based on Three Assumptions

- No more weapons HEU declared excess for Navy
- No change in planned composition of fleet
- No switch to LEU fuel for any nuclear vessels

# Progress on Conversion to LEU Naval Fuel

- 2014 DOE Report: Successful R&D of an “advanced fuel system” could “allow using LEU fuel with less impact on reactor lifetime, size, and ship costs.”
- FY 2016 Appropriation: “**$5,000,000** to start a technical program to develop and qualify a low-enriched uranium (LEU) fuel system for naval reactor cores.” (FY 2016 NDAA also authorized $5 million.)
- 2016 White House: “Consistent with its national security requirements and in recognition of the nonproliferation benefits to minimizing the use of highly enriched uranium globally, **the United States values investigations into the viability of using low-enriched uranium in its naval reactors**.”
- FY 2017: 3 of 4 relevant bills include $5 million for naval LEU fuel R&D. House-passed NDAA: “LEU for aircraft carriers and submarines.”

# Office of Naval Reactors = Ambivalent

- Wants R&D funding
- Open to LEU in CVNs
- Opposed to LEU in submarines

# Notional Timeline for Conversion to LEU Naval Fuel

- 2016 - 2030 R&D of LEU advanced fuel system
- 2031 - 2040 Design & testing of LEU reactor
- 2041 - 2045 Construction of LEU core for naval vessel
- 2046 - LEU could re-fuel existing CVNs, or fuel new classes of submarines

# What if CVNs are Refueled with LEU?

- Assume FY 2046 start.
- Reduce by ~1/3 annual naval HEU requirement (von Hippel, 2016), which otherwise is ~42 tons from 2046 - 2064.
- HEU saved from 2046 - 2064 is 42/3 = ~14 tons. If remaining naval HEU requirement is ~1.5 tons/yr, **refueling CVNs w/ LEU would extend HEU supply for only ~10 years, until at least ~2074.**

→ Unless new classes of submarines are fueled with LEU by 2074, U.S. could need to resume production of HEU (or declare more weapons HEU as excess).

# Convert Subs to LEU Fuel?

- 2 options:
  - Shorter core life → re-fueling
  - Larger reactors → larger submarines
- Naval Reactors officials resist both options – “we’ll get HEU if we need it”
- Unless Congress or the White House compels the Office of Naval Reactors to accept one of these options, the Navy would require additional HEU.

# Latest Vessel Classes in U.S. Naval Nuclear Fleet

| Vessel Type | Latest HEU-fueled class built or under design | First commissioned | Service life (years) |
|---|---|---|---|
| SSN | Virginia (lifetime core) | 2004 | 33 |
| CVN | Ford (mid-life refueling) | 2016 | 50 |
| SSBN | Ohio-replacement (lifetime core) | 2031 | 40 |

# Few Windows for LEU Fuel Introduction

| **Type** | **Class** | **After** |
| --- | --- | --- |
| SSN | next class | 2037 |
| CVN | current class (refuel) | 2041 |
| CVN | next class | 2066 |
| SSN | next-next class | 2070 |
| SSBN | next class | 2071 |

# Conclusions

- Unless LEU starts to be used by the 2040s – both to refuel the current CVN class, and to fuel the next SSN class – the Navy likely will exhaust its existing HEU supply.

- To enable LEU use by the 2040s, the Navy must significantly ramp up its nascent R&D of an advanced LEU fuel system, starting around FY 2018.

# Transparency (Declarations and Verification) under an FMCT

Hal Feiveson

CSIS Conference, June 27-28, 2016

# A Few Sources

Paul Podvig, “Verifiable Declarations of Fissile Material Stocks:  Challenges and Solutions,” UNIDIR 2016  (for this conference)

International Panel on Fissile Materials, *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament*; and *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production*

Zia Mian and Alexander Glaser, “Next Steps in Increasing Transparency of Nuclear Warhead and Fissile Material Stocks for Nuclear Disarmament,” presentation at NPT PrepCom, May 5, 2014, United Nations, New York

# Why Transparency (Declarations and Verification) under an FMCT?

Ensure a cap on nuclear weapons

Rationalize verification under an FMCT

Provide a baseline for verification under further nuclear disarmament steps

# Declarations to Date

Non-nuclear states

Under the NPT, all non-nuclear states declare all their fissile material to the IAEA and have these declarations subject to verification

Nuclear-weapon states not party to NPT (India, Pakistan, Israel, North Korea)

Virtually no declarations of fissile material or weapons stockpiles

NPT nuclear-weapon states (U.S., Russia, UK, France, China)

Some declarations – see nuclear transparency scorecard

# NPT Nuclear Weapon States
# 2010 NPT Review Conference

"All States parties commit to apply the principles of irreversibility, verifiability, and transparency in relation to the implementation of their treaty obligations." (Action 2)

"The nuclear weapon states are encouraged to commit to declare, as appropriate, to the IAEA all fissile material designated by each of them as no longer required for military purposes and to place such material as soon as practicable under IAEA or other relevant international verification and arrangements for the disposition o such material …" (Action 16)

"As a confidence-building measure, all the nuclear-weapon states are encouraged to agree as soon as possible on a standard reporting form and to determine appropriate reporting intervals for the purpose of voluntarily providing standard information …" (Action 21)

# Nuclear Transparency Scorecard 2015

(IPFM, *Global Fissile Material Report 2015*)

| | United States | Russia | United Kingdom | France | China |
|---|---|---|---|---|---|
| Number of total warheads | Approximate | No | Yes (upper limit) | Yes (upper limit) | Relative (out of date) |
| Number of deployed warheads | Yes (strategic only) | Yes (strategic only) | Yes (planned) | Yes | No |
| Dismantlements | Yes | No | Yes (no details) | Yes (no details) | No |
| Verification | Partial | Partial | No | No | No |
| Fissile material stockpiles | Yes | No | Yes (no details) | No | No |
| Production histories | Yes | No | No | No | No |
| Excess/Disposal | Yes (nothing new) | Yes (nothing new) | Yes (nothing new) | No | No |
| Verification | Partial | Partial (but no longer) | Partial (some plutonium) | No | No |
| International R&D activities | Yes | No | Yes | No | Some |

**Table 4. Nuclear Transparency Scorecard, 2015.** Information on nuclear warhead and fissile material inventories and their status in NPT nuclear weapon states. At the 2010 Review Conference, as part of the Action Plan agreed in the Final Document, nuclear weapon states committed to more transparency and to regularly report progress on reductions in the stockpile of nuclear weapons (Actions 2 and 5) and to declare excess and offer for IAEA safeguards material no longer needed for military purposes (Action 16). This scorecard highlights relevant categories and areas (shown in green and in white) in which progress has been made.

# United Kingdom and French Declarations

UK: The UK announced the size of its military stockpiles of plutonium in 1999 (3.51 tons) and HEU as of 2002 (21.86 tons). In January 2015, the UK announced that it had "achieved our commitment to reduce the number of operationally available warheads to no more than 120." The 2010 Strategic Defence and Security Review committed to cut the "overall nuclear weapon stockpile to no more than 180."

The UK fissile material reports were produced because the UK "believes that transparency about fissile material acquisition for defence purposes will be necessary if nuclear disarmament is to be achieved."

France: In February 2015, President Hollande reaffirmed France's planned reduction to 300 warheads.

