

Physics 280: Session 29

Questions

Final: Tuesday May 10th, 7.00 – 10.00 pm
120 Architecture Building

Extra Credit Opportunity D: Today at 4pm in the Spurlock
Museum Auditorium “ISIS and the global rise of religious Rebellions”

ICES

News

Module 8 Arms Control: Safe Guard Technology

Module 9 The Future

Physics/Global Studies 280: Final

The **final exam** will take place on

Tuesday May 10th from 7-10pm

120 Architecture Building

Scope of exam:

96 multi-choice problems

18 questions each on arsenals and arms control

10 questions each on missile defense and current events

8 questions each on nuclear physics, nuclear weapons,
nuclear explosions, delivery methods and terrorism

20% of grade from essay on CRS Aegis System Report

50% of the questions will be taken from the final exams
of the last 3 years (available from the course web-page)

Suggestions for Final Prep

- (1) Study old final exams and use slides + posted reading assignments to verify your answers.
- (2) Review all news discussed in class.
- (3) Bring questions to review session (will schedule review session Tuesday).
- (4) Review course slides.
- (5) Review reading materials.

ICES Course Evaluation Forms Available Online

ICES forms are available online

To use **ICES Online**, click the following URL:

<https://ices.cte.uiuc.edu/>

Please participate! Your feedback will help us

- (1) to further improve the class and to
- (2) make the case for the support needed from the physics department to continue the course in the future: TAs, lecturer, IT support. The Physics department does not receive funds from the campus to teach PHYS/GLBL-280.

11 of 63 so far (deadline is Thursday, May 5th)

Verification of the Nuclear Nonproliferation Treaty

The Additional Protocol

Comprehensive declaration of current and planned materials and facilities

Regular updates of the declaration

Complementary access on short notice (24 hours)

Environmental sampling

- location specific (swipe samples)
- wide-area (to be decided by the Board of Governors)

In addition

Open source information

Satellite imagery

Detection of Horizontal Proliferation

Example: Natanz, Iran

Apparent attempt to hide an underground uranium centrifuge enrichment facility



BEFORE: 20 SEP 02



AFTER: 20 JUN 04

Module 8: Nuclear Arms Control

Nuclear Safeguards

Key Safeguards Terms

- Significant Quantity (SQ): the approximate quantity of nuclear material in respect of which the possibility of manufacturing a nuclear explosive device cannot be excluded. SQs include losses during manufacturing.

Material	Significant Quantity (SQ)
Plutonium (<80% Pu-238)	8 kg
U-233	8 kg
HEU (>20% U-235)	25 kg
LEU (<20 % U-235)	75 kg

- Timely Detection: the time within which a detection must be made is based on the time required to weaponize the material in question.

Material Form	Conversion Time
Pu, HEU or U-233 metal	7-10 Days
Pu, HEU or U-233 oxides or nitrates (pure and unirradiated)	1-3 Weeks
Pu, HEU or U-233 in irradiated fuels	1-3 Months
Uranium with < 20% U-235 or U-233	1 Year

Diversion Methods

A facility operator may attempt to divert material through one of the following methods:

- Tampering with IAEA equipment
- Falsifying records
- Borrowing nuclear material from another site
- Replacing nuclear material with dummy material
- Preventing access to the facility.

Safeguards Methods

Safeguards at nuclear facilities is carried out through various methods and tools that can be described by a few general categories:

- Nondestructive Assaying (NDA)
- Destructive Analysis (DA)
- Containment/Surveillance (C/S)
- Environmental Sampling (ES)

Containment/Surveillance (C/S)

While assaying provides measurements for material accountancy, C/S is used for area monitoring and to ensure that data is not falsified.

Some C/S items include:

- Surveillance cameras
- Area monitors
- Seals/Tags
- Tamper indicating devices

Nondestructive Assay (NDA)

NDA tools can consist of any measurement device that does not destroy the sample.

- Mass scales
- Radiation detectors/neutron counters
- Cherenkov radiation viewing devices

Advantages:

- Can be operated in-situ, remotely
- Cost-effective

Cherenkov Radiation



Ref: Left, "Cherenkov Radiation." Above, "Introduction to Nuclear Safeguards: Nondestructive Analysis."

Destructive Analysis (DA)

As the name implies, DA requires destruction of a small sample of material.

- Mass spectrometry
- Chemical analysis
- Radiochemical analysis

Advantages:

- More precise than NDA measurements
- Lower detection limits

Environmental Sampling (ES)

- Part of the goal for IAEA safeguards is to provide assurance of the absence of undeclared nuclear activity in a state
- All nuclear processes emit trace particles of material into the environment.
- ES helps the IAEA to reach a conclusion on undeclared activity through various environmental signatures and observables
 - May consist of:
 - Soil and water samples
 - Smears
 - Bulk or particle analysis

Sampling and Analysis of Atmospheric Gases



Figure 10: Basic Methodology 1
A mobile on-site laboratory samples and concentrates atmospheric-borne pollutants. Local meteorological conditions and the GPS location are also recorded.

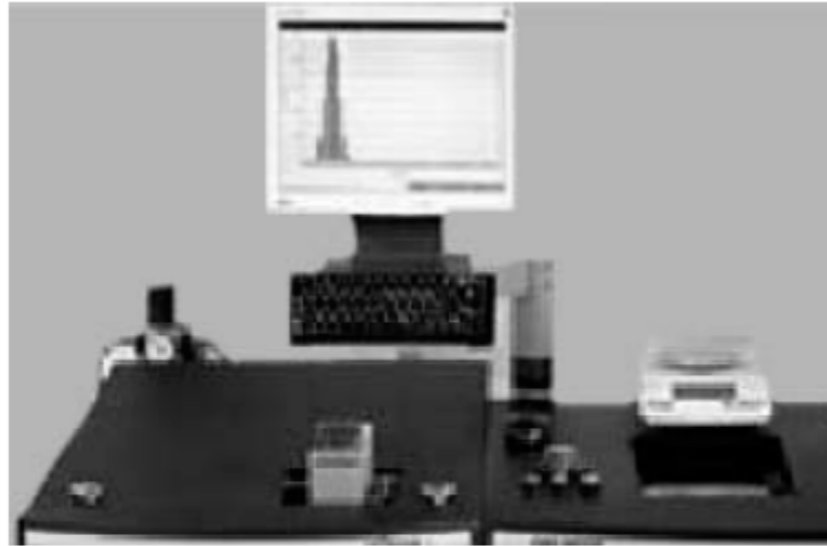


Figure 11: Basic Methodology 2
Samples are brought to a field laboratory for analysis.

Need: To detect the presence and nature of nuclear fuel cycle process activities at suspected locations

Application: Away-from-site (stand-off) detection

Solution:

Use on-site LIBS to determine the nature and history of compounds and elements

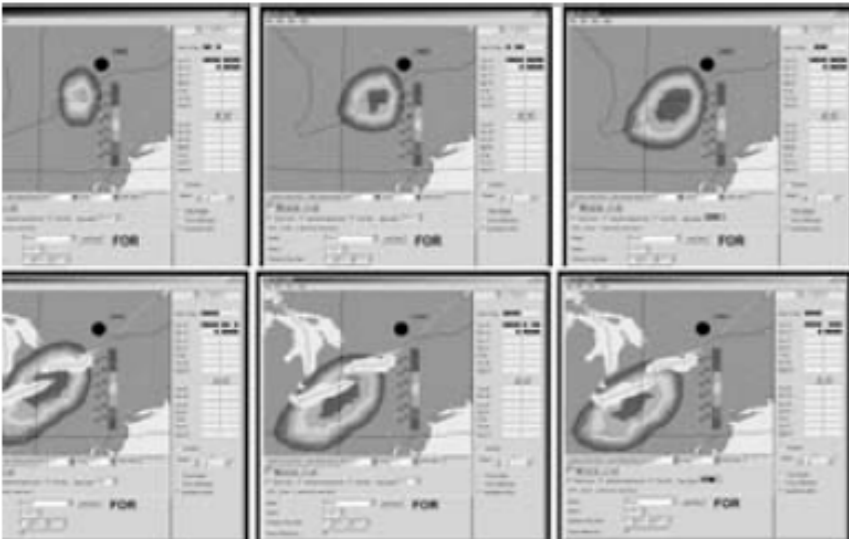


Figure 12: Basic Methodology 3
The sample analysis data is combined with meteorological data and suitable atmospheric modelling to provide an estimate of the source direction.



Figure 13: Basic Methodology 4
The airborne material is identified and the probable location of the source is estimated.

Source: J. Whichello, et al., IAEA Project on Novel Techniques, INESAP Information Bulletin No. 27, Dec. 2006

Laser-Induced Breakdown Spectroscopy (LIBS)

Need: determine whether, or not, an undeclared location has been used for storing radiological material

Application: both on-site and off-site analysis.

