The Iranian Nuclear Program

Timelines, Data, and Estimates

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Current as of SEP 04 2012 using data from IAEA report dated AUG 30 2012

Key Points

IRAN IS DEVELOPING A <u>RAPID NUCLEAR WEAPONS BREAKOUT CAPABILITY</u> BY REDUCING THE TIME IT NEEDS TO PRODUCE FUEL FOR AN ATOMIC WEAPON.

- Iran would need **4.3 MONTHS** to produce <u>25 kg</u> of weapons-grade uranium and **1.9 MONTHS** to produce <u>15 kg</u> of weapons-grade uranium *at the buried Fordow enrichment facility*.* IT CAN CUT THESE TIMES SIGNIFICANTLY USING THE NEWLY INSTALLED CENTRIFUGES AT FORDOW.

- Iran would need **3 WEEKS** to produce <u>25 kg</u> of weapons-grade uranium and **1 WEEK** to produce <u>15 kg</u> of weapons-grade uranium *at the larger Natanz enrichment facility*.*

- These estimates are based on data from Iran's declared operating facilities. The existence of undeclared (covert) enrichment sites, which cannot be ruled out given Iran's record of deception, would have an impact on breakout estimates.

IRAN IS <u>HARDENING ITS ENRICHMENT CAPACITY</u> AND <u>INCREASING INFRASTRUCTURE FOR ~20% LOW-ENRICHED URANIUM (LEU) PRODUCTION</u>.

- A **growing proportion of Iran's near-20% enriched uranium is being produced in the more hardened Fordow facility built under a small mountain**, rather than in the more vulnerable underground Natanz facility.

- The recent installation of **1,076 additional centrifuges at Fordow** has more than doubled capacity at that facility.

IRAN's <5% AND NEAR-20% <u>ENRICHED URANIUM PRODUCTION IS AT HISTORICALLY HIGH RATES</u>.

IRAN HAS PRODUCED ENOUGH <u>LOW-ENRICHED URANIUM TO FUEL FIVE NUCLEAR WEAPONS</u> AFTER CONVERSION TO WEAPONS-GRADE.

IRAN IS PURSUING <u>MULTIPLE PATHS TO OBTAINING NUCLEAR WEAPONS FUEL</u>.

- Iran recently told the International Atomic Energy Agency (IAEA) that it plans to begin operating the Arak heavy water reactor in Q3 2013. This reactor will be capable of producing **two warheads' worth weapons-grade plutonium per year** once operational.

**Estimates assume Natanz and Fordow are used with the operational capacity reflected in the August 2012 IAEA report. Iran may need 15-25 kg weapons-grade uranium for an implosion-type bomb design depending on its level of technical ability.*

FORDOW FACILITY EXPANSION: WHAT IS THE IMPACT?

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Iran installed 1,076 IR-1 centrifuges at Fordow between May and August 2012, bringing its total centrifuges at the facility to 2,140 (12 cascades of 174 centrifuges each and 1 cascade under construction with 52 centrifuges).

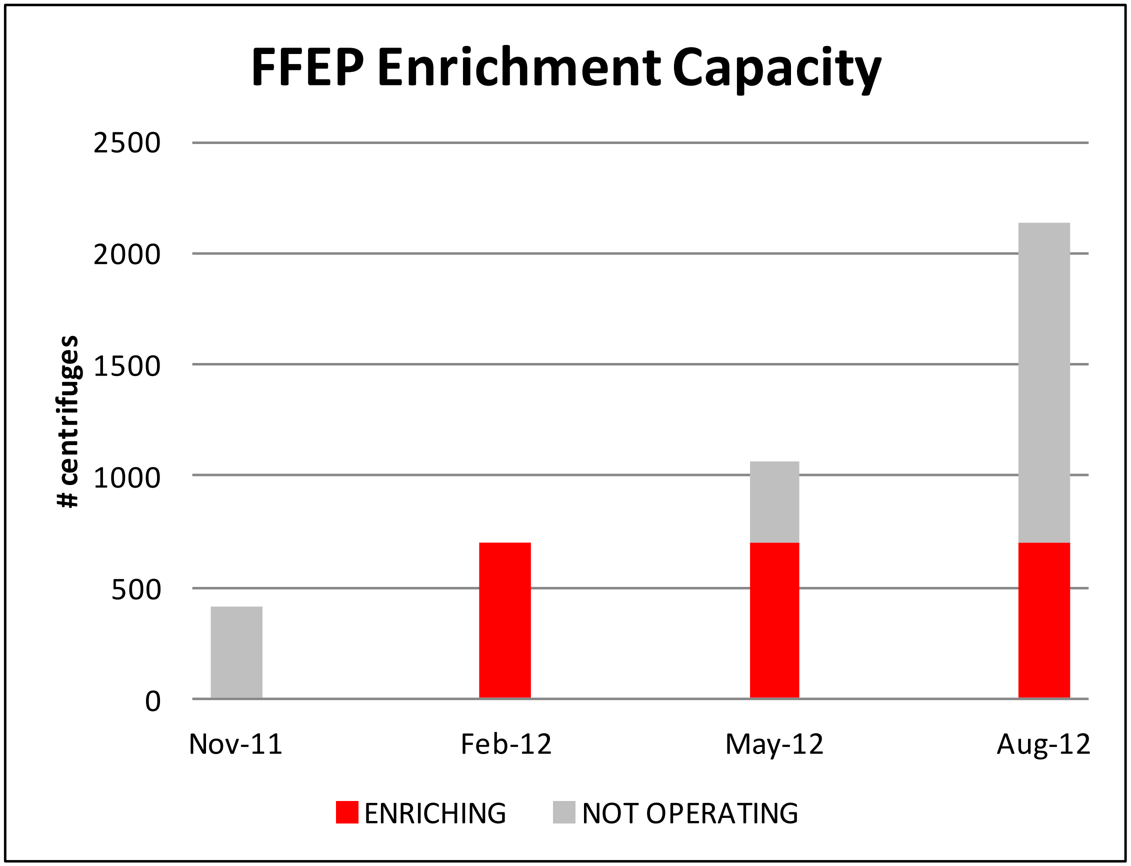
TIME REQUIRED FOR CONVERTING 141 KG NEAR-20% LEU INTO ONE WARHEAD'S WORTH WEAPONS-GRADE URANIUM:

Pre-expansion capacity

95 DAYS

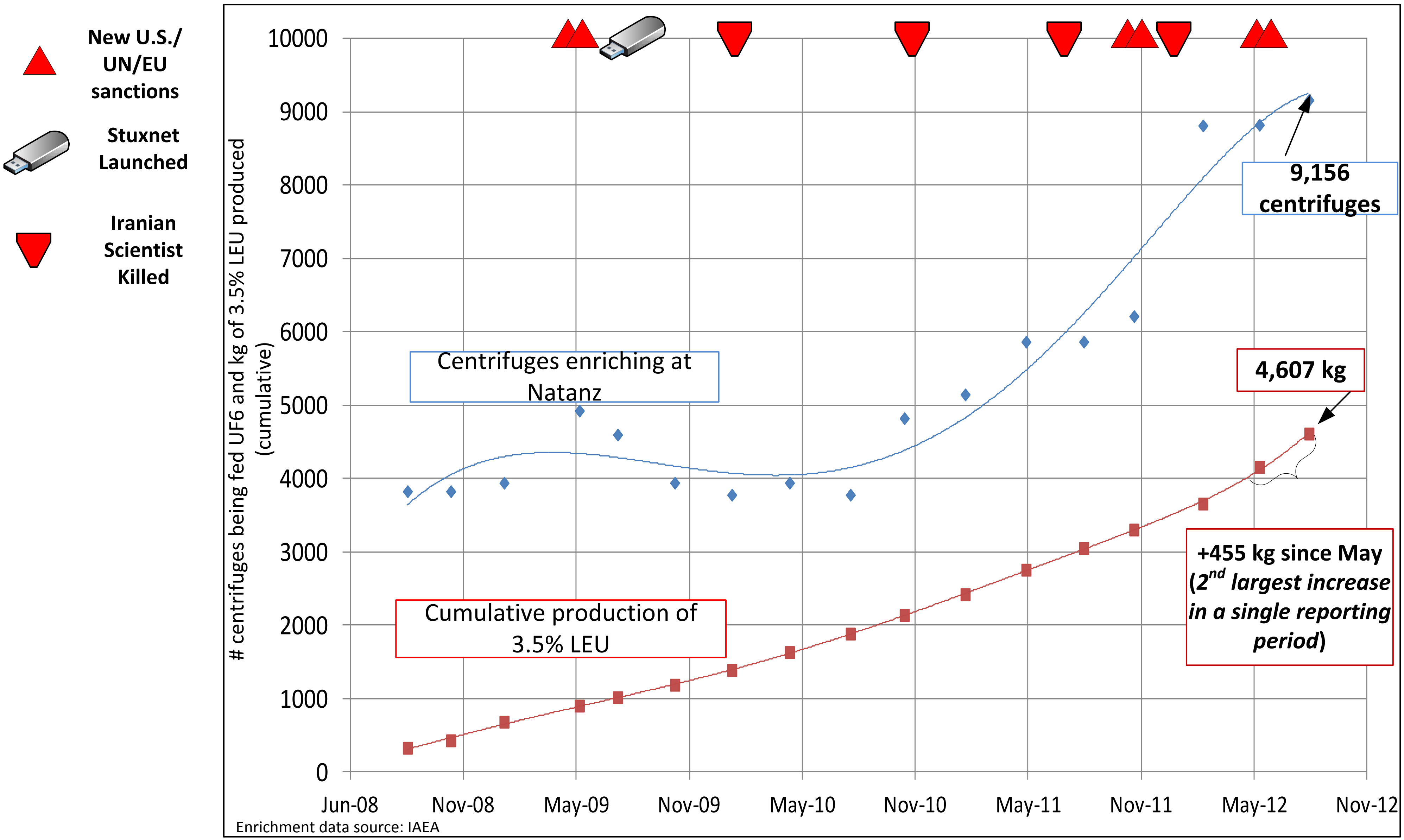
Post-expansion capacity

47 DAYS



Iran's Declared 3.5% LEU Production and IR-1 Centrifuges at Natanz

Assessment: Stuxnet derailed the 2009 Iranian effort to expand enrichment capability for roughly one year, but the enrichment expansion effort recovered in mid-2010. Neither direct actions nor sanctions have had a visible effect on the enrichment program. **Even the Stuxnet success does not appear to have derailed the steady growth of the Iranian 3.5% LEU stockpile.** Iran is running its highest number of centrifuges and production rates since the enrichment program began.



Iran's near-20% LEU Production and Projected Growth at Fordow/Natanz

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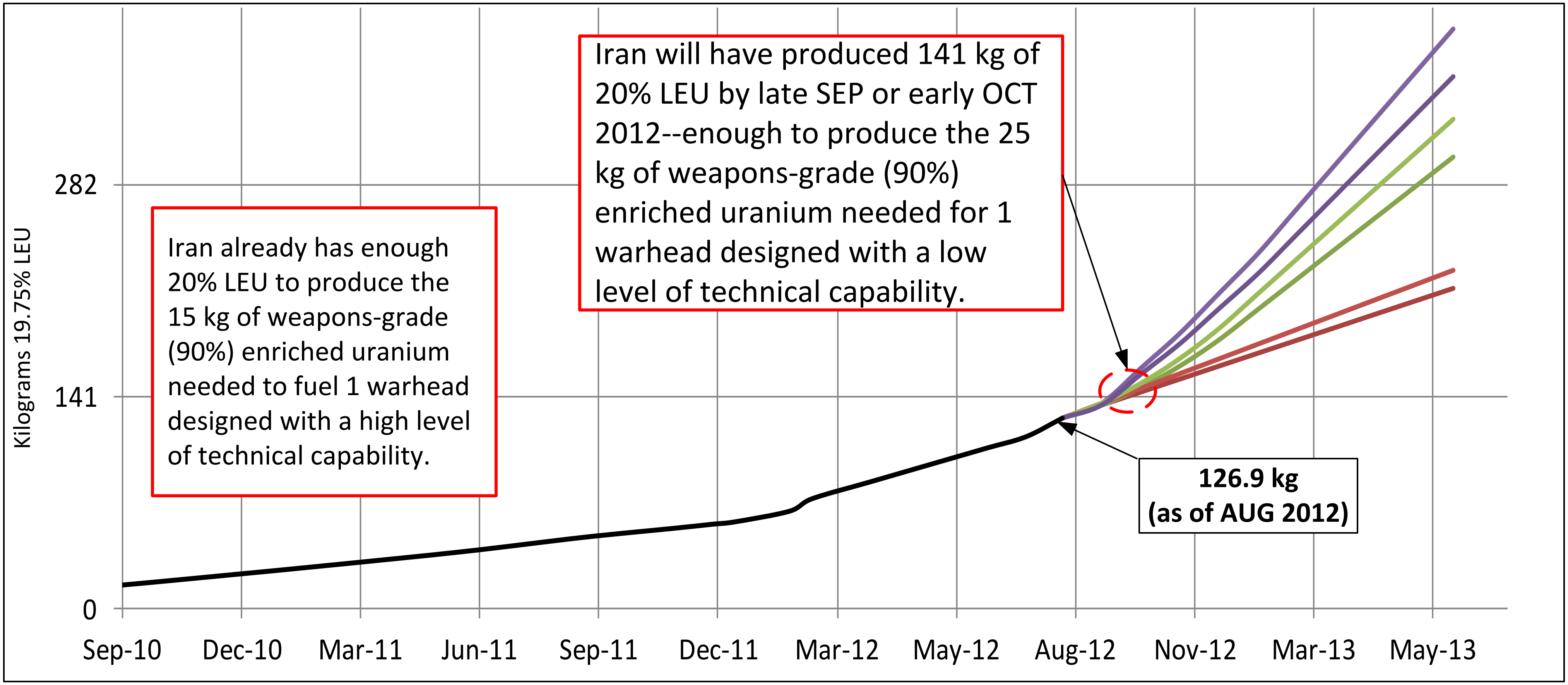