# U.S. Declarations

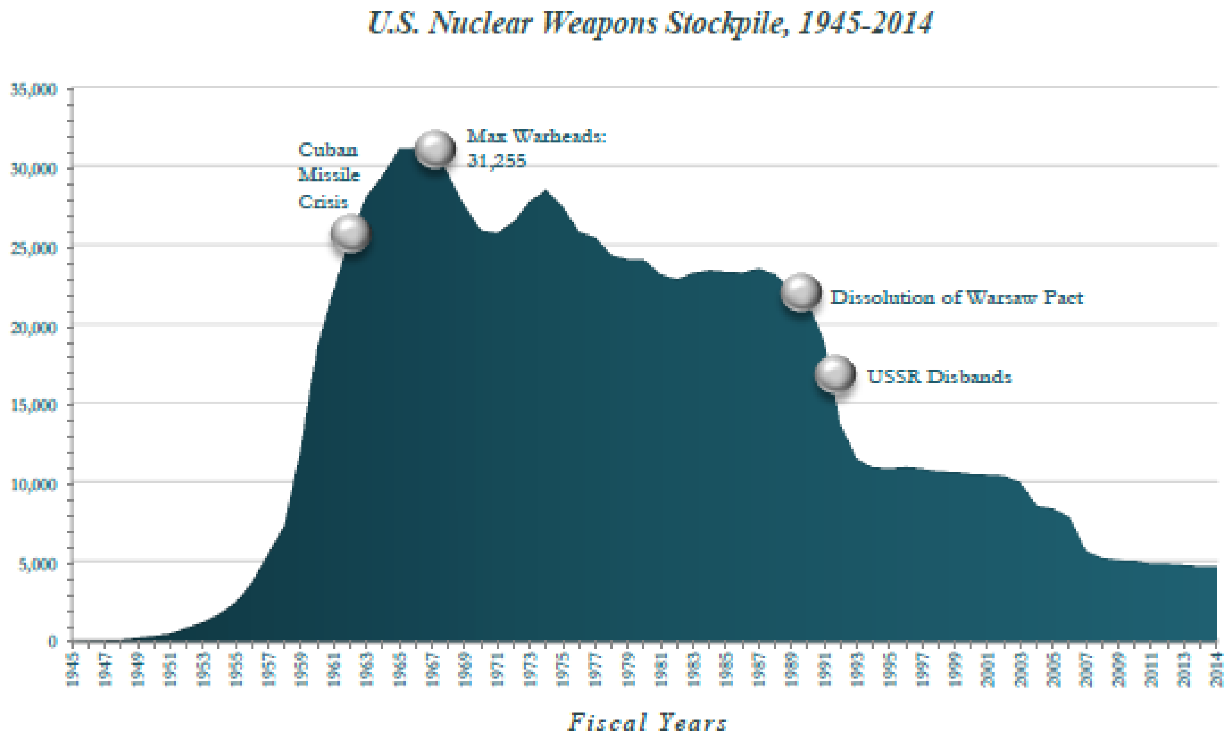
The U.S. has repeatedly published data on its nuclear weapons stockpile, most recently in April 2015 and in 2016.  In the latest declarations, it declared a stockpile of 4571 warheads in 2015, with “several thousand additional nuclear warheads … retired and awaiting dismantlement.” The declarations included stockpile totals from 1962, and dismantlement totals from 1994.

The U.S. has released detailed declarations , with updates, of its fissile material stockpiles.  The plutonium declaration covering the period 1944 to 1994 was released in 1996 and updated in 2012 to cover the period up to 2009. (95.4 tons physical inventory in 2009).

The HEU declaration for the period 1944 to 1996 was completed in 2001 and publicly released in 2006; it was also updated in 2006 to cover the period to 2004, and a more recent update in 2016.  (585.6 tons total inventory in 2013)

The Plutonium and HEU declarations included production histories.

# Fact Sheet: Transparency in the U.S. Nuclear Weapons Stockpile (April 27, 2015)




**Includes active and inactive warheads. Several thousand additional nuclear warheads are retired and awaiting dismantlement.*