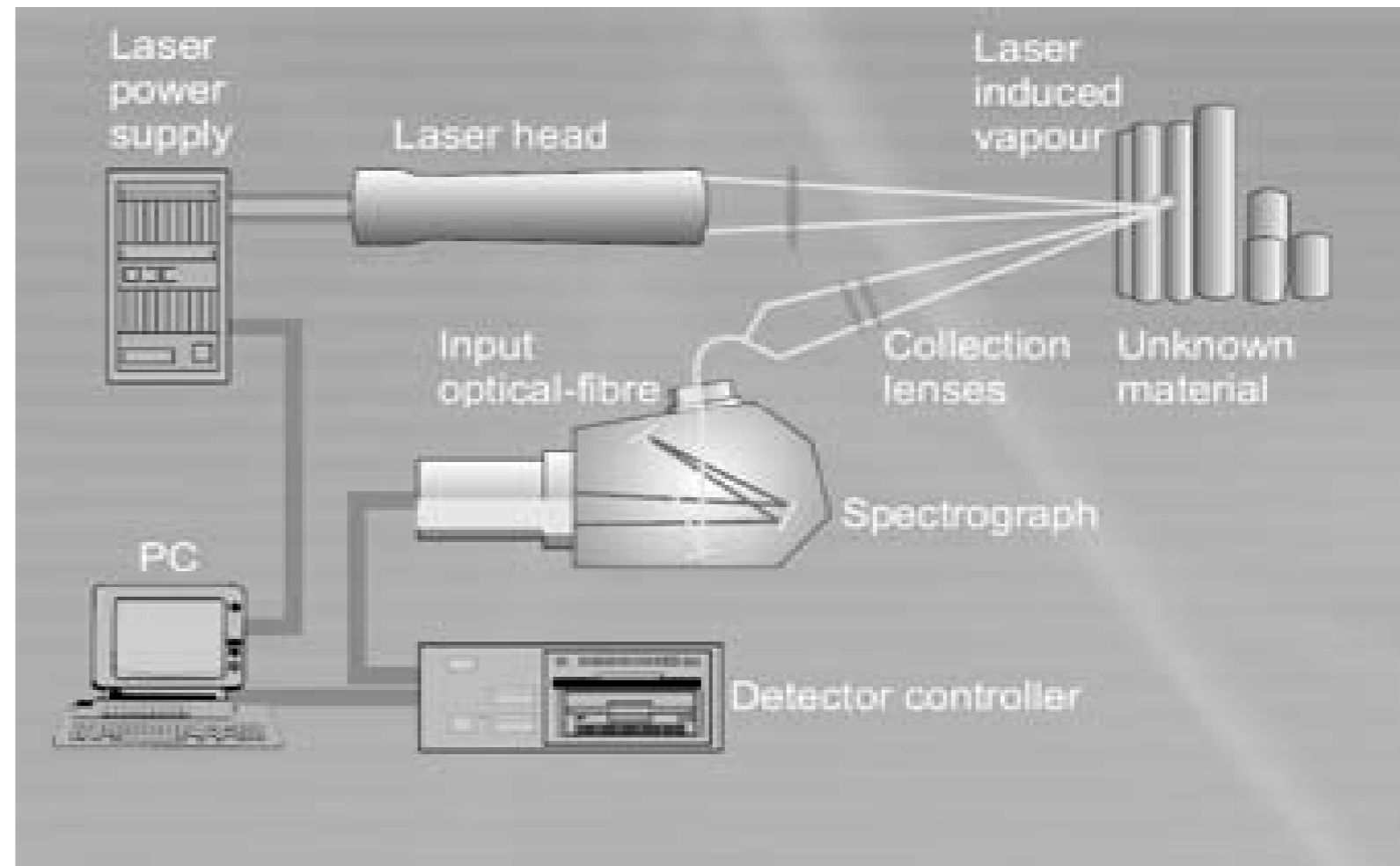


Figure 6: Basic Methodology 2

LIBS is comprised of (i) a laser system to ablate the surface of the material to be analyzed to create a micro-vapour, and (ii) a spectrometer to generate a spectroscopic profile of the micro-vapour's constituent components.

Source: J. Whichello, et al., IAEA Project on Novel Techniques, INESAP Information Bulletin No. 27, Dec. 2006

Material Unaccounted for, Measurement Errors

Material Unaccounted For (MUF): The accounting difference between the amount of recorded material transferred in and out of a facility and recorded inventory at the beginning and end of a particular reporting period.

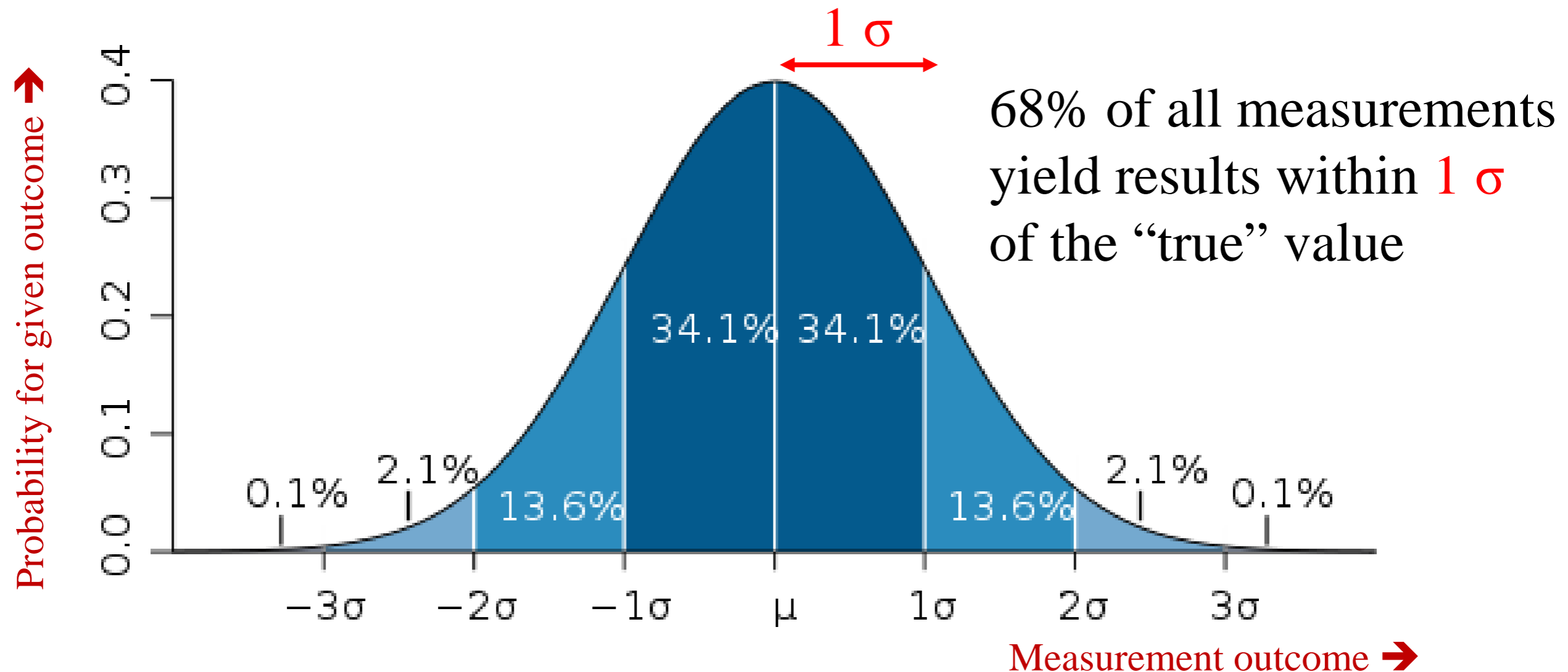
$$\text{MUF} \equiv (\text{Starting Inventory} + \text{Inputs} - \text{Outputs} - \text{Ending Inventory})$$

- MUF is never equal to zero for any facility!
- MUF can be both positive and negative (material created or lost).
- Each variable that contributes to the MUF calculation is based on measurements to quantify the amount of nuclear material in the facility.

All measurements have errors !!

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Distribution and Probabilities of Measurement Results



Ref: “Standard Deviation”

Sigma Level	Percent Confidence
$\pm 1\sigma$	68% Confidence
$\pm 2\sigma$	95% Confidence
$\pm 3\sigma$	99% Confidence

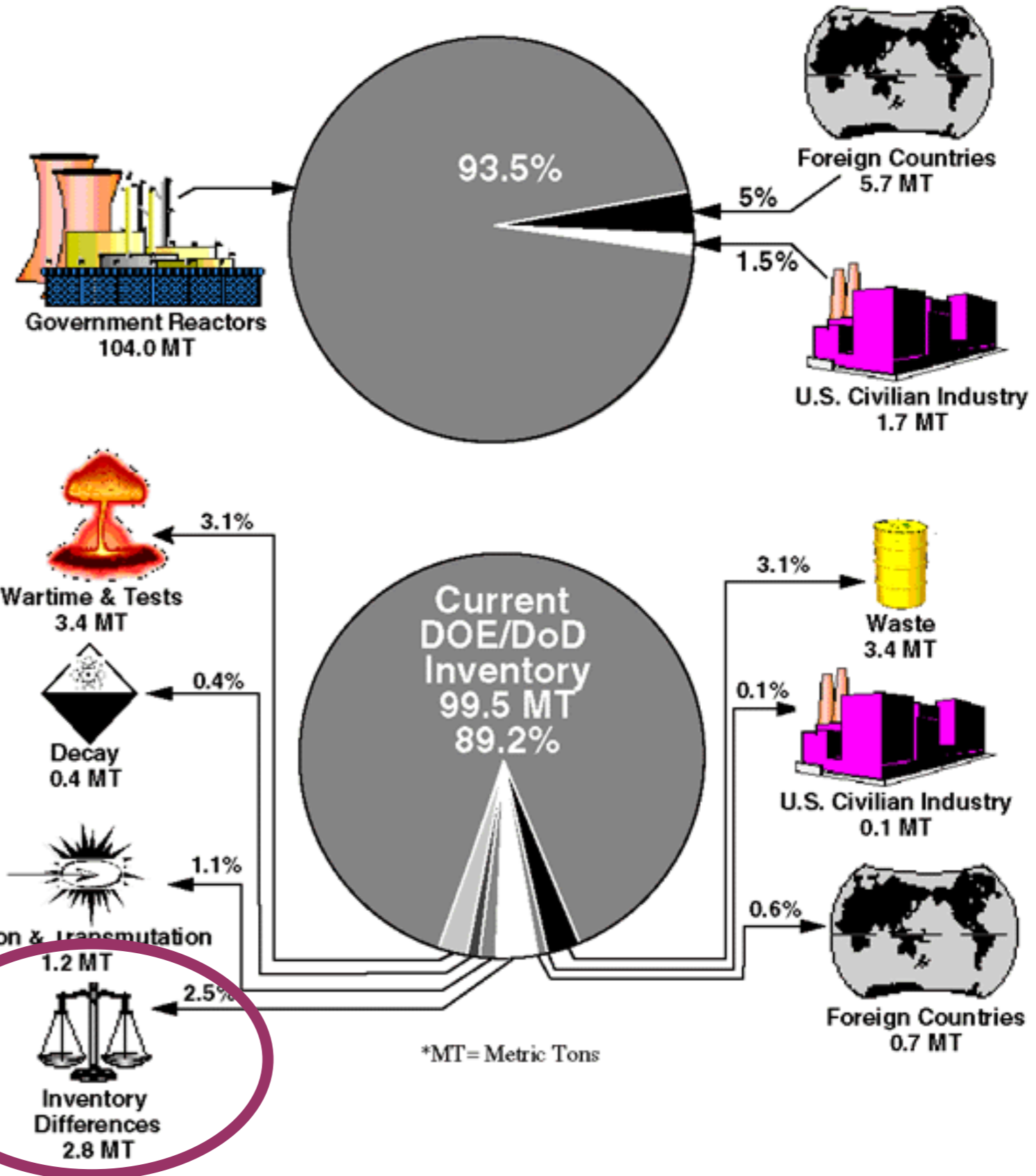
Problem with accountancy at bulk material facilities

MUF = Material Unaccounted For

The problem of bulk material accountancy.