BLACK: Reported production

RED: Steady-state enrichment (a)

GREEN: Enrichment in all currently installed centrifuges (b)

PURPLE: Rapid expansion at Fordow (c)

**The two lines for each colored scenario represent a range based on different calculations of demonstrated centrifuge efficiency.*

(a) 1,024 centrifuges currently enriching (2 cascades with 328 total IR-1 centrifuges at PFEP and 4 cascades with 696 total IR-1 centrifuges at Fordow)

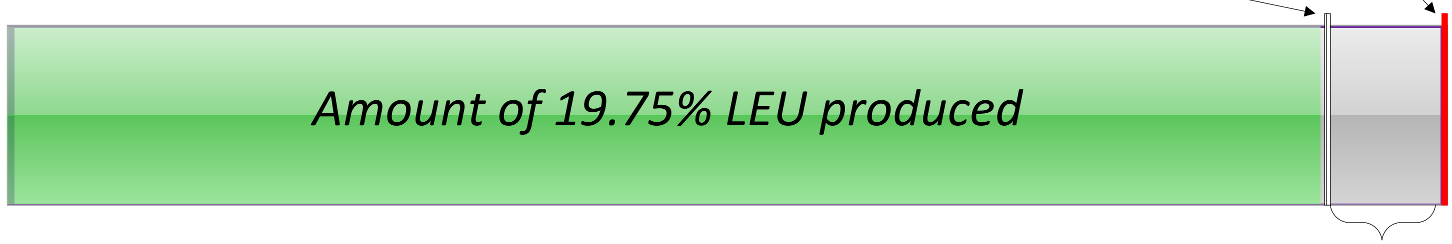
(b) Same as (a) but Iran begins turning on 2 additional cascades every month beginning in SEP until all 12 currently installed cascades at Fordow are operating.

(c) Iran begins enriching in the 8 additional cascades present at Fordow beginning in SEP. It installs and begins operating 2 additional cascades in NOV and in JAN 2013 (Fordow at full operational capacity with 16 cascades).

19.75% LEU: APPROACHING THE THRESHOLD

~126.9 kg produced*
(mid-AUG estimate)

141 kg needed
to produce 25 kg weapons-grade uranium



Iran can close the gap in approximately 5-6 weeks at recent production rates

Note: Amounts in elemental uranium

**Iran has converted some of this material to U_3O_8 for fuel plate production; fuel plates can be converted back to UF_6 gas in a short period of time for a breakout (see slide 21 for an explanation). Only after these fuel plates have been irradiated in the core of a reactor are they rendered unusable for a conversion back to UF_6 gas.*

When Could Iran Produce Fuel For One Nuclear Weapon?

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WORST-CASE BREAKOUT

15 KG REQ.

SEP 19 START*

116 kg 19.75% LEU

⇩

15 kg 90% HEU

SEP 24 (a) **COMPLETE**

25 KG REQ.

SEP 19 START

193 kg 19.75% LEU

⇩

25 kg 90% HEU

OCT 12 (b) **COMPLETE**

September 12

M	T	W	T	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

October 12

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	**12**	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

November 12

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	**15**	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

December 12

M	T	W	T	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

January 13

M	T	W	T	F	S	S
	1	2	3	4	5	6
7	8	9	10	11	**12**	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

February 13

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28			

March 13

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

April 13

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

May 13

M	T	W	T	F	S	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

MOST LIKELY BREAKOUT

15 KG REQ.

SEP 19 START

85 kg 19.75% LEU

⇩

15 kg 90% HEU

NOV 15 COMPLETE

25 KG REQ.

OCT 9 START

141 kg 19.75% LEU

⇩

25 kg 90% HEU

JAN 12 COMPLETE

These dates reflect Iran's technical capabilities in various scenarios. They are NOT estimates of Iran's intentions and they are NOT predictions of when Iran WILL acquire given amounts of 90% enriched uranium.

See slide 17 for assumptions and technical details underlying the estimates.

*SEP 15 start date for the worst-case scenario (15 kg, 25 kg) and most likely case (15 kg) assumes Iran needs 2 weeks to convert U_3O_8 enriched up to 20% for fuel plates back to gaseous form for breakout (see slide 21). OCT 9 start date for the most likely case (25 kg) assumes Iran breaks out after it has enough 20% enriched uranium at current production rates.

(a) If Iran breaks out using a three step process, the conversion would take an additional 25 days after this date.

(b) If Iran breaks out using a three step process, the conversion would take an additional 51 days after this date.

Key Upcoming Events

Bold dates are fixed; *italicized* dates are estimates
Listed inspection windows are approximate. The IAEA may be conducting inspections outside of these windows.

9/30/2012
Review of CBI sanctions waivers granted MAR 2012

10/9/2012
Approx. date by which Iran will have produced enough ~20% LEU to convert to weapons-grade fuel for 1 bomb