# 2016 Update on Nuclear Stockpile

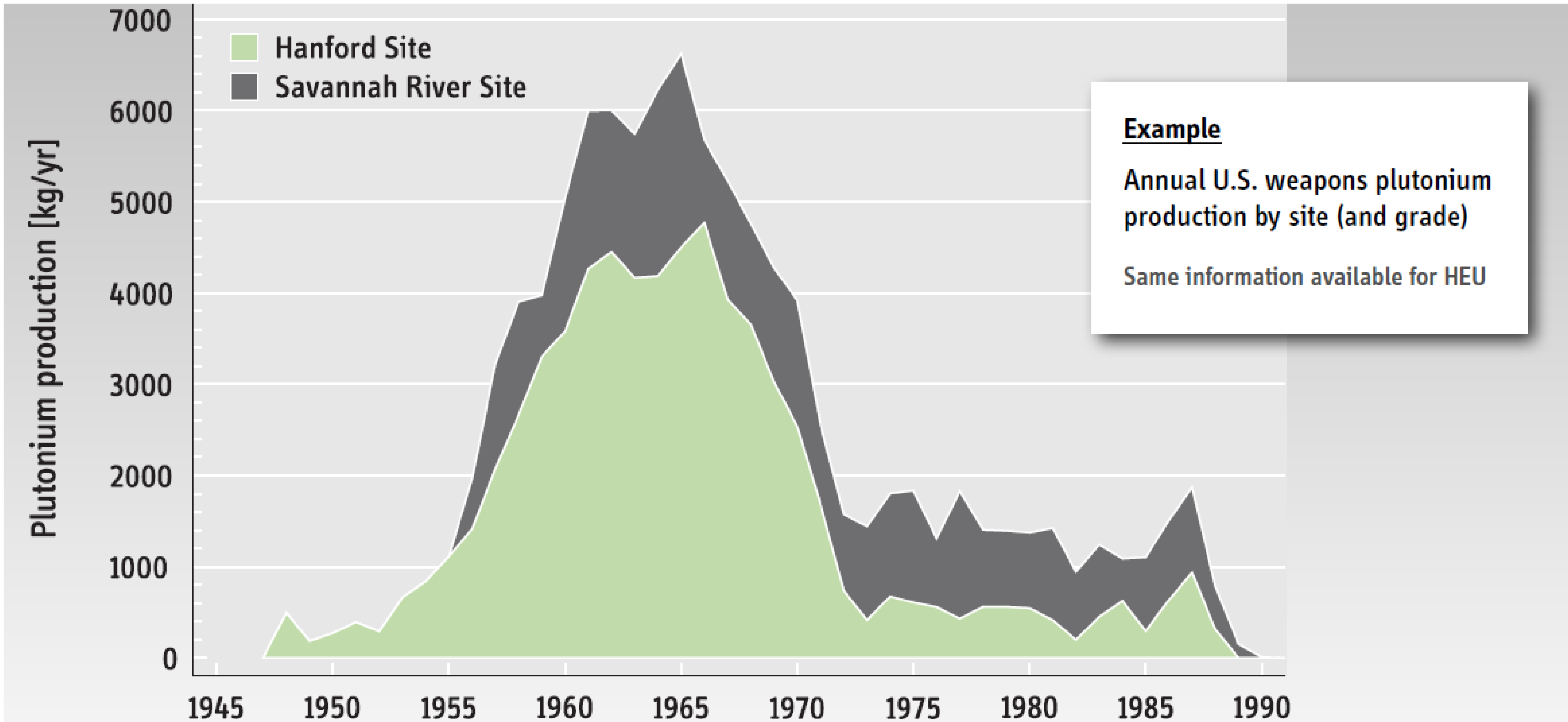
**Stockpile Numbers**

**End of Fiscal Years 1962-2015***

*Data prior to 1962 released by Department of Energy in December 1993*

| Year | Weapons | | Year | Weapons |
|---|---|---|---|---|
| 1962 | 25,540 | | 1990 | 21,392 |
| 1963 | 28,133 | | 1991 | 19,008 |
| 1964 | 29,463 | | 1992 | 13,708 |
| 1965 | 31,139 | | 1993 | 11,511 |
| 1966 | 31,175 | | 1994 | 10,979 |
| 1967 | 31,255 | | 1995 | 10,904 |
| 1968 | 29,561 | | 1996 | 11,011 |
| 1969 | 27,552 | | 1997 | 10,903 |
| 1970 | 26,008 | | 1998 | 10,732 |
| 1971 | 25,830 | | 1999 | 10,685 |
| 1972 | 26,516 | | 2000 | 10,577 |
| 1973 | 27,835 | | 2001 | 10,526 |
| 1974 | 28,537 | | 2002 | 10,457 |
| 1975 | 27,519 | | 2003 | 10,027 |
| 1976 | 25,914 | | 2004 | 8,570 |
| 1977 | 25,542 | | 2005 | 8,360 |
| 1978 | 24,418 | | 2006 | 7,853 |
| 1979 | 24,138 | | 2007 | 5,709 |
| 1980 | 24,104 | | 2008 | 5,273 |
| 1981 | 23,208 | | 2009 | 5,113 |
| 1982 | 22,886 | | 2010 | 5,066 |
| 1983 | 23,305 | | 2011 | 4,897 |
| 1984 | 23,459 | | 2012 | 4,881 |
| 1985 | 23,368 | | 2013 | 4,804 |
| 1986 | 23,317 | | 2014 | 4,717 |
| 1987 | 23,575 | | 2015 | 4,571 |
| 1988 | 23,205 | | | |
| 1989 | 22,217 | | | |

# U.S. Production History -- Plutonium




*Plutonium: The First 50 Years: United States Plutonium Production, Acquisition and Utilization from 1944 Through 1994*
U.S. Department of Energy, DOE/DP-0137, 1996, www.ipfmlibrary.org/doe96.pdf

# 2016 Update on HEU

The White House
Office of the Press Secretary

For Immediate Release March 31, 2016

## FACT SHEET: Transparency in the U.S. Highly Enriched Uranium Inventory

Today, the United States announces the declassification and public release of data on the national inventory of highly enriched uranium (HEU) as of September 30, 2013. This announcement marks the first time in fifteen years that the United States has declassified and released information of this kind. The newly declassified information shows that, from 1996 to 2013, U.S. HEU inventories decreased from 740.7 metric tons to 585.6 metric tons. This reflects a reduction of over 20 percent. Moreover, further reductions in the inventory are ongoing; the U.S. Department of Energy's material disposition program has down-blended 7.1 metric tons of HEU since September 30, 2013, and continues to make progress in this area.

# Why U.S. Transparency?

As President Obama noted in 2010, “When the United States improves its own security and transparency, it encourages others to do the same.”  The U.S. commitment to sharing appropriate nuclear security-related information has also been demonstrated by recent actions such as the declassification of information on the U.S. nuclear weapons stockpile and transparency visits by officials from non-nuclear weapon states to Los Alamos and Sandia National Laboratories.  These actions show that countries can increase transparency without revealing sensitive information.

White House Fact Sheet, March 31, 2016

# Civil Declarations
# Guidelines for the Management of Plutonium

In 1996, under INFCIRC/549, Guidelines for the Management of Plutonium, the U.S., Russia, U.K., France, China, Japan, Germany, Belgium, and Switzerland agreed to publish annually all their stocks of civilian plutonium. The UK, France, and Germany also report their civilian HEU.

## Why not HEU?

- Many more countries would be involved, possibly complicating negotiations
- Plutonium used as a fuel while no commercial interest in HEU as fuel
- HEU agenda on blend-down and conversion of research reactors to use LEU already underway

# Civilian Plutonium Stockpile Declarations

(IPFM, *Global Fissile Material Report 2015*)

| | France (Addendum [illegible]) | | | Japan (Addendum [illegible]) | | | Russia (Addendum [illegible]) | | | United Kingdom (Addendum [illegible]) | | | United States (Addendum [illegible]) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 65.4 | 30.0 | 0.2 | 5.0 | 0.0 | 15.1 | 28.2 | 0.0 | 0.0 | 54.8 | 6.1 | 0.9 | 45.0 | 0.0 | 0.0 |
| 1997 | 72.3 | 33.6 | <0.05 | 5.0 | 0.0 | 19.1 | 29.2 | 0.0 | 0.0 | 60.1 | 6.1 | 0.9 | 45.0 | 0.0 | 0.0 |
| 1998 | 75.9 | 35.6 | <0.05 | 4.9 | 0.0 | 24.4 | 30.3 | 0.0 | 0.0 | 69.1 | 10.2 | 0.9 | 45.0 | 0.0 | 0.0 |
| 1999 | 81.2 | 37.7 | <0.05 | 5.2 | 0.0 | 27.6 | 32.0 | 0.0 | 0.0 | 72.5 | 11.8 | 0.9 | 45.0 | 0.0 | 0.0 |
| 2000 | 82.7 | 38.5 | <0.05 | 5.3 | 0.0 | 32.1 | 33.4 | 0.0 | 0.0 | 78.1 | 16.6 | 0.9 | 45.0 | 0.0 | 0.0 |
| 2001 | 80.5 | 33.5 | <0.05 | 5.6 | 0.0 | 32.4 | 35.2 | 0.0 | 0.0 | 82.4 | 17.1 | 0.9 | 45.0 | 0.0 | 0.0 |
| 2002 | 79.9 | 32.0 | <0.05 | 5.3 | 0.0 | 33.3 | 37.2 | 0.0 | 0.0 | 90.8 | 20.9 | 0.9 | 45.0 | 0.0 | 0.0 |
| 2003 | 78.6 | 30.5 | <0.05 | 5.4 | 0.0 | 35.2 | 38.2 | 0.0 | 0.0 | 96.2 | 22.5 | 0.9 | 45.0 | 0.0 | 0.0 |
| 2004 | 78.5 | 29.7 | <0.05 | 5.6 | 0.0 | 37.1 | 39.7 | 0.0 | 0.0 | 102.6 | 25.9 | 0.9 | 44.9 | 0.0 | 0.1 |
| 2005 | 81.2 | 30.3 | <0.05 | 5.9 | 0.0 | 37.9 | 41.2 | 0.0 | 0.0 | 104.9 | 26.5 | 0.9 | 45.0 | 0.0 | 0.0 |
| 2006 | 82.1 | 29.7 | <0.05 | 6.7 | 0.0 | 38.0 | 42.4 | 0.0 | 0.0 | 106.9 | 26.5 | 0.9 | 44.9 | 0.0 | 0.0 |
| 2007 | 82.2 | 27.3 | <0.05 | 8.7 | 0.0 | 37.9 | 44.9 | 0.0 | 0.0 | 108.0 | 26.8 | 0.9 | 53.9 | 0.0 | 0.0 |
| 2008 | 83.8 | 28.3 | <0.05 | 9.6 | 0.0 | 37.8 | 46.5 | 0.0 | 0.0 | 109.1 | 27.0 | 0.9 | 53.9 | 0.0 | 0.0 |
| 2009 | 81.8 | 25.9 | <0.05 | 10.0 | 0.0 | 36.15 | 47.7 | 0.0 | 0.0 | 112.1 | 27.7 | 0.9 | 53.9 | 0.0 | 0.0 |
| 2010 | 80.2 | 24.2 | <0.05 | 9.9 | 0.0 | 35.0 | 48.4 | 0.0 | 0.0 | 114.8 | 28.0 | 0.9 | 53.9 | 0.0 | 0.0 |
| 2011 | 80.3 | 22.8 | <0.05 | 9.3 | 0.0 | 35.0 | 49.5 | 0.0 | 0.0 | 118.2 | 27.9 | 0.9 | 49.3 | 0.0 | 0.0 |
| 2012 | 80.6 | 22.2 | <0.05 | 9.3 | 0.0 | 34.9 | | | | 120.2 | 23.8 | 0.9 | | | |
| 2013 | 78.1 | 17.9 | <0.05 | 10.8 | 0.0 | 36.3 | 51.9 | 0.0 | 0.0 | 123 | 23.4 | 0.9 | 49.3 | 0.0 | 0.0 |
| 2014 | 78.8 | 16.9 | <0.05 | 10.8 | 0.0 | 37.0 | 52.8 | 0.0 | 0.0 | 126.3 | 23.0 | 0.0 | 49.3 | 0.0 | 0.0 |