U.S. Plutonium: Where it Came From and Current Balance Statement

111.4 Metric Tons Produced or Acquired: 1944 – 1994



The Iran Nuclear Deal

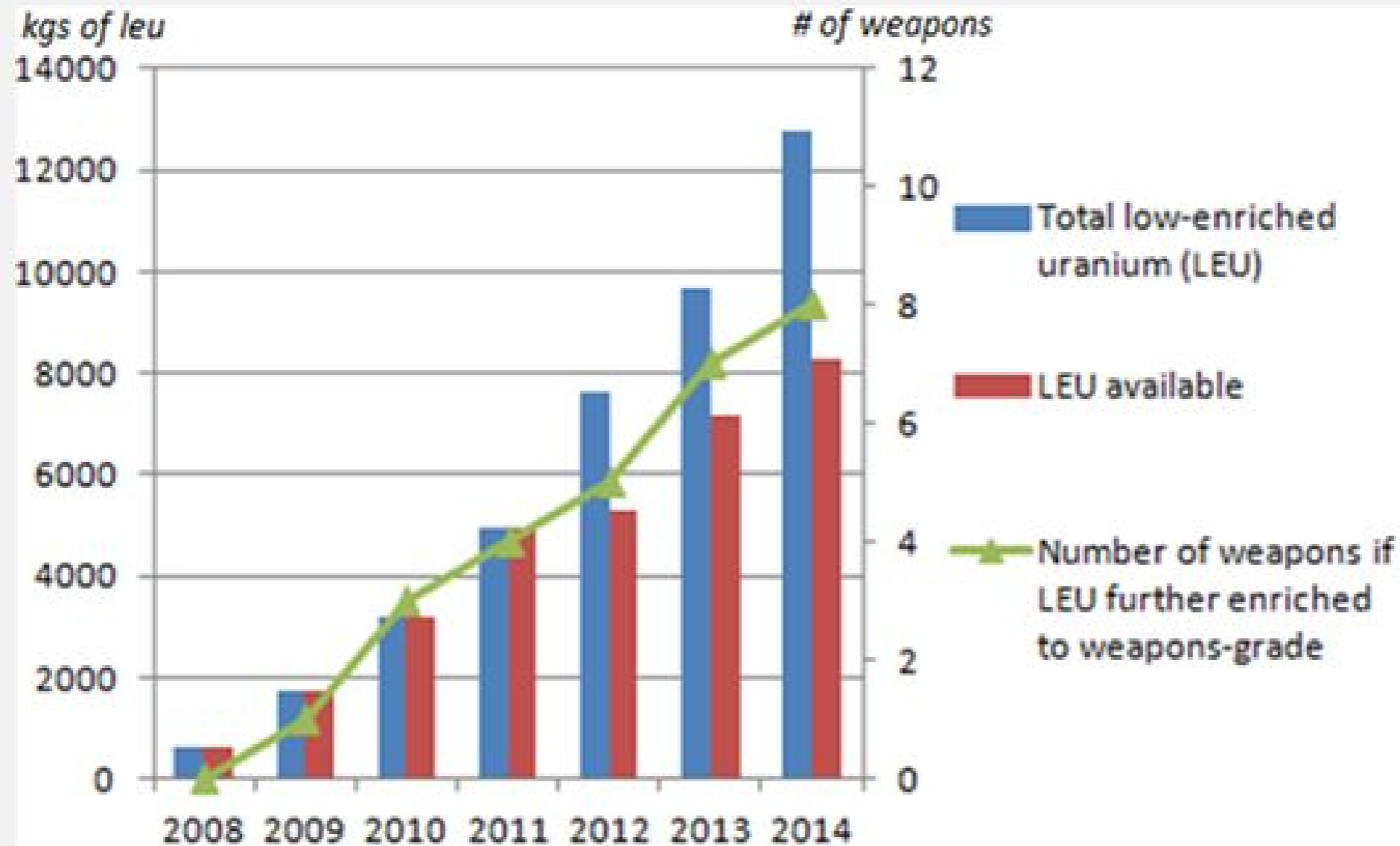
- **Iran's nuclear program: history & capabilities**
- **Joint Plan of Action (JPA) and Joint Comprehensive Plan of Action (JCPOA) limits on fissile isotope production & verification**

Sources of information:

- (1) K. Katzman and P.K. Kerr, Iran Nuclear Agreement
Congressional Research Service, July 30, 2015 -
<https://fas.org/sgp/crs/nuke/R43333.pdf>
- (2) Joint Comprehensive Plan of Action (JCPA) – original text
<http://apps.washingtonpost.com/g/documents/world/full-text-of-the-iran-nuclear-deal/1651/>

Why Worry? Accumulation of Low Enriched Uranium in Iran: Breakout Time to Nuclear Weapon only ~ 2 months for about 7 nuclear warheads !

Iran's Uranium Enrichment Has Surged Since 2009



Source: Institute for Science and International Security; Harvard University Belfer Center, Institute for Science and International Security. See slide 18 for the assumptions behind these estimates.



Iran is a large country (~78M people) with a Strong Highly Educated Technical Work Force

Country	Name of Physics Society	Membership	Founded in
USA	American Physics Society	48,000	1899
Iran	Physics Society of Iran	5,100	1921
Saudi Arabia	Saudi Physical Society	300	2002

**Iran has a strong scientific community with substantial history.
Iran certainly has the ability to quickly advance a nuclear weapons program!**

What is the Iran Nuclear Deal (JCPOA)

An agreement between the Islamic Republic of Iran and **China, France, Germany, Russia, the United Kingdom, the United States** in consultation with the **European Union** to **reduce the Iranian Nuclear Program and to place it under Supervision of the International Atomic Energy Agency (IAEA)** in Vienna. In exchange certain economic sanctions on Iran are discontinued.

Signed in Vienna, July 14th, 2015

China, France, Russia, the United Kingdom and the United States are the 5 permanent members of the United Nations Security Council. They are also the “nuclear weapon states” under the non-proliferation treaty.

Two Paths to Nuclear Weapons

- Isotope U-235 of the natural element Uranium (99.3% U-238 + 0.7% U-235)
 - Low Enriched Uranium (LEU): fraction of U-235 < 20%
 - Weapons-grade HEU: fraction of U-235 > 80%

Going from 0.7% U-235 to > 80% U-235 → Isotope Enrichment!
- Isotope Pu-239 of Plutonium produced in nuclear reactors
 - Reactor-grade: < 80% Pu-239
 - Weapons-grade: > 93% Pu-239

Bred in Uranium reactors and chemically separated from spent reactor fuel.

The Iran Nuclear Complex

Iran possesses:

Uranium mines

Uranium processing

Uranium 235 enrichment

Heavy water reactor for
Plutonium production



Uranium Enrichment Facility in Natanz

Natanz, Iran

Apparent attempt to hide an uranium centrifuge enrichment facility underground



BEFORE: 20 SEP 02

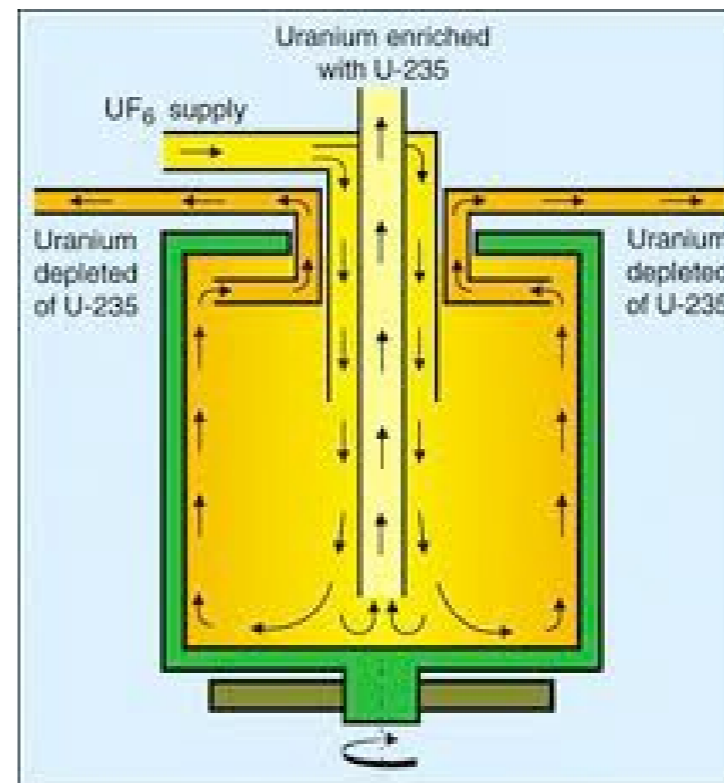


AFTER: 20 JUN 04

Enrichment of Uranium-235 in Iran

Gas centrifuge isotope separation

- o Massive version of centrifuges used in science and medicine
- o Feed stock is uranium hexafluoride (UF_6) gas
- o Iran has Uranium enrichment facilities in Natanz and Fordow
- o Total number of IR-1 centrifuges: ~15,400 (~8,800 used for U-235 enrichment)
in addition ~ 1000 more modern IR-2m centrifuges (not used)
- o **Stock of about 12,500 kg of LEU prior to JCPOA in 2014**



How Did Iran Gain Access to Ultra Centrifuge Technology? Proliferation from Pakistan!

The New York Times

A Chain Reaction of Proliferation

"The Nuclear Express," a new book on the history of the atomic age, describes the interlocking web of influence and espionage behind the proliferation of nuclear technology. This diagram gives a summary of the authors' tracking of the transfers of nuclear technology and secrets.

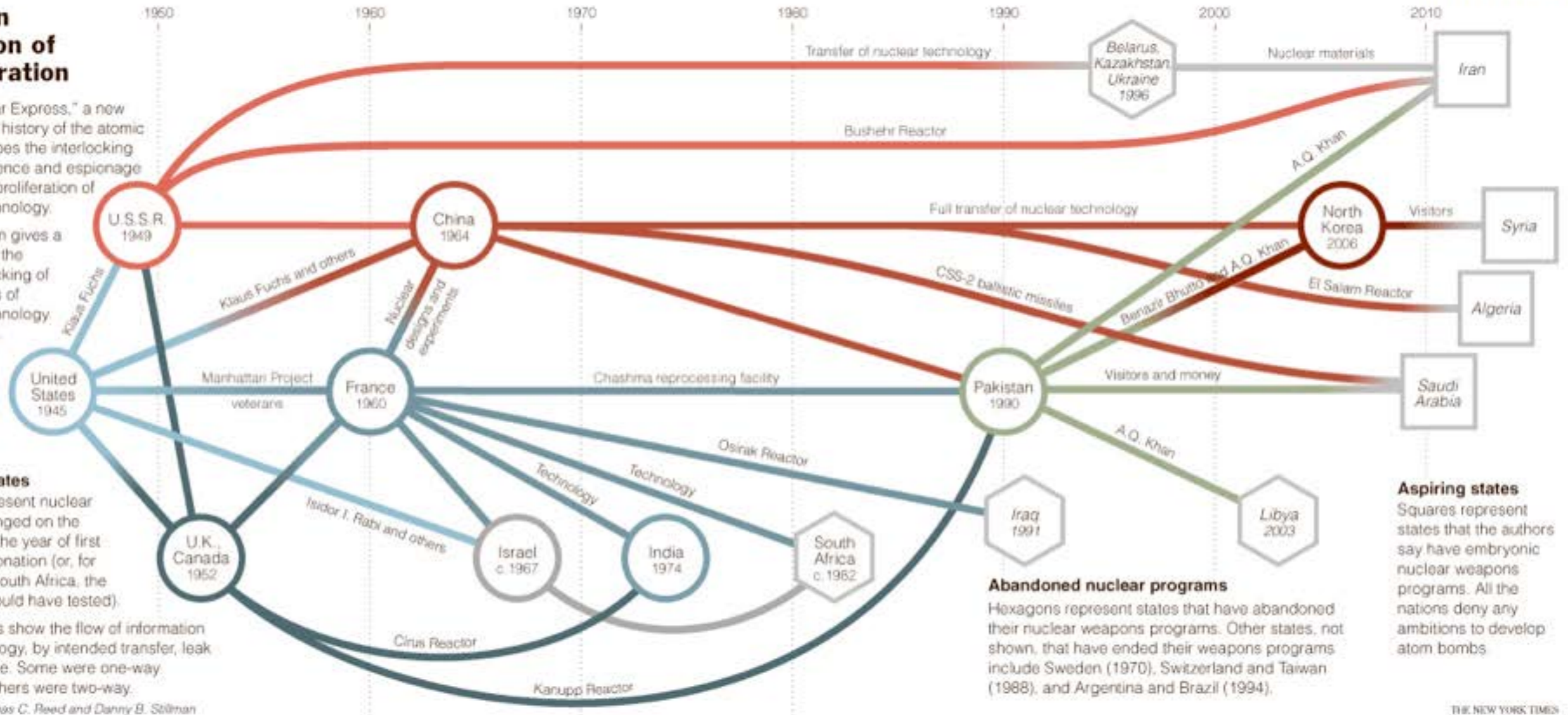
Connections show the flow of information and technology, by intended transfer, leak or espionage. Some were one-way transfers; others were two-way.