12/11/2012
Review of CBI sanctions waivers granted JUN 2012

10/1/2012 | 11/1/2012 | 12/1/2012 | 1/1/2013 | 2/1/2013 | 3/1/2013

9/10/2012
IAEA BOG meets

10/21/2012 - 11/11/2012
IAEA Inspection Window

11/29/2012
IAEA BOG meets

11/19/2012
IAEA Report

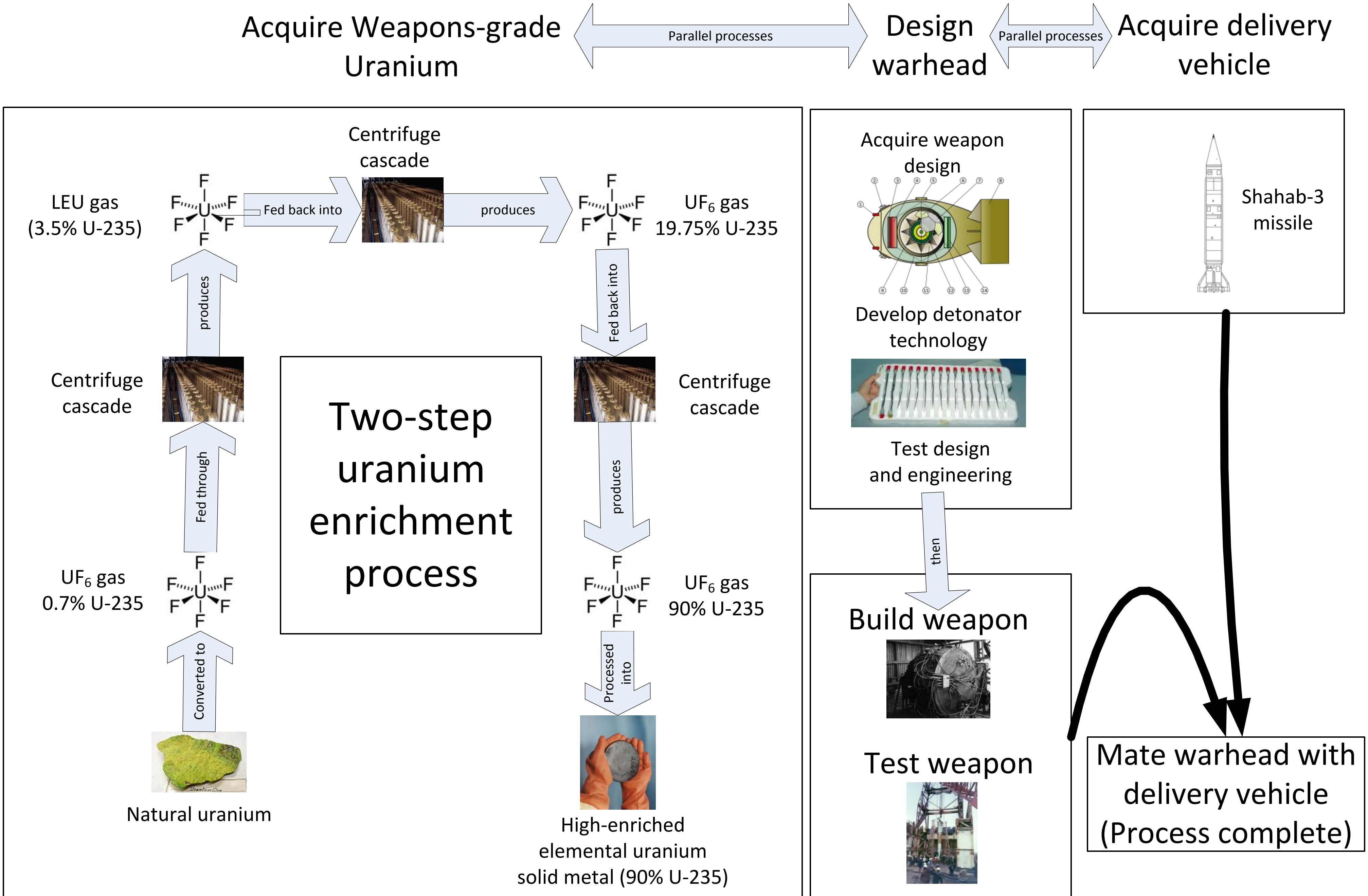
1/25/2013 - 2/15/2013
IAEA Inspection Window