☐ Inventory held in country ☐ Foreign-owned (included in local inventory)
☐ Stored outside the country (not included in local inventory)

# Further Steps on Transparency

The Draft Final Document* of the 2015 NPT Review Conference called upon the nuclear weapon states to report on:

1. The number, type, and status of nuclear warheads
2. The number and the type of delivery vehicles
3. The measures taken to reduce the risk of unintended, unauthorized, or accidental use of nuclear weapons
4. The measures taken to de-alert or reduce the operational readiness of nuclear weapon systems
5. The number and type of weapons and delivery systems dismantled
6. The amount of fissile material for military purposes

*The Final Document was not formally adopted

# Possible Reporting Form for Warheads by Deployment Status
(IPFM, *Global Fissile Material Report 2013*)

Total number of warheads as of (DATE)

Operationally deployed warheads (strategic)

Operationally deployed warheads (tactical)

Warhead in active reserve

Warheads in inactive reserve (no tritium)

Retired warheads in dismantlement queue

Warhead components in storage, primaries

Warhead components in storage, secondaries

# Possible Reporting Form for Fissile Material Declarations

(IPFM, *Global Fissile Material Report 2013*)

| | Plutonium | HEU |
|---|---|---|
| Inventory as of (DATE) | | |
| Military, available for weapons | | |
| Military, for non-weapons purposes | | |
| Military in irradiated fuel | | |
| Excess military, available for safeguards | | |
| Civilian, available for safeguards | | |

In addition, nuclear weapon states could undertake to provide a history of fissile material production as has the U.S. For states just embarking on transparency initiatives, such declarations could be implemented step by step.

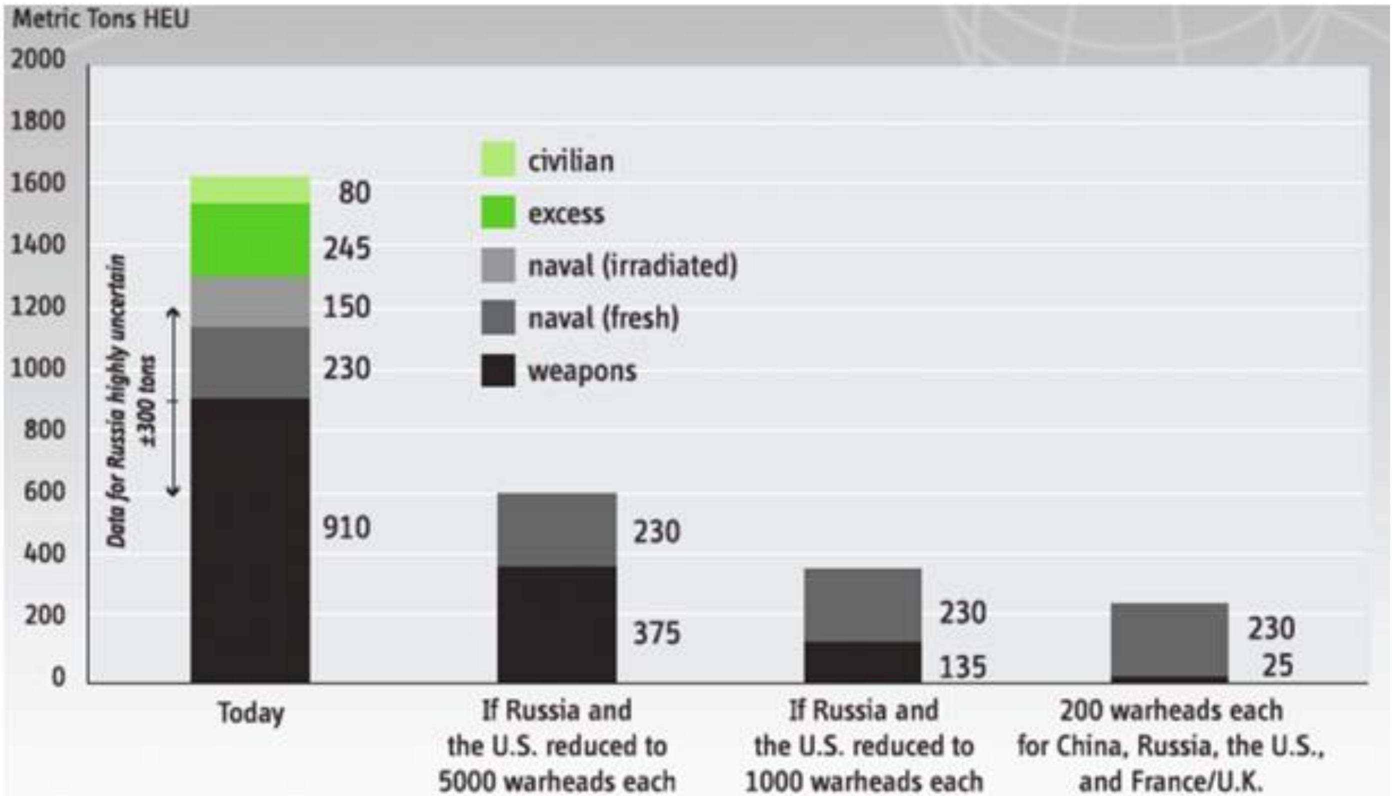
# Transparency and Verification

Verification of declarations could also be implemented step by step with some verification deferred until further progress on nuclear disarmament.

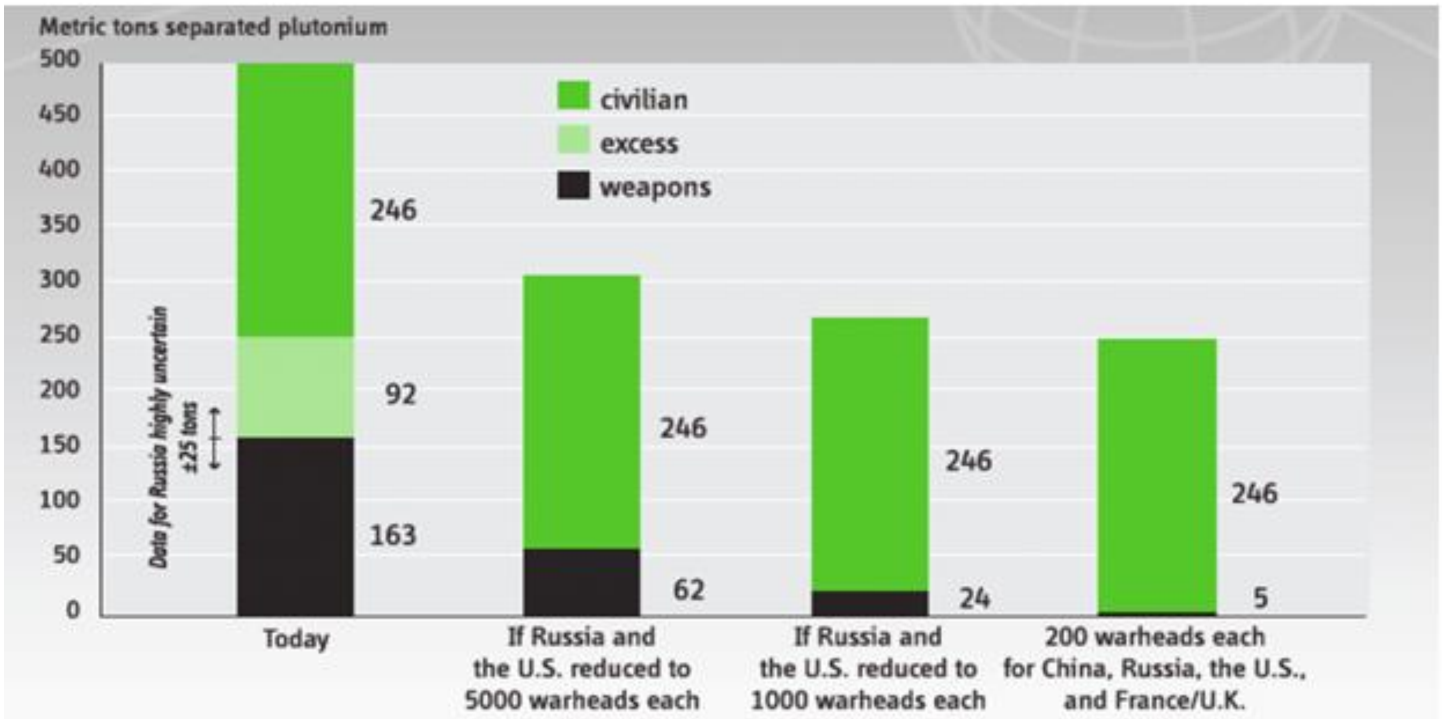
To set the stage for more intrusive verification, in addition to providing a history of fissile material production, nuclear weapon states could:

- Agree on the most important types of operating records to be preserved
- Agree to catalogue, characterize, and preserve waste materials
- Agree to demonstrate "nuclear archaeological" methods (forensic techniques to analyze trace impurities in structural materials or waste materials at former fissile production sites) for all relevant production plants
- Eventually, agree to apply unique identity tags for all nuclear warheads and containers of fissile materials

# More Fissile Material Could Be Declared Excess (HEU)



# More Fissile Material Could Be Declared Excess (plutonium)



# Limiting enrichment plants and enrichment levels of new production

**Frank von Hippel**
Program on Science and Global Security
Princeton University

Workshop on Fissile Material Restrictions in Nuclear Weapon States: Treaties and Transparency
Center for Strategic and International Studies
28 June 2016

# Outline

1. Enrichment ranges
2. Enrichment capacity by owner
3. Economies of scale and advanced technology
4. National incentives for acquiring national enrichment plants
5. Multinational or international ownership as an alternative.
6. Limiting enrichment at most facilities to <6%
7. Arrangements for supplying 6-19.75% LEU
8. Summary

# Current enrichment ranges

- **Weapon-grade HEU (>90% U-235)** for: weapons, US-UK naval reactors, some Russian icebreakers, Mo-99, pre-1978 research reactors, and Germany's FRM II.

- **HEU with 21-60% U-235** for: Russian/Indian naval reactors, some Russian icebreaker reactors, Russian breeder reactors, "transition" fuel for France's new research reactor (& others pending availability of new high-density fuel?)

---

- **LEU with 6-19.75% U-235** for: Converted research reactors and Mo-99 production, Russia's new icebreaker reactors, France's naval propulsion reactors, French naval reactors, Chinese HTGR.

- **LEU with < 5% U-235** for: LWR power reactors, Chinese submarine reactors? (***about 98% of enrichment work***)

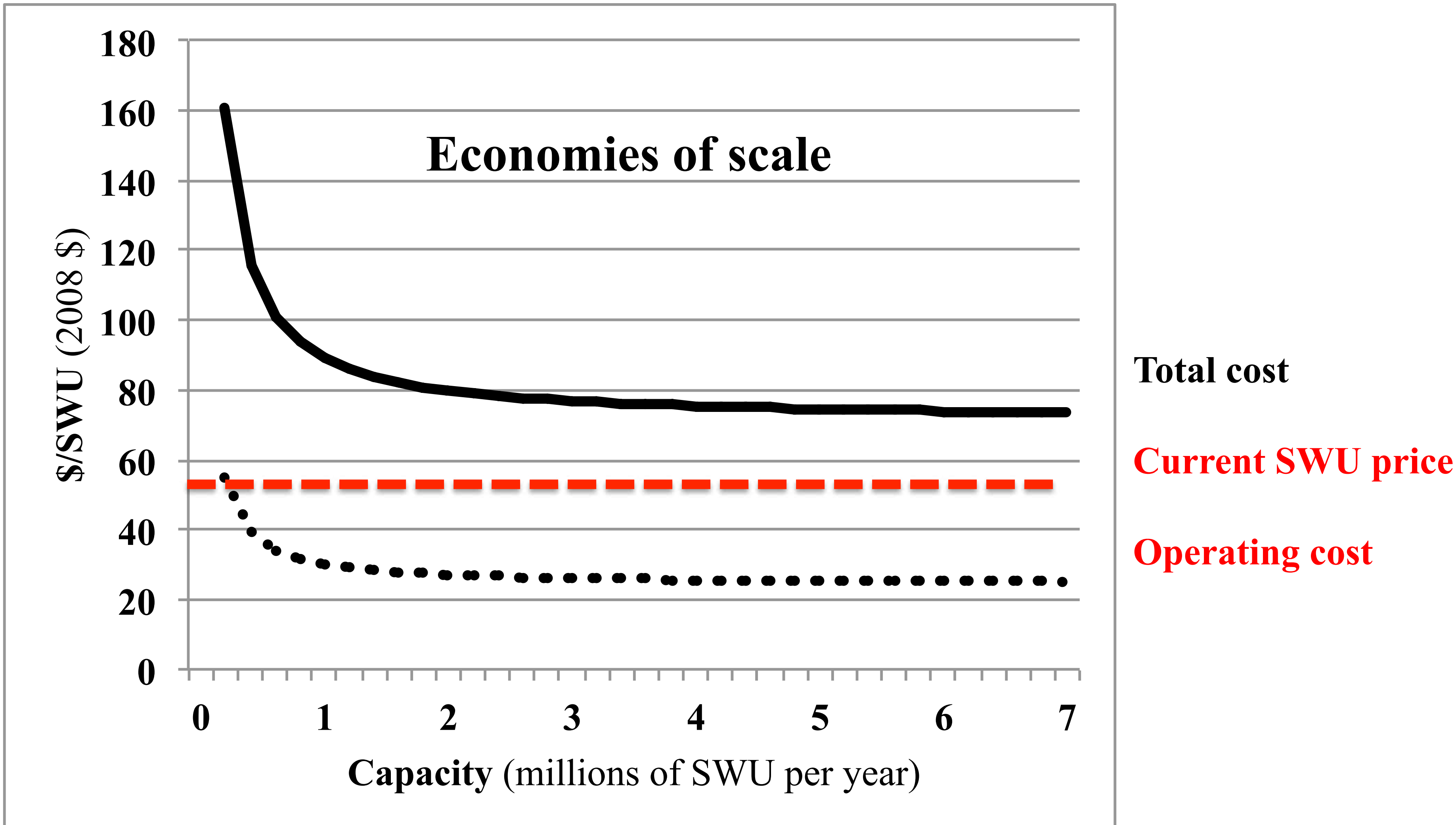
***No need for producing more HEU. Focus below will be on LEU.***

## **Enrichment capacity by owner** (nuclear weapon states in red)

| Large plants | MSWU/yr | Small | MSWU/yr |
|---|---|---|---|
| **China** | ~5→9 | **Argentina** | 0.02? |
| **France** | 7.5 | **Brazil** | 0.03→0.2 |
| **Japan** | 1 | **India** | 0.015-0.03 |
| **Russia** | 27 | **Iran** | 0.005 |
| ***Urenco*** | 18→20 | **N. Korea** | ~0.01? |
| | | **Pakistan** | 0.015-0.045? |
| **Total** | **~60** | **Total** | **~ 0.1→0.3** |
| **Global demand** | **~45** | | |