Nuclear states

Circles represent nuclear states, arranged on the timeline by the year of first nuclear detonation (or, for Israel and South Africa, the year they could have tested).

Connections show the flow of information and technology, by intended transfer, leak or espionage. Some were one-way transfers; others were two-way.

Sources: Thomas C. Reed and Danny B. Stillman



Aspiring states
Squares represent states that the authors say have embryonic nuclear weapons programs. All the nations deny any ambitions to develop atom bombs.

Abandoned nuclear programs

Hexagons represent states that have abandoned their nuclear weapons programs. Other states, not shown, that have ended their weapons programs include Sweden (1970), Switzerland and Taiwan (1988), and Argentina and Brazil (1994).

THE NEW YORK TIMES
RECOMMEND

This article has been revised to reflect the following correction:

Correction: December 15, 2008

A chart last Tuesday with an article about the proliferation of the atomic bomb, showing the exchange of nuclear information and technology between countries, misidentified the type of reactor that India acquired from Canada, which allowed India to make fuel for its first nuclear test. It was a CIRUS reactor, not a Candu reactor.

Plutonium could be Created in Arak Heavy Water Reactor and Chemically Separated from Spent Reactor Fuel

The fissile isotope Pu-239 can be created by bombarding U-238 with neutrons in a nuclear reactor. **Heavy water reactors, like the one under construction in Arak, Iran are well suited from Plutonium production starting from natural Uranium (no enrichment necessary)!**



Arak: 40 MW heavy water reactor + plant



Potential: Pu-239 for ~2 warheads/year

Picture credit: LA Times

Selected history of Iran's nuclear program

- 1967** Iran's 1st nuclear reactor, the Tehran Research Reactor (TRR)—which was supplied by the U.S.—goes critical, using U enriched to 93% (converted to run on 20% in 1993)
- 1970** Iran ratifies the Nuclear Nonproliferation Treaty (NPT)
- 1974** The Shah, with U.S. support, announces plans to build 23 nuclear power plants and to develop a full nuclear fuel cycle
- 1979** The Iranian revolution breaks U.S.-Iranian ties; nuclear projects are halted
- 1984–1996** The U.S. imposes a series of sweeping sanctions on Iran
- 2002** Iran's nuclear facilities near Natanz and Arak become public knowledge
- 2003** IAEA calls on Iran to suspend all enrichment and reprocessing related activities and to allow inspectors to conduct environmental sampling at any location; Iran agrees to voluntarily suspend activities and abide by NPT Additional Protocol
- 2004** IAEA rebukes Iran for not cooperating with IAEA inspectors
- 2005** Iran begins producing UF₆; IAEA finds Iran noncompliant with NPT safeguards

Selected history of Iran's nuclear program

2006 Iran stops implementing the Additional Protocol and inspection procedures, announces it has enriched U for 1st time, to 3.5%

2006–2009 Sequence of UNSC resolutions and sanctions against Iran; Obama reverses U.S. policy and agrees to talk to Iran; Iranian government agrees to ship most of its LEU abroad and not replace its MEU stock, which has been used up; outcry from all sides in Iran causes the government to withdraw from the agreement

2007 U.S. intelligence community says Iran halted its weapons program in 2003

2010 Iran begins to produce 20% MEU, allegedly for the TRR

2010–2012 More UNSC resolutions, more sanctions, more negotiations; talks founder over Iran's insistence on its right to enrich U

2013 Hassan Rouhani elected president of Iran, offers more flexibility, calls for resumption of serious negotiations with the P5+1*; Joint Plan of Action (JPOA) signed, laying out first-phase agreement and a broad framework to guide talks

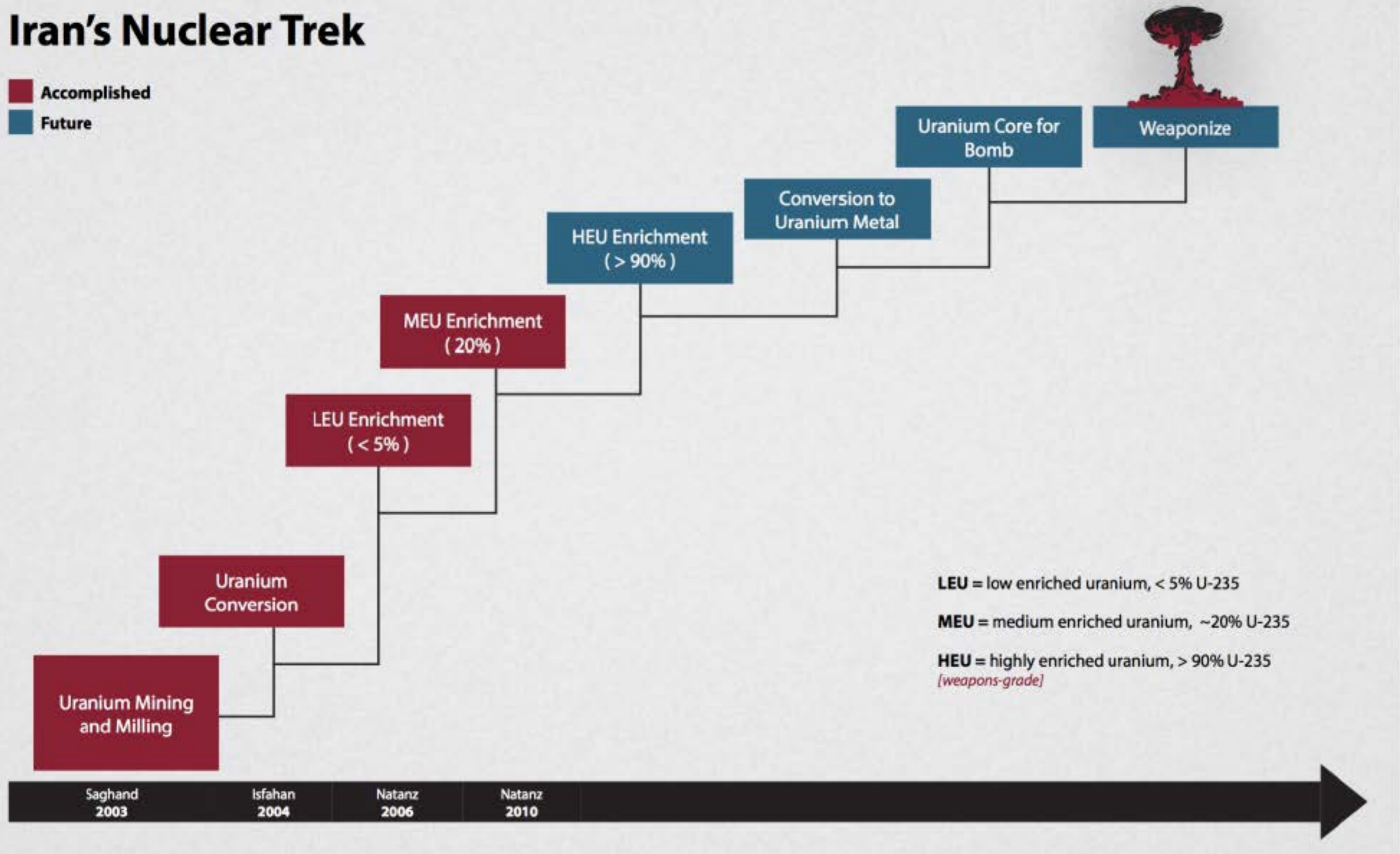
2014 Implementation of Joint Plan of Action (JPOA) begins, Iran complies fully