3/4/2013
IAEA BOG meets

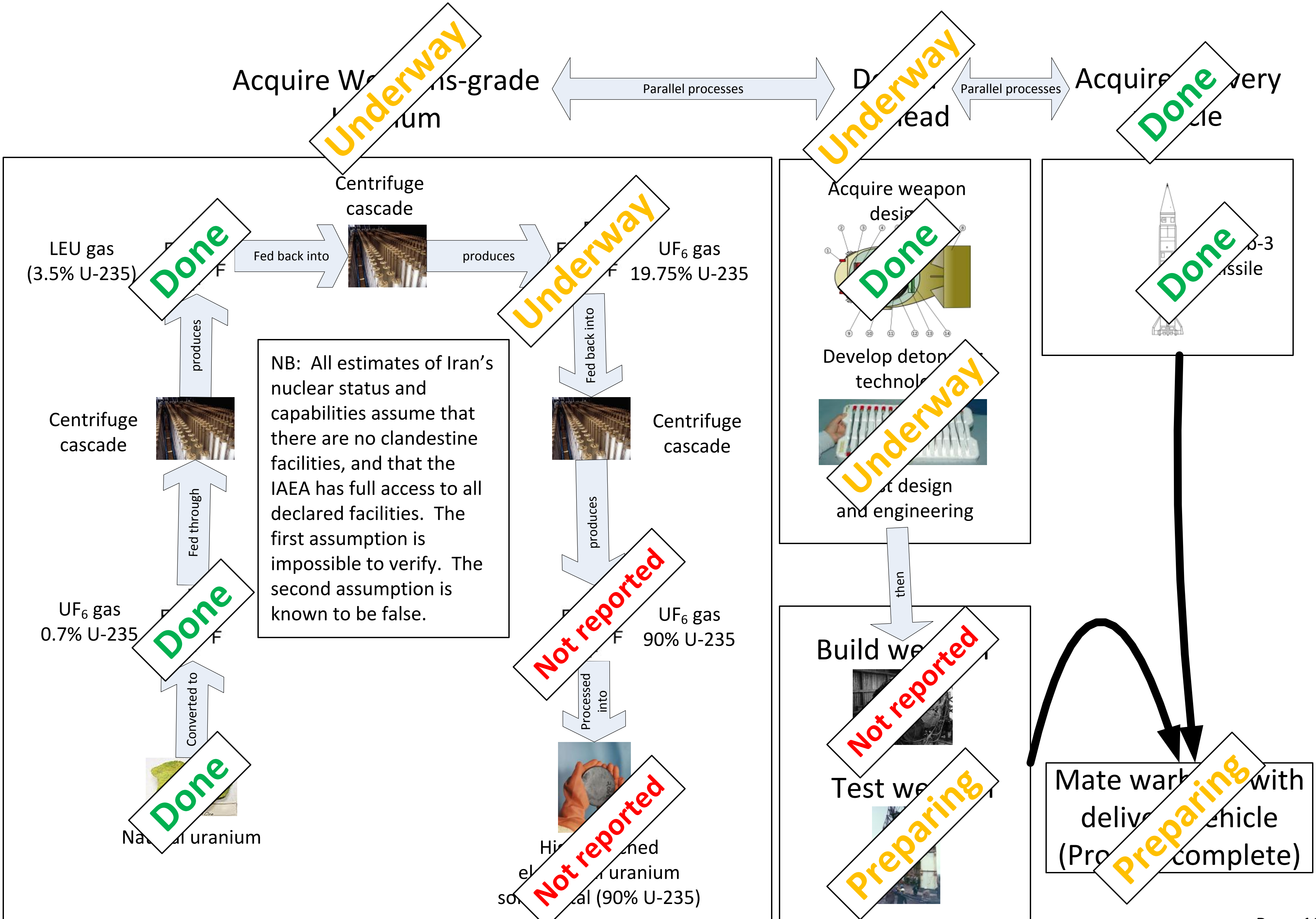
2/22/2013
IAEA Report

IAEA BOG = International Atomic Energy Agency Board of Governors

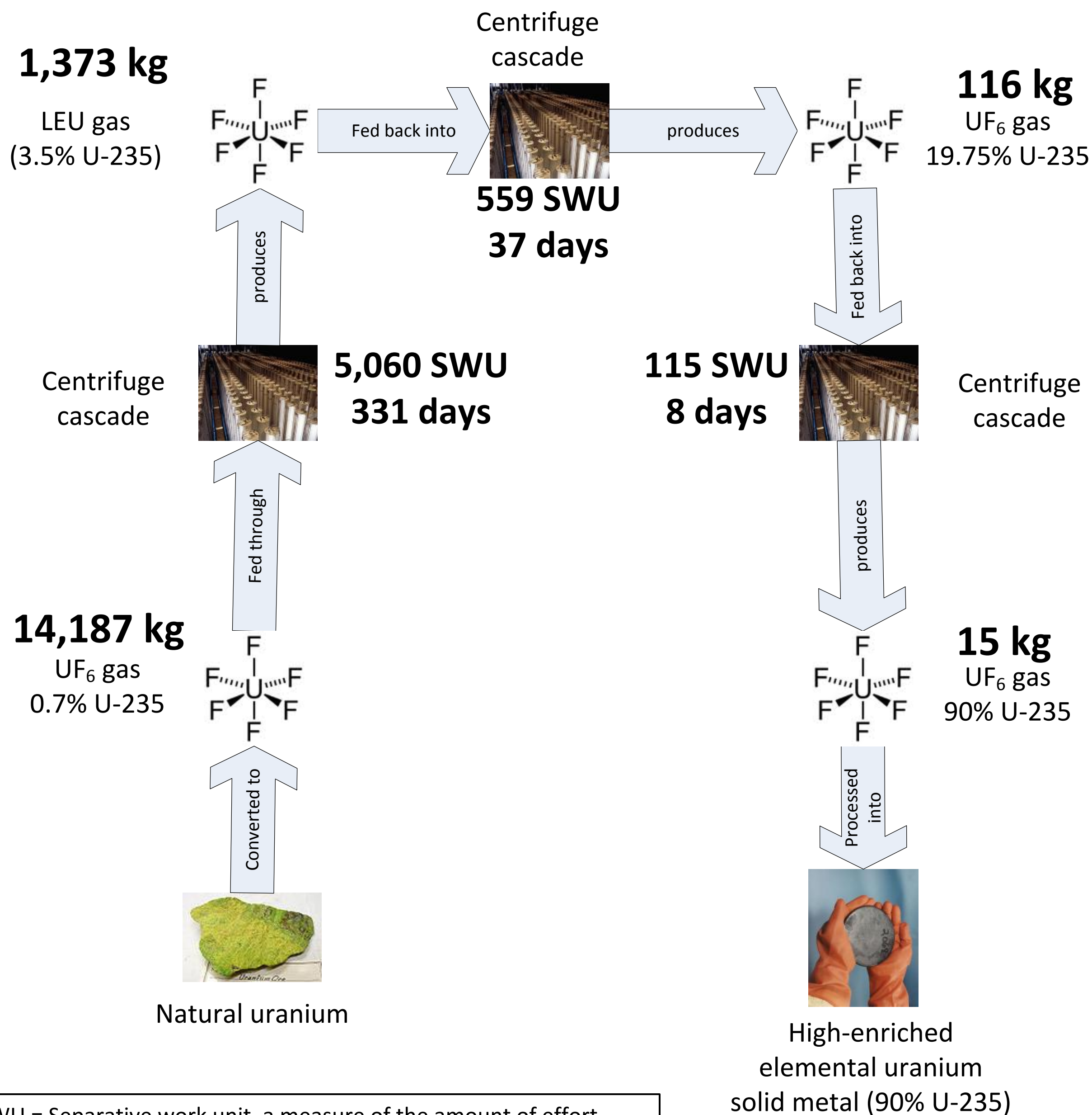
Making an Atomic Bomb (Concept)



Making an Atomic Bomb (Status as of 01 SEP 2012)



Why Enrichment Accelerates at Higher Concentration of U-235



The work and time required to enrich uranium from its natural concentration (0.7%) to 3.5% LEU is an order of magnitude greater than that required to enrich 20% LEU to weapons-grade concentrations (~90% U-235).

That is because centrifuges must spin more than 14,000 kg of uranium ore to produce 1,373 kg of 3.5% LEU, but only 116 kg of 20% LEU to produce 15 kg of weapons-grade uranium.

SWU = Separative work unit, a measure of the amount of effort required to process nuclear material. The SWU requirement is used to determine the time needed to enrich uranium with a given number of centrifuges operating at a given efficiency.