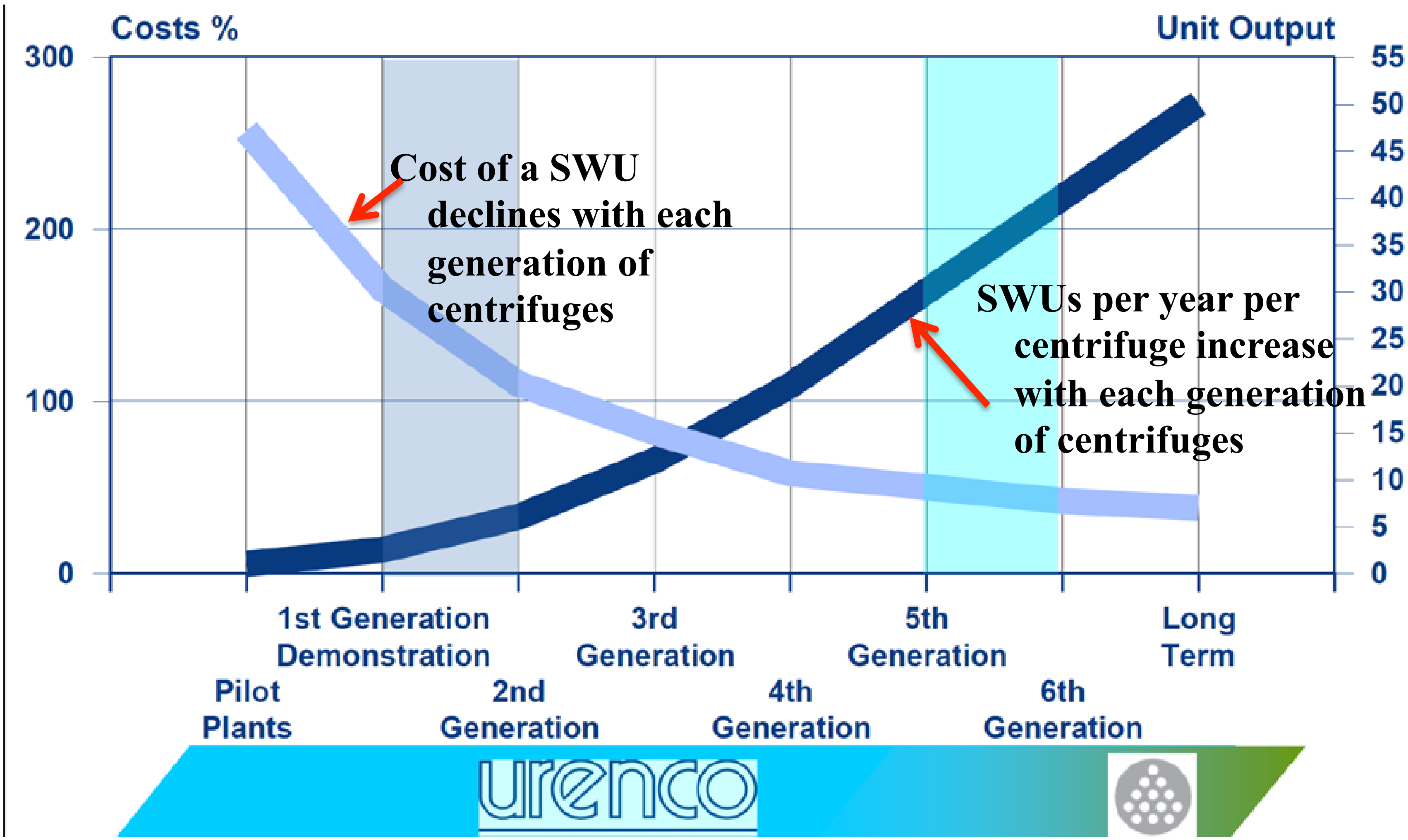
It requires about 0.12 MSWU/yr to support a 1 GWe LWR.
Small plants are not significant producers for power reactor fuel but spread of small plants raises proliferation concerns.
Global over-capacity for foreseeable future.

# Small plants can't compete
# Also, new plants can't compete with existing plants today.
## Capital cost ~ $1 billion/(million-SWU plant)




(based on Rothwell, "Market Power in Uranium Enrichment," *Science & Global Security 17* (2009) p. 132.

# New entrants also are behind in centrifuge technology unless they buy from the leaders



## Incentives to acquire national enrichment plants

1. To have supply security for domestic reactors (Iran)
2. To make money by selling SWU internationally (not today)
3. To produce fuel for naval reactors (Brazil, India, Iran?, U.S.)

   (Only 6 out of 40 countries with submarines have nuclear submarines because nuclear submarines are very costly.

   *Virginia* attack submarines cost $3 billion each.

   Conventional German attack submarine $0.36 billion.

   Brazil started enriching in the 1980s. Thirty years later, does not have an operating land-based prototype propulsion reactor.)
4. To acquire nuclear-weapons (most recently Pakistan and North Korea) or a nuclear-weapon option.

# Proposals for discouraging acquisition of national enrichment plants

Acheson-Lilienthal, 1946: ***international control***.

After India's 1974 nuclear test, ***multinational control*** of reprocessing plants but economic interest in reprocessing waned. (International control seemed out of reach during the Cold War.)

After the surfacing of Iran's enrichment program in 2003, IAEA Director General ElBaradei proposed multinational control of both enrichment and reprocessing plants.

These still look like the only politically acceptable options.

Urenco is a multinational and the Nuclear Suppliers Guidelines "encourage recipients to accept, as an alternative to national plants, supplier involvement and/or other appropriate multinational participation in resulting facilities."

## How does international/multinational control fit with the reasons for acquiring an enrichment plant?

***1. Supply security for domestic reactors.***

Given today's constellation of suppliers, very few countries have legitimate concerns about supply security.

Those that do have such concerns can acquire domestic stockpiles of LEU at a time when prices are very low. For a carrying charge of 5%, it takes 14 years to double the cost.