*P5+1 = China, France, Russia, UK, US + Germany

Key steps in Iran's nuclear program

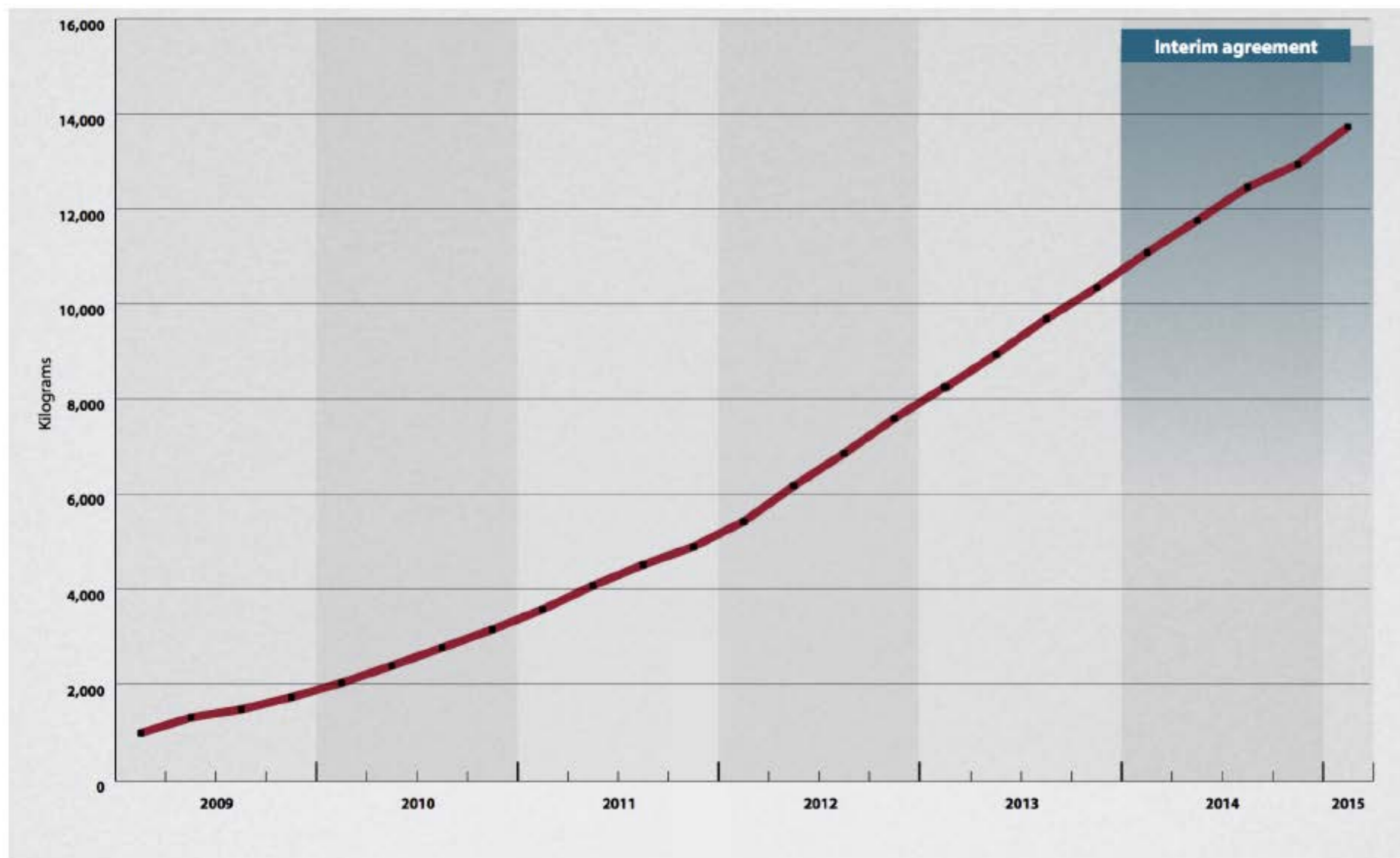
Iran's Nuclear Trek

■ Accomplished
■ Future



Credit: Belfer Center for Science and International Affairs

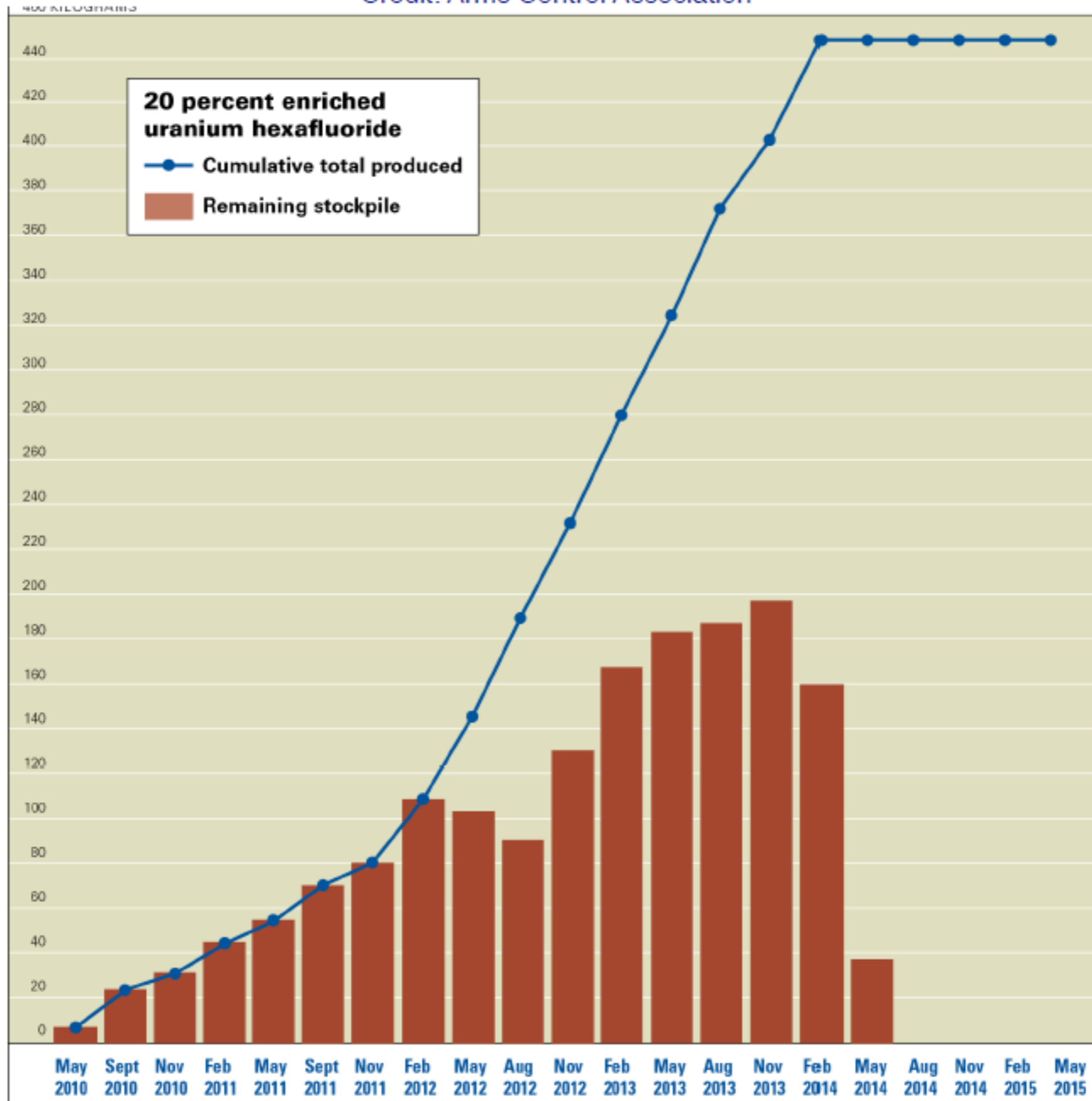
Cumulative LEU production at Natanz



Credit: Belter Center for Science and International Affairs

Impact of December 2013 JPOA on 20% LEU Stockpile

Credit: Arms Control Association



Physics 280: Session 30

Questions

Final: Tuesday May 10th, 7.00 – 10.00 pm
120 Architecture Building

Final Prep:

Office hours Wed. 5-4 from 1-4pm in Grainger

Review: Monday 5-9 from 5 to 8pm in Loomis 464

ICES current: 25/63

News

Module 9 The Iran Nuclear Deal, The Future

US to buy 32 metric tons of Iranian heavy water to fulfill nuclear deal terms

Republicans criticized \$8.6m purchase of nuclear materials, which will be resold for research purposes, as going 'well beyond' scope of last year's accord

AP in Washington

Friday 22 April 2016 13.46 EDT

The US is buying 32 metric tons of Iranian heavy water, a key component for one kind of nuclear reactor, to help Iran meet the terms of last year's landmark nuclear deal under which it agreed to curb its atomic program in exchange for billions of dollars in sanctions relief.

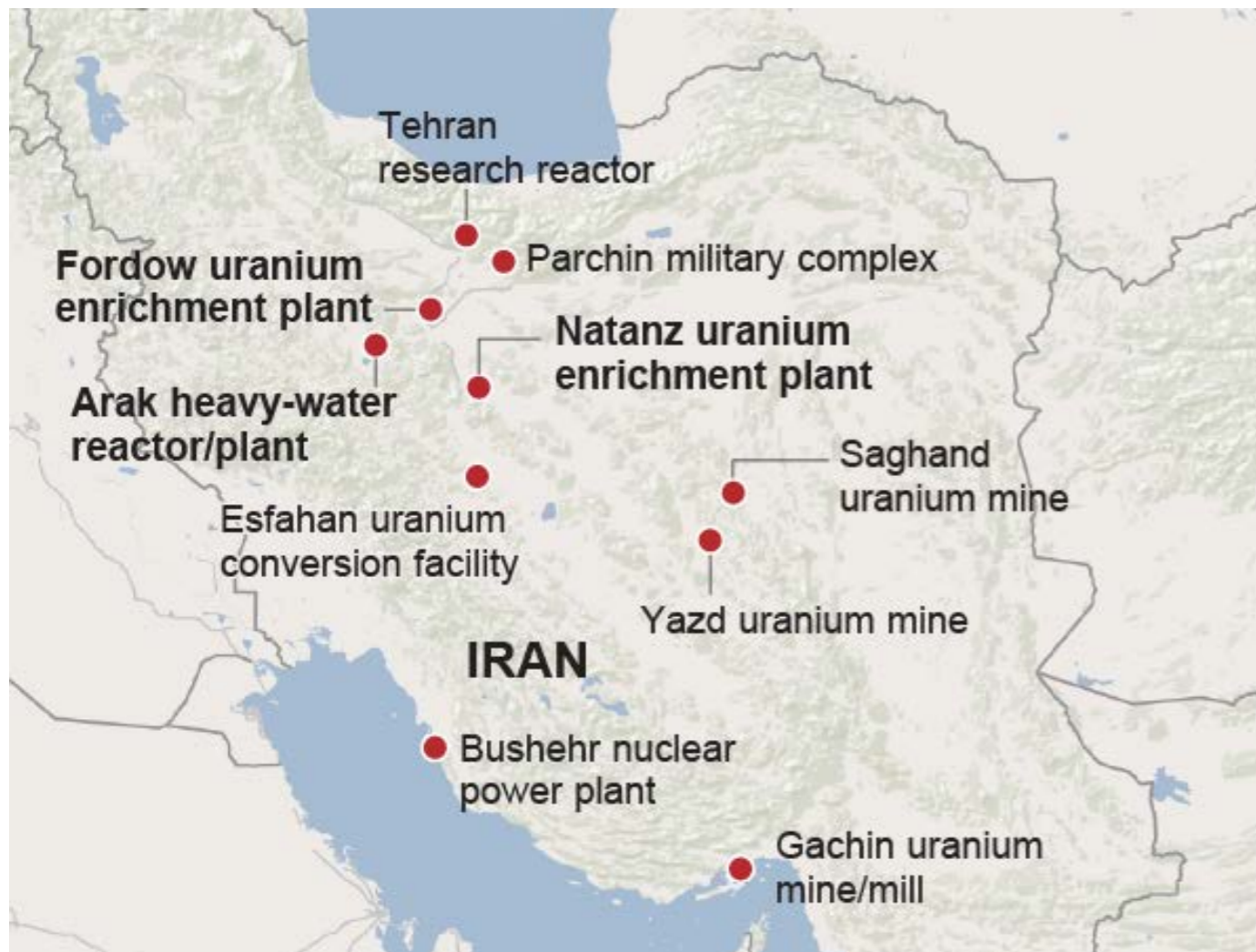
The US state and energy departments said a sales agreement would be signed Friday in Vienna by officials from the six countries that negotiated the nuclear deal. The agreement calls for the energy department's Isotope Program to purchase the heavy water from a subsidiary of the Atomic Energy Organization of Iran for about \$8.6m, officials said. They said the heavy water will be stored at the Oak Ridge national laboratory in Tennessee and then resold on the commercial market for research purposes.