Iran's Declared Uranium Enrichment Facilities

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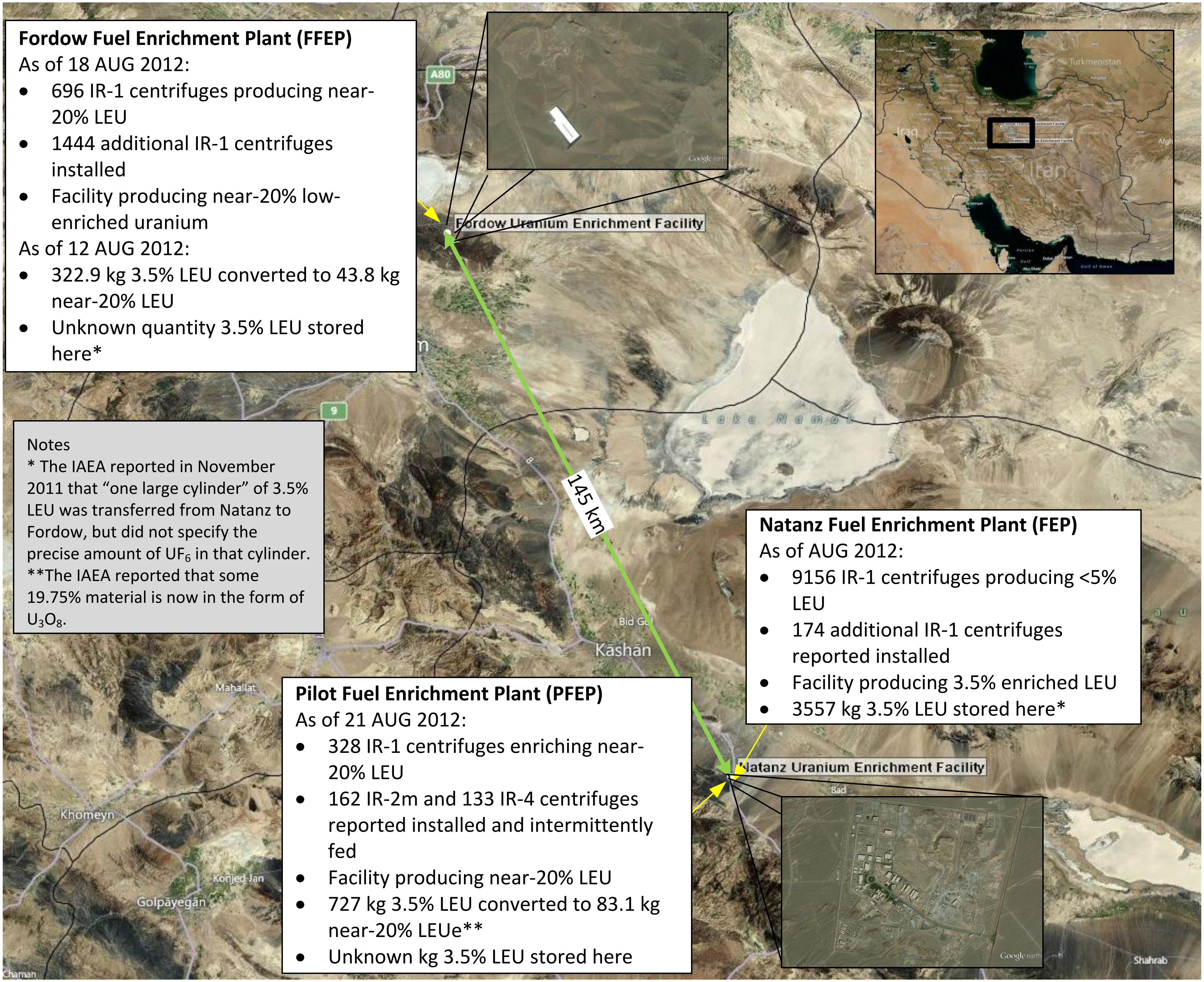


Fordow Fuel Enrichment Plant (FFEP)

As of 18 AUG 2012:

- 696 IR-1 centrifuges producing near-20% LEU
- 1444 additional IR-1 centrifuges installed
- Facility producing near-20% low-enriched uranium

As of 12 AUG 2012:

- 322.9 kg 3.5% LEU converted to 43.8 kg near-20% LEU
- Unknown quantity 3.5% LEU stored here*

Notes
* The IAEA reported in November 2011 that "one large cylinder" of 3.5% LEU was transferred from Natanz to Fordow, but did not specify the precise amount of UF_6 in that cylinder.
**The IAEA reported that some 19.75% material is now in the form of U_3O_8.

Natanz Fuel Enrichment Plant (FEP)

As of AUG 2012:

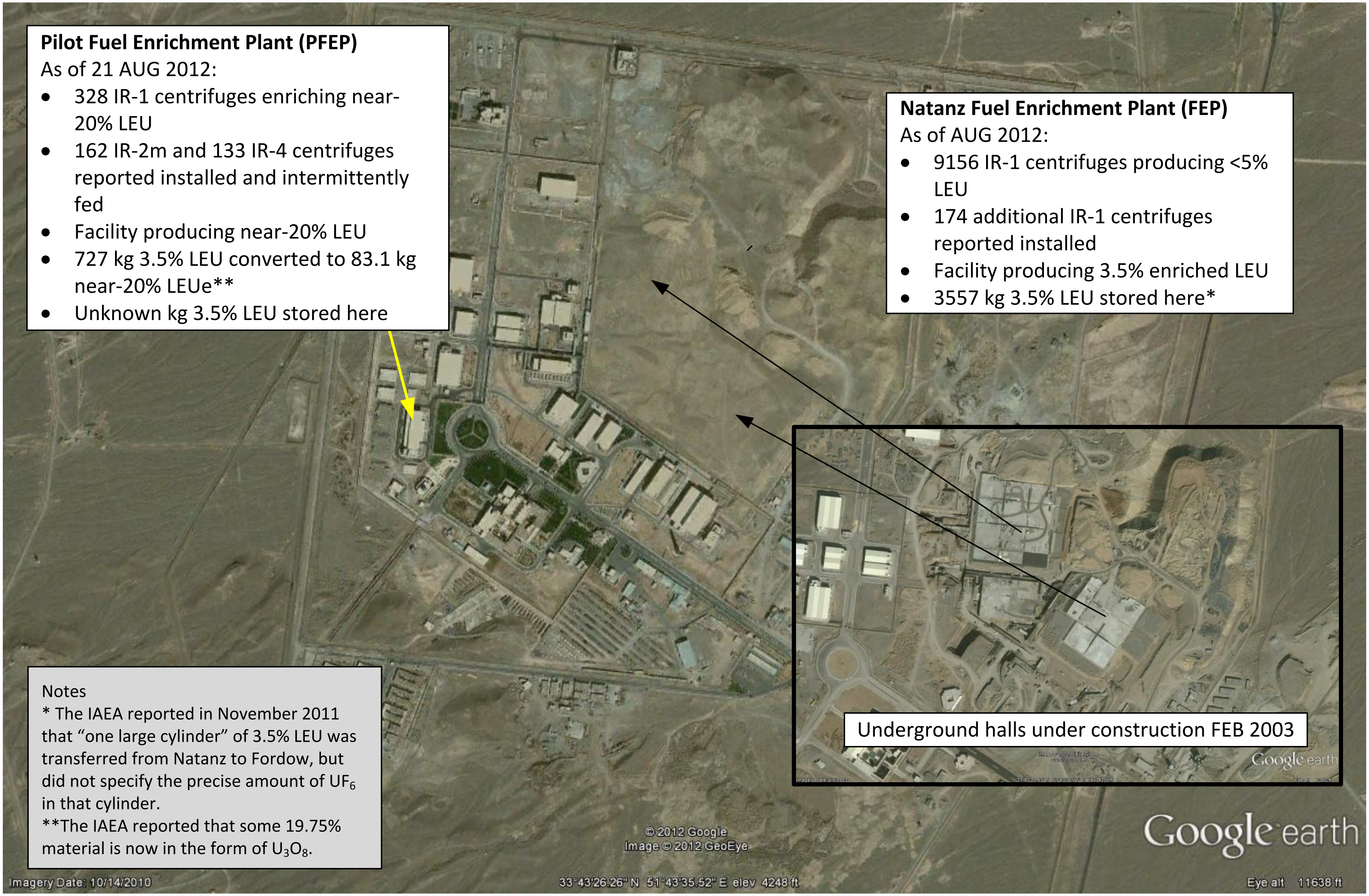
- 9156 IR-1 centrifuges producing <5% LEU
- 174 additional IR-1 centrifuges reported installed
- Facility producing 3.5% enriched LEU
- 3557 kg 3.5% LEU stored here*