***2. To make money by selling SWU internationally***.

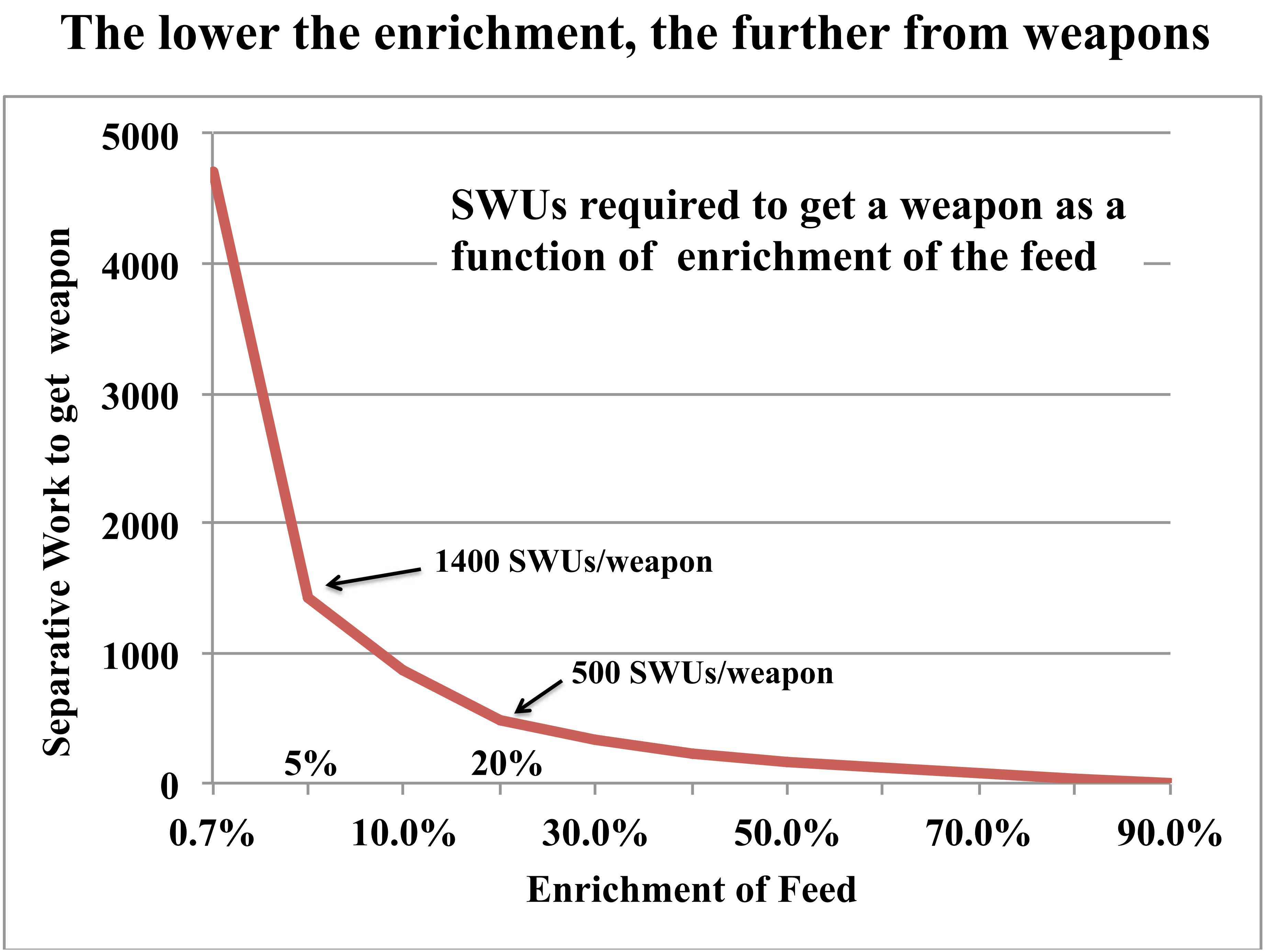
Economies of scale for a larger multinational plant.

***3. To produce fuel for naval reactors.***

See below.

***4. To acquire nuclear-weapons or a nuclear-weapon option.***

Makes it more difficult. That's the point!


The lower the enrichment, the further from weapons
SWUs required to get a weapon as a function of enrichment of the feed
1400 SWUs/weapon
500 SWUs/weapon
5%
20%
5000
4000
3000
2000
1000
0
0.7%
10.0%
30.0%
50.0%
70.0%
90.0%
Enrichment of Feed
Separative Work to get weapon

# Levels of enrichment in LEU use and production

***All commercial nuclear power plants use LEU enriched to <5%.***
Some proposed small modular reactors would use >5% LEU.

***Urenco*** plants licensed to enrich to < 5%.

***AREVA*** to < 6%

***Rosatom*** to <5% at Angarsk, Seversk, <30% at Novouralsk, Zelenogorsk has cascade producing HEU for icebreaker, breeder & research reactors.

***China*** produces all or almost all <5%

***Currently, virtually all demand for civilian HEU and LEU >5% being met by U.S. blend-down and Russian blend-down and enrichment.***

***Is there a window of opportunity to agree not to produce > 6% LEU except at one or two agreed international or multinational-controlled enrichment facilities?***

## Assuming all current consumptive uses of HEU are shifted to 19.75%, LEU how large would the requirements be?
## (*No need for more than 50 years because of excess Cold War HEU.*)

Naval reactors ~ 25 tons of 19.75% LEU/yr

~ 225,000 SWU/yr from 5% LEU

Research reactors ~ 2 GWt @ 60% capacity factor, ~ 5 tons/yr

~ 45,000 SWU/yr from 5% LEU

***Total of ~300,000 SWU/yr, 0.2% of current global enrichment capacity.***

***In a rational world, the LEU would be supplied by a single international or multinational enrichment facility.***

## **What about a multinational supplier of 19.75% LEU for naval reactor fuel?** (> 50 years in the future)

The precedent: U.S. supplies UK with HEU for its naval fuel.

China and France could continue on with <6% LEU from national enrichment plants.

For non-weapon states (Brazil, Iran) – or a weapon-state not recognized by the NPT (India, Israel, Pakistan) international safeguards would be required to verify non-diversion to weapons.

Only politically acceptable if U.S., UK and Russia also accept safeguards on their naval fuel cycles?

Vulnerability to cutoff could be mitigated with large stockpiles.

# Summary

1. An FMCT should ban all HEU production with IAEA verification.
2. Multinational enrichment with in-country stockpiles for countries worried about supply security as an alternative to the proliferation of national enrichment plants.
3. Only one or two facilities enrich uranium to > 6 percent for civilian purposes.
4. If safeguards on naval fuel cycles can be worked out, we could even discuss international supply of $\leq$19.75% LEU for naval reactors owned by countries that forego enrichment.

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# *Moving Away from National Enrichment and Reprocessing*

## Session V


Sharon Squassoni

Director, Proliferation Prevention Program


*CSIS Workshop*

*June 27-28, 2016*

*Washington, DC*

PROLIFERATION PREVENTION PROGRAM

# Bottom line

- If you're not making fissile material for weapons, a purely national enrichment or reprocessing facility is unnecessary (and uneconomic)
  - Undue emphasis on sovereignty when it comes to fuel cycle decisions
  - Requiring multilateralization could level the playing field

# Approach

- Narrative of multilateralization not very appealing from fuel cycle policy perspective
  - Allergy to supra-national management
  - Requires significant political flexibility that is absent in most parts of the world
  - Lack of trust within NPT context
- Nuclear security frame has gained more acceptance
  - If paired with limits on stockpiles, would there be more traction?
- From an industrial viewpoint, may not make too much of a difference

# Some trends in nuclear industry

- Ownership and management of the front and back end of the international fuel cycle
- Size and nature of the global market
- Forecasted development of the global market over the next 20-40 years