Heavy water, formed with a hydrogen isotope, is not radioactive but has research and medical applications and can also be used to produce weapons-grade plutonium. Under the nuclear deal, Iran is allowed to use heavy water in its modified Arak nuclear reactor, but must sell any excess supply of both heavy water and enriched uranium on the international market.

Iranian news agencies reported in early March that a deal would soon be finalized. Members of Congress on Friday were criticizing the deal as another example of the Obama administration giving Iran more than it is entitled to. Those concerns have been fueled by indications the administration may be preparing to ease financial restrictions on transactions involving Iran.

Plutonium could be Created in Arak Heavy Water Reactor and Chemically Separated from Spent Reactor Fuel

The fissile isotope Pu-239 can be created by bombarding U-238 with neutrons in a nuclear reactor. **Heavy water reactors, like the one under construction in Arak, Iran are well suited from Plutonium production starting from natural Uranium (no enrichment necessary)!**



Arak: 40 MW heavy water reactor + plant



Potential: Pu-239 for ~2 warheads/year

Picture credit: LA Times

Foreign firms dash to get in on Iran 'gold rush' - but US companies left out in cold

With Washington's economic sanctions against Tehran set to continue even after implementation of the nuclear deal, investment in what many believe is the world's last great emerging economy may prove too risky for US firms

David Smith in Washington

Saturday 2 January 2016 07.21 EST

American companies risk missing out on a "gold rush" in Iran if sanctions are lifted as expected this year under the controversial nuclear deal, experts have warned.

Companies from Asia and Europe are already flocking to do business in the emerging economy, which is set to come in from the cold should Tehran meet its obligations to not pursue a nuclear weapon.

But while the accord has been billed as a flagship of Barack Obama's foreign diplomacy, the US might be among the last to benefit commercially. Only a small fraction of US sanctions - those related to Iran's nuclear activities - will be suspended as part of the deal, which also allows for a "snapback" of all sanctions in the event of non-compliance.

Although US companies' foreign subsidiaries will be allowed to engage with Iran, a minefield of regulatory, transparency and legal issues could present more risk than reward in the eyes of many. Investors are also likely to be wary of the next US presidential election, with Republican candidates vowing to scrap the deal if they come to office.

Other countries, however, appear to have embraced the deal and Iran's potential as a sleeping giant. "If you want to see optimism, you just go to Dubai airport at about 8am," Adam Smith, a lawyer focused on international trade compliance, told the Atlantic Council thinktank in Washington recently. "Ten flights a day between Dubai and Tehran, all packed.

"It's really quite amazing and every discussion you have with big companies, small companies, middle companies throughout the Gulf starts exactly the same way. They say, 'Mr Smith, please have some tea. Let me tell you about my recent trip to Tehran.' It's exactly the same discussion every single time. Even companies that are subsidiaries of US companies: really, it's everybody."

The New York Times

John Kerry Confronts Concerns of Arab States After Iran Nuclear Deal

By DAVID E. SANGER APRIL 7, 2016

MANAMA, Bahrain — A year after he struck the outlines of a nuclear deal with Iran, Secretary of State John Kerry finds himself confronting a new challenge from Tehran: While it is observing the nuclear agreement to the letter, its missile launches, arms shipments to Yemen and involvement in Syria have, if anything, accelerated.

Mr. Kerry arrived here for a meeting of the Arab states this week with the objective of reassuring them with an array of plans for new missile and cyberdefenses. Instead, he found himself disputing the argument of one leading diplomat from the United Arab Emirates that Tehran today is “as dangerous as ever.”

Without nuclear fuel or the ability to produce more, Mr. Kerry argued, Iran is far less of a threat than it was, adding that “the crisis was the potential of a nuclear weapon.”

But his hosts at a meeting of the Gulf Cooperation Council echoed the concern here on Thursday that, even with the nuclear threat off the table, the Islamic Revolutionary Guards Corps seemed to be active everywhere.

Context and purposes of the Iran nuclear deal

Prior to the Iran deal —

- Iran was a threshold nuclear weapon state
- In 1–2 months it could have produced enough HEU to make a nuclear weapon
- In 12 months it could have developed and tested a nuclear weapon

Purposes of the Iran deal —

Increase to 12 months the time required for Iran to make enough HEU for a bomb

Very stringent, beyond the usual NPT regime, restrictions for nuclear program in Iran for 8-20 years aims to stop technology development for nuclear weapons and to direct expertise acquired for nuclear weapons program into civilian research.

Beyond 20 years: Iran will be a regular state party to the NPT.

Credit: U.S. Department of State



Ernie Moniz

Components of the Iran nuclear deal

- Joint Comprehensive Plan of Action (JCPOA)
- Nonproliferation Treaty (NPT)*
- NPT Expanded Declaration*
- NPT Additional Protocol*
- Modified Code 3.1 Agreement*

*Iran must comply with these in perpetuity

JCPO Actions with Regards to Arak

- (1) Iran will redesign and rebuild reactor into lower power research reactor with P5+1 partnership.
- (2) Iran would take out the original core of the reactor and make it unusable.
- (3) Permanent: Iran will not produce weapons grade plutonium.
- (4) For 15 years: no additional heavy water reactors in Iran.
- (5) Permanent: Iran exports all spent fuel from the Arak reactor and does not process spent reactor fuel.
- (6) Iran only keeps the fraction of heavy water production that is needed for the operation of Arak, any balance is exported.

JCPO Actions with Regards to Natanz

- (1) For 10 years: # of centrifuges reduced to 5,060 IR-1. Excess centrifuges stored under IAEA monitoring
- (2) For 15 years: level of uranium enrichment capped at 3.67%
- (3) For 15 years: stockpile kept under 300 kg up to 3.67% enriched UF6 (98% reduction from existing stockpiles).
- (4) Excess sold based on international prices.
Uranium oxide enriched 5-20% fabricated into fuel for Tehran Research Reactor.
- (5) For 15 years: Natanz will be Iran's only enrichment facility.
- (6) Between years 11-15: Iran can replace IR-1 centrifuges at Natanz with more advanced ones.

JCPO Actions with Regards to Fordow

- (1) Converted to (international) research facility. No more Uranium enrichment or R&D at this facility.
- (2) 1,044 IR-1 centrifuges in six cascades will remain here, for medical and industrial isotope enrichment.
- (3) For 10 years: R&D with uranium will only include IR-4, IR-5, IR-6 and IR-8 centrifuges.
- (4) After 8 years: Iran starts manufacturing agreed numbers of IR-6 and IR-8 centrifuges without rotors.
- (5) After 10 years: begin phasing out IR-1 centrifuges.

On the Possibility of Fordow as International Science and Technology Center

Reasons for a Science Center at Fordow: (see online article in Nature:

<http://www.nature.com/news/iran-nuclear-deal-raises-hopes-for-science-1.17321>

- engage Iran's scientific and technological elite in interesting fundamental research and gainful applied research. Reduce alignment with needs of nuclear weapons program. Reduce alignment with political elite.
- bring foreign scientists into Iran for exchange (breaking Iranian propaganda myths and obtaining first hand information).
- from the Iranian side: maintain workforce in nuclear physics and engineering.

Two previous examples of scientific exchange to contribute to enhancing mutual understanding:

CERN, the European Laboratory for Nuclear and Particle Physics, Geneva, CH

- exchange and collaboration between European scientists after WWII
- “ between Western and Soviet Scientist