Pilot Fuel Enrichment Plant (PFEP)

As of 21 AUG 2012:

- 328 IR-1 centrifuges enriching near-20% LEU
- 162 IR-2m and 133 IR-4 centrifuges reported installed and intermittently fed
- Facility producing near-20% LEU
- 727 kg 3.5% LEU converted to 83.1 kg near-20% LEUe**
- Unknown kg 3.5% LEU stored here

Natanz Enrichment Facilities



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Fordow Enrichment Facility: Status and Construction

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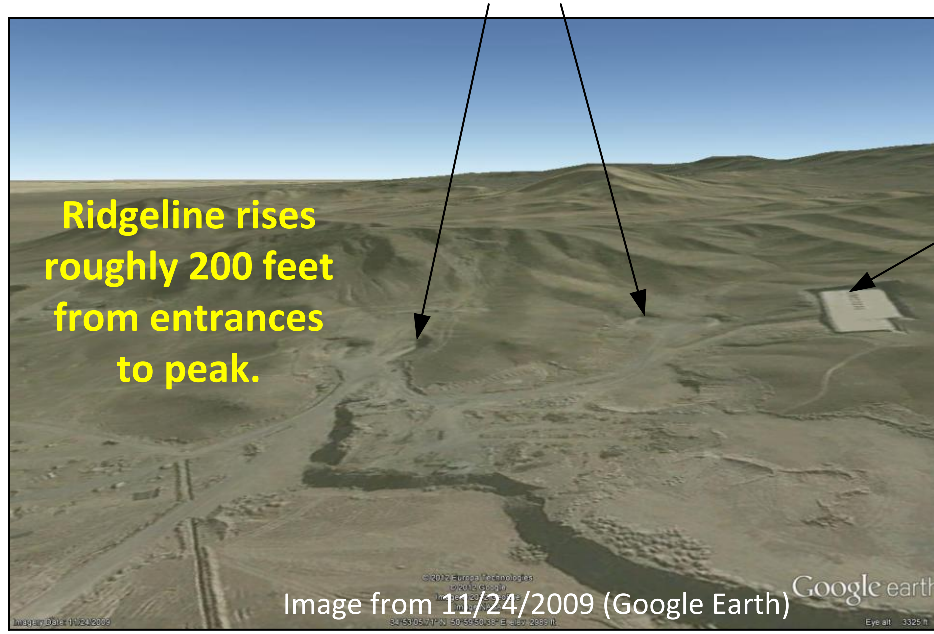
Areas covered in 2005 appear as entrances to underground facilities in 2009

New above-ground facility appears between 2005 and 2009



Scope, Assumptions and Technical Points

Scope

This product is an exposition of the technical data contained in numerous International Atomic Energy Association (IAEA) reports informed by the discussions of experts in the field of nuclear proliferation. It is a work-in-progress in that it will be revised continuously based on new information from the IAEA and other sources and on feedback from readers.

We welcome your informed commentary on the technical considerations presented in this document. Please send your comments, with references to source-data or documentation, to INP@AEI.ORG.

This product does NOT contain policy recommendations. It is intended solely to inform the policy community and the American public about the nature and progress of the Iranian nuclear program.

This product does NOT assess Iran's intentions to weaponize or to pursue break-out scenarios. It is focused entirely on technical feasibility.

Breakout Scenarios

Worst-case

- The worst-case scenarios assume that Iran devotes all operational centrifuges at Natanz (as of 21 AUG 2012) to producing first additional 19.75% LEU and then 90% highly-enriched uranium (HEU), ceasing production of 3.5% LEU. Such actions would be visible to inspectors and so would most likely occur between inspections. Iranian nuclear policy and strategy does not appear to be going down this road.
- The scenarios assume 9,156 centrifuges spinning (the number being fed uranium as of 21 AUG 2012) operating with an efficiency of 0.9 separative work units (SWU)/centrifuge/year (roughly the efficiency they have demonstrated).
- 15 kg requirement: Iran begins to race to breakout by producing 116 kg total of 19.75% LEU and then enriching that material to 90% HEU.
- 25 kg requirement: Iran begins to race to breakout by producing 193 kg total of 19.75% LEU and then enriching that material to 90% HEU.
- If Iran breaks out using a three-step process, it would need to produce 240 kg total of 19.75% LEU in total, then enrich to 60% HEU and then to 90% HEU to yield 15 kg. Using this three-step process, Iran could acquire fuel for 1 weapon in 1 month. Assuming Iran needs 25 kg 90% HEU, it would need to produce 399 kg total of 19.75% LEU before it could convert to 60% and then 90%; this process would take approximately 2.5 months.
- *These calculations assume tails assays of 2.0% and 9.3% for the two steps in the first process and 2.0%, 12.0%, and 41.1% for the three steps in the second process (see slide 21). These data are derived from the Natanz facility; the Fordow installations are notably more efficient with lower tails assays.*