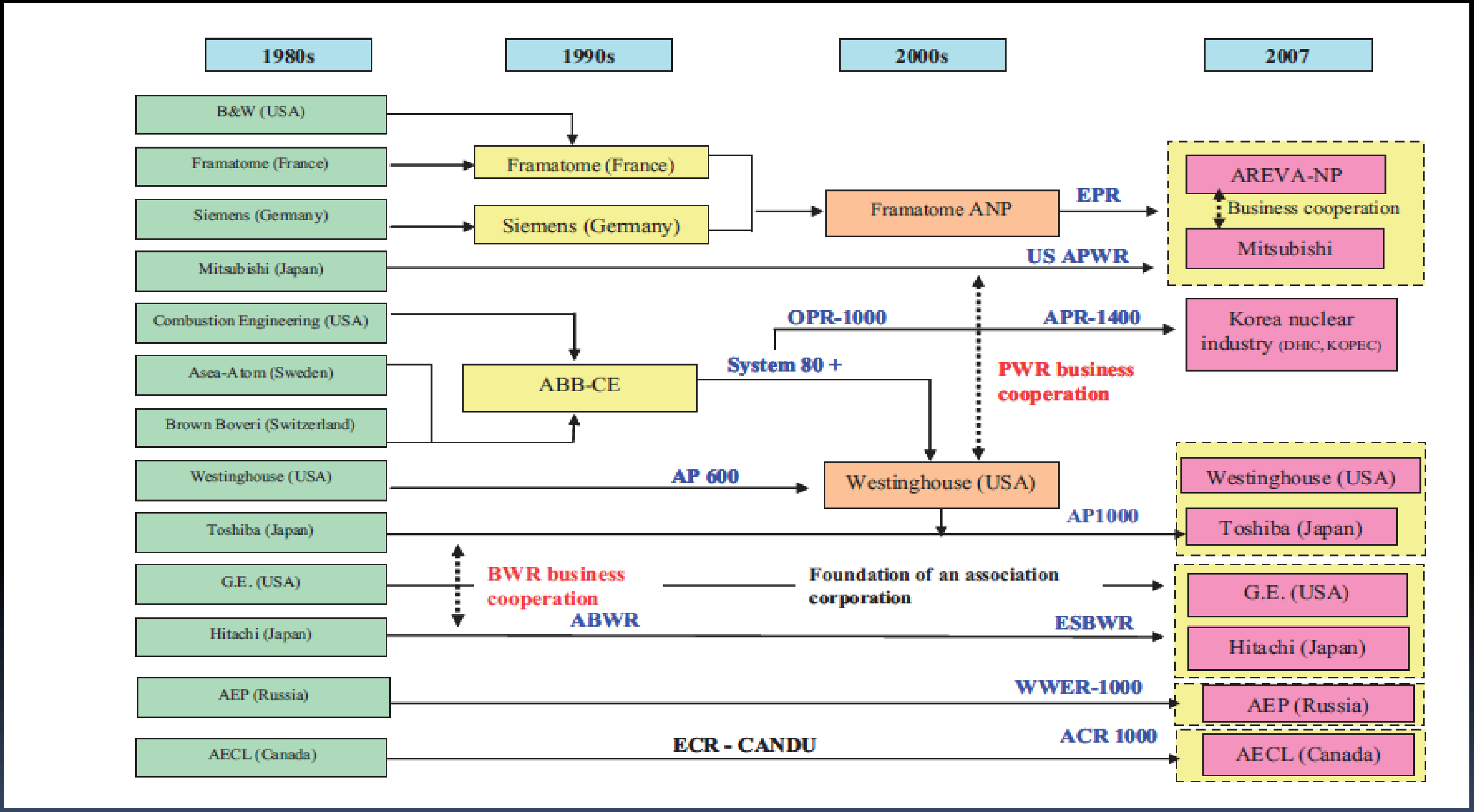
# Defining "multilateral" (a la Carl Stoiber)

- "A broader kind of arrangement which could involve participation by different types of entities (commercial, governmental or other) from several countries."
- The term suggests "significant flexibility in how such an arrangement might be structured in terms of investment, management, regulatory control and the like, as long as meaningful participation of entities from several States was involved."

# Industry trends (data from 2011)

| Company | Ownership | Mining | Conversion | Enrichment | Fabrication | Reactors | Storage | Repro-cessing | Disposal |
|---|---|---|---|---|---|---|---|---|---|
| Areva | G-France | X | X | X | X | X | X | X | X |
| AECL | G-Canada | | | | X | X | X | X | X |
| Rosatom | G-Russia | X | X | X | X | X | X | X | X |
| Babcock & Wilcox | P | | | | | X | | | |
| BHP Billiton | P | X | | | | | | | |
| Cameco | P | X | X | (a) | | | | | |
| Converdyn | P | | X | | | | | | |
| CNCC | G-China | X | X | X | X | X | X | X | X |
| KEPCO-KHNP (b) | G-Korea | | | | | X | | | |
| GE/HItachi | P | | | (a) | X | X | | | |
| JNFL | P (c) | | | X | X | | X | X | X |
| Kazatomprom | G-Kazakhstan | X | X | X (d) | X (e) | | | | |
| Mitsubishi | P | | | | | X | | | |
| Nuclear Power Corp. of India | G-India | | | | | X | X | X | X |
| Nukem | P | | X | X | | | | X | |
| Rio Tinto | P | X | | | | | | | |
| Toshiba-Westinghouse | P | | | | X | X | | | |
| URENCO | G, P (f) | | | X | | | | | |
| USEC/Centrus | P | | | X | | | | | |

# Consolidation over time



# Relevant trends

- Moving toward greater vertical integration?
- Toward bundled services?
- Do private companies stand a chance against government-supported enterprises?
- How will China, India, Korea fare against traditional suppliers?

# Relevant trends

- Moving toward greater vertical integration?
- Toward bundled services?
- Do private companies stand a chance against government-supported enterprises?
- How will China, India, Korea fare against traditional suppliers?

# Enrichment services (2011 data)

| Company | Ownership | Location / Name of Facility(ies) | Process | Capacity ('000 SWU) | % of Global Market |
|---|---|---|---|---|---|
| **Areva** | Government – France | France/ Georges Besse | Gaseous diffusion | 10,000 | 17.1 |
| **Atomenergoprom** | Government – Russia | Russia/<br>- Sverdlovsk-44<br>- Seversk<br>- Krasnoyarsk<br>- Angarsk | All centrifuge | 22,500 | 38.5 |
| **CNNC** | Government -- China | China/<br>- Lanzhou 2<br>- Shaanxi | All centrifuge | 1,000 | 1.7 |
| **Japan Nuclear Fuel Ltd (JNFL)** | Private consortium of Japanese utilities | Japan/ Rokkasho | Centrifuge | 1,000 | 1.7 |
| **URENCO** | Government – UK and Netherlands Privately Owned – E.ON (Germany), RWE (Germany) | UK – Urenco UK Limited<br>Netherlands – Urenco Neth.<br>Germany – Urenco Deutch.<br>US – National Enrichment Facility/ New Mexico* | All centrifuge | 8,500 | 14.5 |
| **USEC** | Private | US – Paducah/ Kentucky | Gaseous diffusion | 15,500 | 26.5 |
| TOTALS | -- | -- | | 58,500 | 100 |

# Relevant Trends

- The high costs of entry and the sensitive nature of the technology have limited private sector investment in enrichment.
- Increasing level of interest in multinational investment in enrichment capabilities?

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# Reprocessing services (2011 data)

| Company | Ownership | Location of Facility(ies) | Production (tHM) | % of Global Market |
|---|---|---|---|---|
| **Areva** | Government – France | France | 1,015 | 91.0 |
| **Atomenergoprom** | Government -- Russia | Russia | 100 | 9.0 |
| **JNFL** | Private – Japanese utilities | Japan | 0 | 0 |
| **NDA / Sellafield** | Private - NDA | UK | 0 | 0 |
| **TOTALS** | -- | -- | 1,115 | 100 |

- Will fuel leasing mean more or less reprocessing for international customers?

# Assessing Alternatives to National Fuel Cycle Facilities 2005 IAEA MNA Report

- Nonproliferation Value
  - (global, "suppliers")
  - Diversion
  - Breakout
  - Technology Diffusion
  - Security

Assurance Value

("recipients")

Guarantees

Economic

Political/Public Opinion

Safety & Security

**Siting**

**Access**

**Involvement**

**Safeguards**

**Other inducements**

# Devilish details

- Siting
  - Technology holder? Extraterritorial? Non-technology holder?
- Technology Access
  - None? Operational Know-how? Assembly/maintenance? Full access?
- Involvement
  - From minimal to ownership (equity), management, operation?
- Safeguards
  - Additional Protocol? Special monitoring?

# Questions

- Absent progress on a FM(C)T, would a push toward multilateral ENR help
  - Reduce some of the friction within the NPT?
  - Stop production of fissile material for nuclear weapons outside of the 5 NPT nuclear weapon states?
  - Reduce risks of further proliferation of ENR (including Iran post-JCPOA)?
- Would it provide additional verification assurances under an FMCT?
- Is it feasible absent some restrictions on HEU for naval fuel?