SESAME, the International Synchrotron Light Source in Allaan Jordan

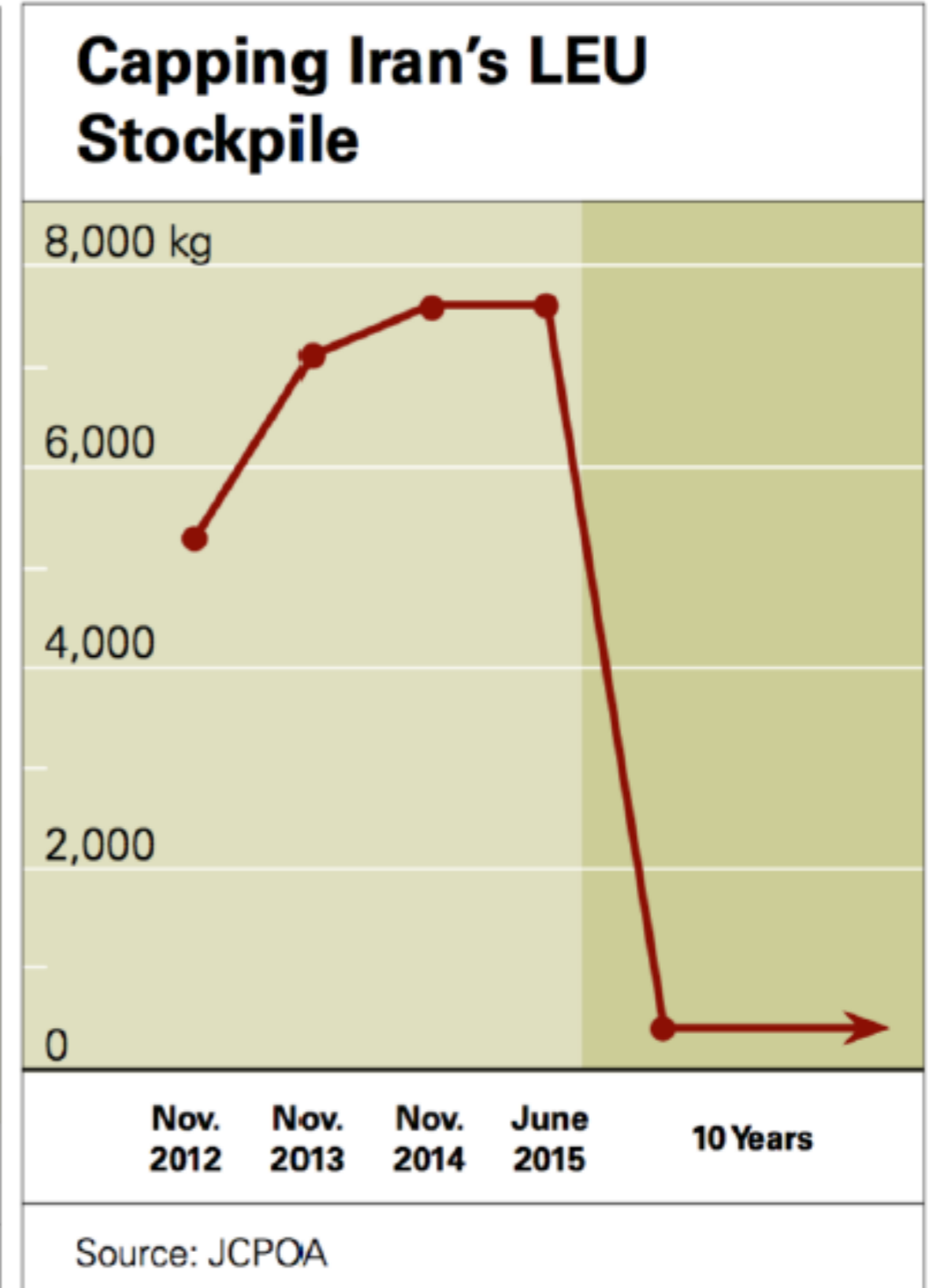
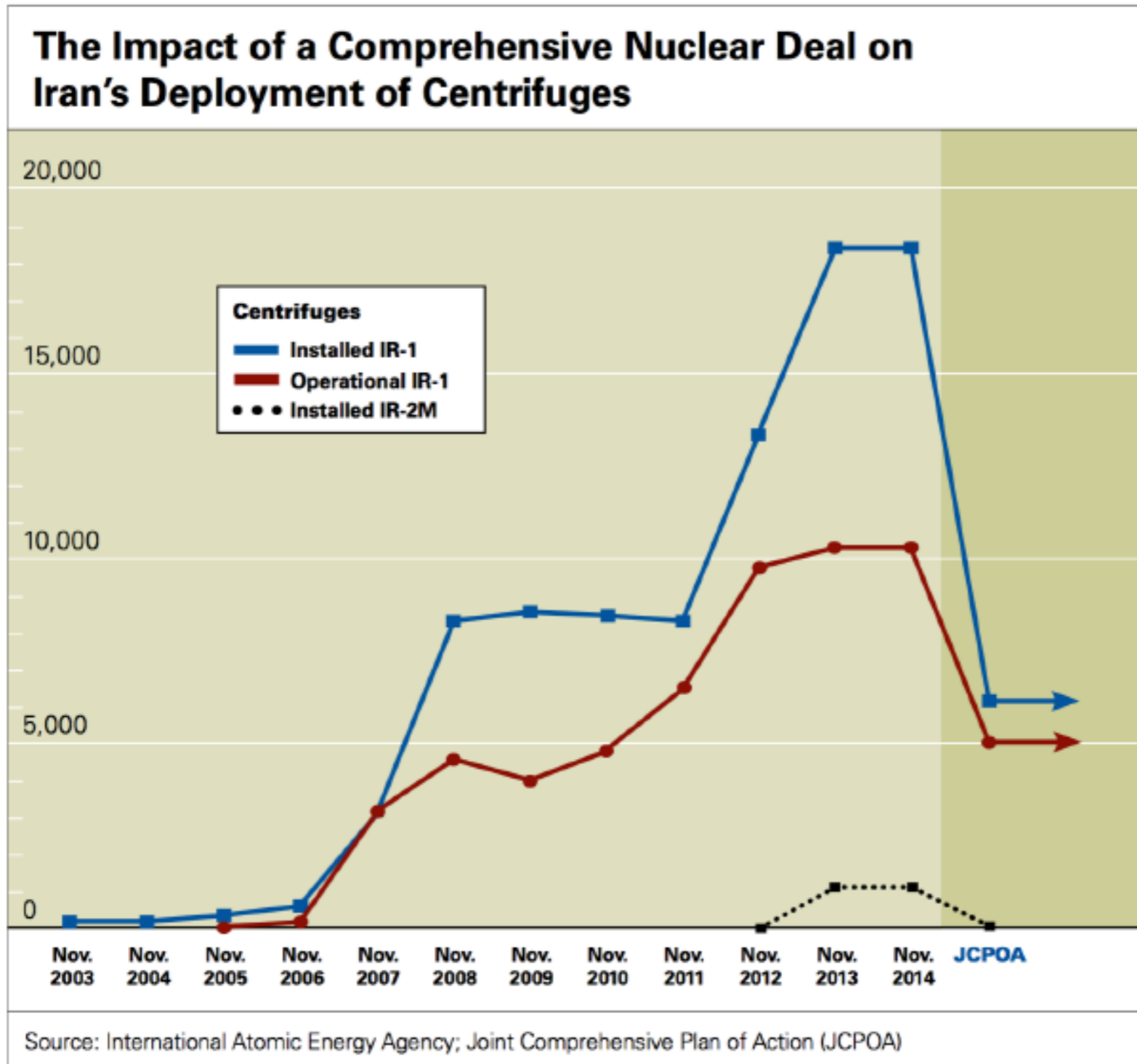
- “ between Scientists from Jordan, Israel, Cyprus, Pakistan, Egypt and Iran (initiated by former CERN directors, uses former BESSY accelerator)

Key Iran deal restrictions and durations

Credit: Belter Center for Science and International Affairs

Uranium route	Plutonium route	Duration
<ul style="list-style-type: none"> No enrichment above 3.67% (low-enriched uranium) Stockpile of low-enriched uranium reduced to 300 kg No other enrichment facilities Fordow: 1,044 centrifuges installed (not enriching) 	<ul style="list-style-type: none"> No construction of additional heavy water reactors Ship out unused heavy water 	15 years
<ul style="list-style-type: none"> Natanz: 5,060 centrifuges enriching Roughly one year breakout No enrichment using advanced centrifuges (some R&D permitted) 		10 years
	<ul style="list-style-type: none"> No reprocessing of spent fuel All spent fuel from Arak shipped out of country for lifetime of reactor 	Permanent
	<ul style="list-style-type: none"> Destruction or removal of Arak core 	

Iran deal cut Iran's centrifuges and LEU stockpile



Credit: Arms Control Association

Iran deal monitoring and verification provisions

Credit: Belter Center for Science and International Affairs

IAEA granted:	Iran agrees:
"Regular access" to all nuclear facilities	To implement Additional Protocol and Modified Code 3.1
Monitoring of nuclear-related purchases from abroad through "dedicated procurement channel"	To "implement an agreed set of measures to address" possible military dimensions
Access to uranium mines and continuous surveillance of uranium mills for 25 years	
"Continuous surveillance" of centrifuge production and storage facilities for 20 years	
Access "to investigate suspicious sites or allegations of covert" nuclear facilities	

Examples of Iran deal verification provisions

Among other things, Iran is required, in perpetuity, to report —

- all nuclear fuel cycle development plans for 10 years ahead
- all nuclear fuel cycle-related R&D activities not involving nuclear material
- all production of uranium and thorium at mines and mills
- all nuclear-related imports and exports
- any production of heavy water or graphite
- manufacture of centrifuge and other enrichment components
- manufacture of flasks for irradiated fuel
- construction of large hot cells
- the location, and any further processing, of nuclear wastes

Examples of Iran deal verification provisions

Iran must, in perpetuity, submit design information for new nuclear facilities as soon as the decision is made to construct them or to authorize construction (Modified Code 3.1)

IAEA inspectors have access rights to —

- anywhere on a declared nuclear site
- locations included in the Expanded Declaration
- locations anywhere else that the IAEA identifies for investigation

Timelines for access —

- within 2 hours or less, if carried out with an inspection
- within 24 hours elsewhere
- if Iran contests an inspection at an undeclared or military facility, that triggers a process that guarantees access within 24 days

Swipe sampling of equipment



Other examples of environmental sampling



Current environmental sampling capabilities

Environmental sampling for verifying compliance is based on strong evidence that every nuclear process—no matter how leak tight—emits small amounts of material to the environment.

Current verification techniques can locate micron-sized particles of nuclear materials and determine their composition.

Current analytical techniques can detect *picograms of U* (10^{-12} g = parts per trillion) and *femtograms of Pu* (10^{-15} g = parts per quadrillion) and determine their isotopic composition and the implications for compliance with the Iran deal.

Implementation of the Iran deal

- 2015 July 14** Iran and P5+1 announce a comprehensive deal
- July 20** UN Security Council unanimously endorses the deal
- Aug 15** IAEA confirms that Iran is addressing its unresolved concerns
- Sept 9** IAEA submits follow-up questions to Iran
- Sept 17** Motions in U.S. Senate to vote on disapproval end
- Sept 20** IAEA carries out environmental sampling at the Parchin site
- Oct 14** Iran's Parliament and Guardian Council ratify the Iran Deal
- Dec 2** IAEA reports on possible military dimensions of Iran's nuclear program

Iran disassembles centrifuges, ships MEU and LEU to Russia, pours concrete into the core of the Arak nuclear reactor.

2016 Jan 16 – Implementation Day IAEA verifies that Iran has met its commitments, triggering the lifting of nuclear-related sanctions

Incentives for Iran's continued compliance

Credit: Arms Control Association



iClicker Question

Can the IAEA inspect any site in Iran (including undeclared sites or military sites) ?

- A. Yes
- B. No
- C. Yes, after an arbitration process no later than 24 days after the request has been made

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iClicker Question

Environmental sampling includes taking swipes.
Is it correct that in some cases Iranian technicians will be taking the swipes?

- A. No, propaganda of hawkish media!
- B. Yes, Iran does not allow IAEA inspectors access to military facilities and in this case swipes are taken by Iranian technicians.
- C. Yes, under the direct supervision of IAEA inspectors to avoid possible external contaminations carried in by IAEA personnel.

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The Future: Some recommendations

- Securing the Bomb 2008 (by Matthew Bunn, for the Nuclear Threat Initiative)
- Unilateral U.S. actions (Union of Concerned Scientists)
- President Obama's approach (outlined in his Prague speech)

See the reading assignments on these topics

The Future: Securing the Bomb

Some threats —

- Insecurity of Pakistan's nuclear stockpile
- Security weaknesses in Russia
- many research reactors around the world still use HEU
- The United States “lost” six nuclear weapons

The Future: Securing the Bomb -> GTRI

Since 2004 GTRI (Global Threat Reduction Initiative National Nuclear Security Administration) has accomplished:

Convert

- Successfully **converted to LEU fuel or verified the shutdown of 49 HEU research reactors in 25 countries**, including Argentina, Australia, Bulgaria, Canada, Chile, China, the Czech Republic, France, Germany, Hungary, India, Japan, Kazakhstan, Libya, the Netherlands, Portugal, Poland, Russia, Ukraine, the United Kingdom, United States, Uzbekistan, and Vietnam; and verified the cessation of the use of HEU targets for isotope production in Indonesia.
- **Accelerated the establishment of a reliable supply of the medical isotope molybdenum-99 (Mo-99) produced without HEU** by establishing partnerships with South Africa, Belgium, and the Netherlands to convert Mo-99 production from HEU targets to LEU targets, and with four domestic commercial entities to produce Mo-99 in the United States with non-HEU technologies.

Remove

- Successfully **removed or confirmed the disposition of more than 4,100 kilograms of HEU and plutonium** (more than enough material for 165 nuclear weapons);
- **Removed all weapons-usable HEU from 16 countries and Taiwan**, including: Greece (December 2005), South Korea (September 2007), Latvia (May 2008), Bulgaria (August 2008), Portugal (August 2008), Romania (June 2009), Taiwan (September 2009), Libya (December 2009), Turkey (January 2010), Chile (March 2010), Serbia (December 2010), Mexico (March 2012), Ukraine (March 2012), Austria (December 2012), and Czech Republic (April 2013); and
- Removed more than 36,000 disused and unwanted radiological sources from sites across the United States.

Protect

- **Completed physical protection upgrades at more than 1,700 buildings** in the United States and internationally with high-activity radiological sources; and
- **Provided Alarm Response Training to more than 3,000 site security, local law enforcement officers and other first responders** from across the country on responding to a potential incident involving radiological material.

The Future: Nunn-Lugar Cooperative Threat Reduction Program

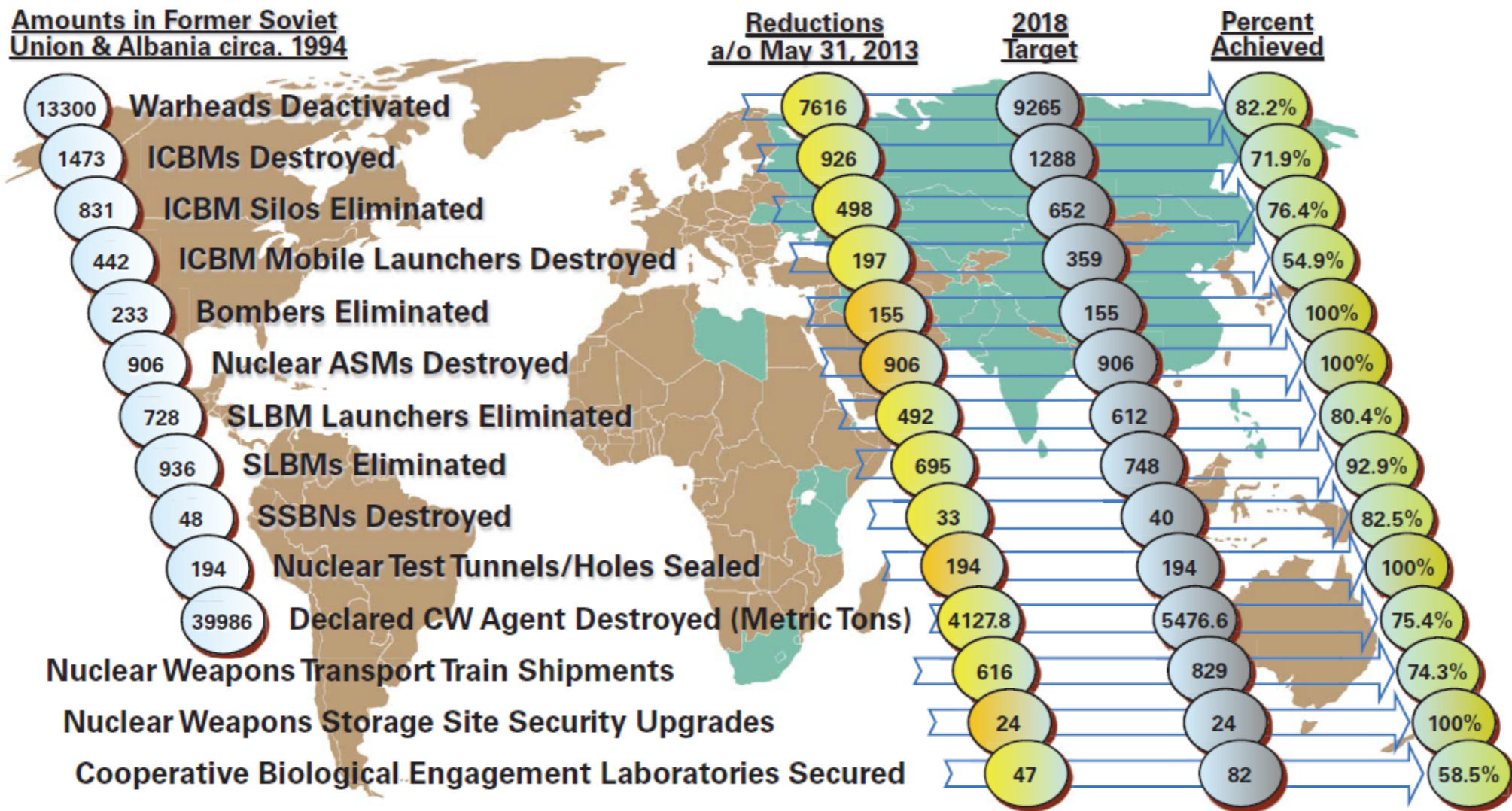


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Nunn-Lugar CTR Scorecard

Ukraine, Kazakhstan, & Belarus are Nuclear Weapons Free
Albania is Chemical Weapons Free

Amounts in Former Soviet Union & Albania circa. 1994



■ CTR partner states
■ Rest of the world

UNCLASSIFIED

2

The Future: Securing the Bomb

Achieving effective and lasting nuclear security —

- Launch a fast-paced global security campaign
- Seek to ensure that *all* nuclear weapons, plutonium, and highly enriched uranium are secure
- Expand and accelerate efforts to consolidate nuclear stockpiles
- Gain agreement on effective global nuclear security standards
- Build sustainability and a security culture

The Future: Securing the Bomb

In addition to nuclear security —

- Disrupt: focus counter-terrorism efforts on nuclear risks
- Interdict: counter the nuclear black market
- Prevent and deter: reduce the risk of nuclear transfers to terrorists by states
- Respond: global nuclear emergency response
- Impede: impede recruitment of nuclear personnel by terrorists
- Reduce: reduce stockpiles and end production
- Monitor: monitor nuclear stockpiles and reductions

The Future: Securing the Bomb

Leadership and commitment —

- Build the sense of urgency and commitment worldwide
- Put someone in charge
- Develop a comprehensive, prioritized plan
- Assign adequate resources
- Provide information and analysis to support policy
- Reduce: reduce stockpiles and end production
- Monitor: monitor nuclear stockpiles and reductions

The Future: Securing the Bomb

Put the United States' own house in order —

- Put more stringent nuclear security measures in place
- Convert U.S. research reactors to LEU
- Upgrade security on HEU research reactors
- Phase out HEU research reactor security exemptions
- Reverse the rule exempting HEU from almost all security requirements if it is radioactive enough to produce a dose rate of more than 1 Sv/hour at a distance of 1 m
- Convert medical isotope production using HEU to use LEU
- Increase preparations for nuclear mass casualties

Possible U.S. Unilateral Actions

(from the Union of Concerned Scientist and others)

10 Steps the United States Could Take Without Waiting for Others

Possible U.S. Unilateral Actions

The following recommendations were authored by analysts from the Federation of American Scientists (FAS), Natural Resources Defense Council (NRDC), Union of Concerned Scientists (UCS), and independent experts with long experience in nuclear weapons policy issues.

For further information, go to:

http://www.ucsusa.org/global_security/nuclear_weapons/trueseconomy.html

The greatest nuclear dangers to the United States are an accidental, unauthorized or mistaken Russian nuclear attack, the spread of nuclear weapons to more nations, and the acquisition of nuclear materials by terrorists. U.S. nuclear weapons policy fails to adequately address these risks and too often exacerbates them.

By taking 10 unilateral steps, the next president would bring U.S. nuclear weapons policy into line with today's political realities, and demonstrate to the rest of the world that the United States is serious about addressing what remains one of the gravest threats to human civilization.

Possible U.S. Unilateral Actions

1. Declare that the sole purpose of U.S. nuclear weapons is to deter and, if necessary, respond to the use of nuclear weapons by another country. Making it clear that the United States will not use nuclear weapons first would reduce the incentive for other nations to acquire these weapons to deter a potential U.S. first strike.
2. Reject rapid-launch options by changing U.S. deployment practices to allow the launch of nuclear forces within days instead of minutes. Increasing the amount of time required to launch U.S. weapons would ease Russian concerns about the vulnerability of its nuclear weapons and in turn give it the incentive to take its weapons off alert, reducing the risk of an accidental or unauthorized Russian launch on the United States.
3. Eliminate preset targeting plans, and replace them with the capability to promptly develop a response tailored to the situation if nuclear weapons are used against the United States, its armed forces, or its allies.

Possible U.S. Unilateral Actions

4. Promptly and unilaterally reduce the U.S. nuclear arsenal to no more than 1,000 warheads, including deployed and reserve warheads. There is no plausible threat that justifies maintaining more than a few hundred survivable nuclear weapons, and no reason to link the size of U.S. nuclear forces to those of any other country. The United States would declare all warheads above this level to be in excess of its military needs, move them into storage, begin dismantling them in a manner transparent to the international community, and begin disposing—under international safeguards—of all plutonium and highly enriched uranium beyond that required to maintain these 1,000 warheads. By making the end point of this dismantlement process dependent on Russia's response, the United States would encourage Russia to reciprocate.

5. Halt all programs for developing and deploying new nuclear weapons, including the proposed Reliable Replacement Warhead.

6. Promptly and unilaterally retire all U.S. nonstrategic nuclear weapons, dismantling them in a transparent manner, and take steps to induce Russia to do the same.

Possible U.S. Unilateral Actions

7. Announce a U.S. commitment to reducing its number of nuclear weapons further, on a negotiated and verified bilateral or multilateral basis.

8. Commit to not resume nuclear testing, and work with the Senate to ratify the Comprehensive Test Ban Treaty.

9. Halt further deployment of the Ground-Based Missile Defense system, and drop any plans for space-based missile defense. The deployment of a U.S. missile defense system that Russia or China believed could intercept a significant portion of its survivable long-range missile forces would be an obstacle to deep nuclear cuts. A U.S. missile defense system could also trigger reactions by these nations that would result in a net decrease in U.S. security.

10. Reaffirm the U.S. commitment to pursue nuclear disarmament, and present a specific plan for moving toward that goal, in recognition of the fact that a universal and verifiable prohibition on nuclear weapons would enhance both national and international security.

Priorities of the Obama Administration

As outlined by President Obama in his 2009 Prague speech

- Hosting a Global Summit on Nuclear Security, (2010 Washington, 2012 Seoul)
- Strengthening the Nuclear Non-Proliferation Treaty, achieved in part by actions at the NPT Five-Year Review Conference in 2010
- To “immediately and aggressively” pursue ratification of a Comprehensive Nuclear Test Ban Treaty
- Ending the production of fissile materials that can be used in nuclear weapons
- Expanding international inspections to detect treaty violations
- Securing all vulnerable nuclear material around the world within four years

The Future

**What will you do to reduce the
threat of nuclear weapons?**