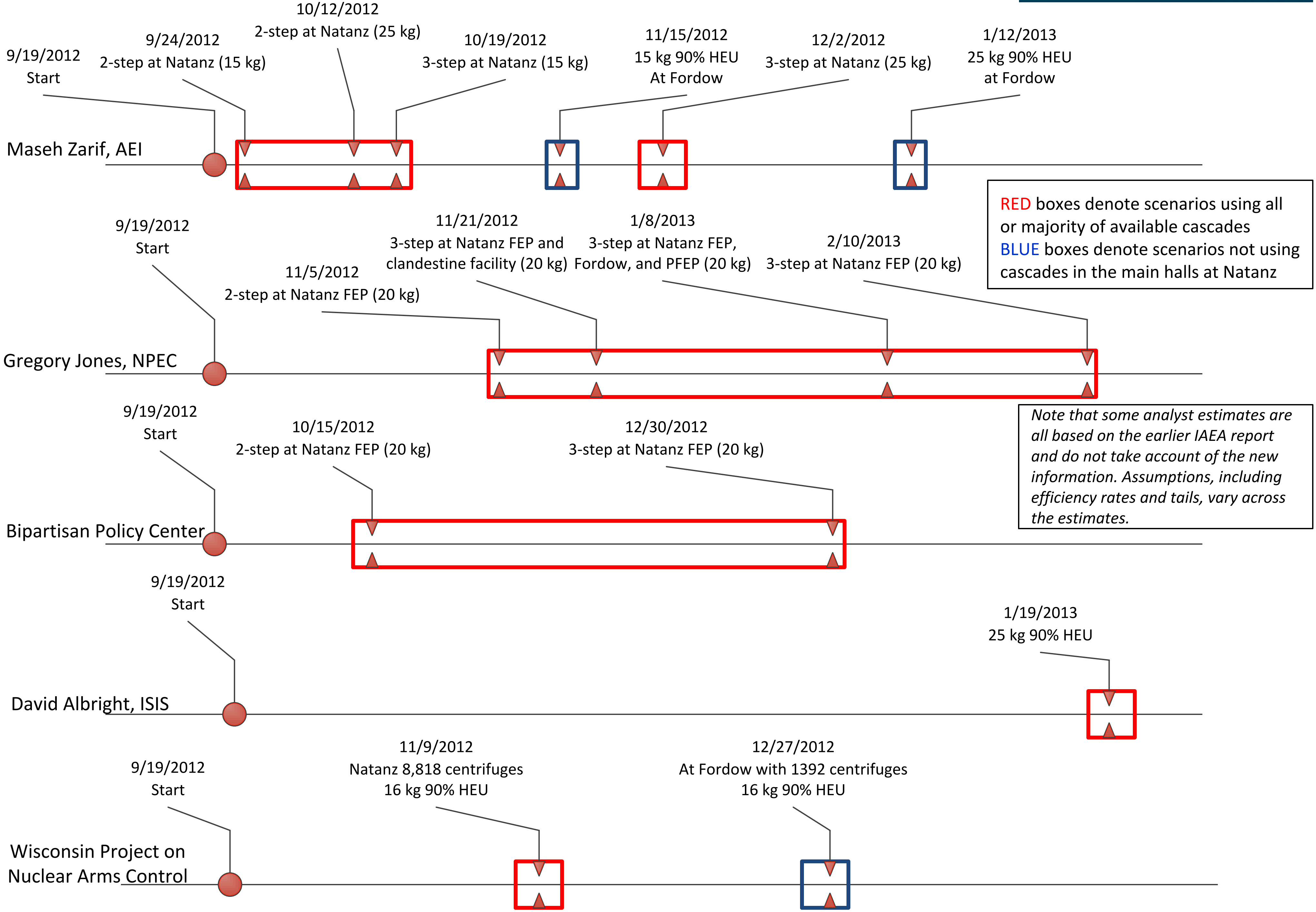
Most Likely

- The 9,156 centrifuges being fed in the main cascade hall at Natanz continue to produce 3.5% LEU and are not diverted to higher-level enrichment. Iran uses 85 kg 19.75% LEU to produce 15 kg 90% HEU or continues enriching to 19.75% until it has amassed approximately 141 kg 19.75% LEU, which can yield 25 kg 90% HEU.
- Enrichment to 19.75% occurs in 4 cascades totaling 696 IR-1 centrifuges at Fordow (2 sets of 2 interconnected cascades) and 2 cascades totaling 328 IR-1 centrifuges at the Natanz PFEP (all currently operational).
- Enrichment from 19.75% to 90% occurs in 6 cascades at Fordow in one step using a tails assay of 4.6%. *The difference in the tails between the worst-case and most likely breakout scenarios reflects the fact that the cascades at Fordow, like the ones at Natanz PFEP, are interconnected in pairs.*

Atomic Weapons Data

- Small atomic weapons can be built from cores consisting of 10-25 kg of uranium enriched to 90% U-235 (weapons-grade HEU). We use 15 kg and 25 kg to assess breakout timelines.
- The explosive yield of a 15 kg core is on the close order of 15 kilotons.
- Uranium can be enriched to HEU in a two-step or a three-step process.
- Both processes begin by enriching natural uranium (0.7% U-235) to 3.5% LEU.
- The two-step process enriches from 3.5% LEU to 19.75% LEU, and then from 19.75% LEU directly to 90% HEU.
- The three-step process proceeds from 3.5% LEU to 19.75% LEU, from 19.75% LEU to 60% HEU, and then from 60% HEU to 90% HEU.
- The most important difference between these processes is the amount of LEU required initially—the time required to enrich from 19.75% to 90% is virtually the same for either process.
- The two-step process for producing 15 kg weapons-grade HEU requires 85 kg of 19.75% LEU using interconnected cascades (such as at Fordow) or 116 kg using non-interconnected cascades (such as those at Natanz). Producing 25 kg weapons-grade HEU in a two-step process requires 141 kg of 19.75% LEU using interconnected cascades or 193 kg using non-interconnected cascades. The three-step process requires significantly more in non-interconnected cascades (such as at Natanz).
- There is disagreement among experts about Iran's ability to execute a two-step process with its current technology and cascade configuration.
- If Iran were forced to use a three-step process, the primary delay would result from the time required to produce the additional 19.75% LEU, a factor that Iran could affect either by bringing more centrifuge cascades online or by beginning to enrich with more efficient centrifuges, some of which are already installed but not yet producing enriched uranium.

Comparison of Estimated Breakout Times



Projections for the November 2012 IAEA Report

IR-1 centrifuges being fed at Natanz FEP: 9,430 (*low confidence*)

Total 3.5% LEU produced at Natanz FEP: 5,105 kg (*moderate confidence*)*

IR-1 centrifuges being fed for 19.75% enrichment at Natanz and Fordow: 1,372 (*low confidence*)

Total 19.75% LEU produced at Natanz PFEP and Fordow FEP: 149.4 kg (*moderate confidence*)*

PREVIOUS PROJECTIONS

<u>3.5% LEU</u>

We previously estimated that Iran would produce an additional 324 kg of 3.5% enriched uranium at Natanz during the last reporting period. The IAEA reported that Iran produced about 450 kg 3.5% enriched uranium during the period. The difference was largely due to a recent increase in Iran's production rate (with a roughly constant number of centrifuges) that was not previously accounted for in the model. November 2012 estimates have been adjusted accordingly.

<u>19.75% LEU</u>

We previously estimated that Iran would produce an additional 26.85 kg of 19.75% enriched uranium at Natanz and Fordow during the last reporting period. The IAEA reported that Iran produced about 29.35 kg 19.75% enriched uranium. This error is due to Iran's increased rate of production at Fordow.

*Assuming IAEA measurement on 4 NOV 2012

Sources

International Atomic Energy Agency (IAEA) – The IAEA publishes quarterly reports on Iran's nuclear program and enrichment progress. Enriched uranium stockpile, centrifuge count, potential inspection windows, and other technical data provided by the IAEA are used in our analysis to determine historical rates of production and to serve as a basis for building projections. IAEA reports on Iran are available at http://www.iaea.org/newscenter/focus/iaeairan/iaea_reports.shtml.

World Information Service Project on Energy (WISE) – WISE provides a uranium enrichment calculator for calculating the separative work required to achieve specific levels of U-235 concentration. The calculator uses manual inputs of feed, product, and tails figures to calculate separative work units (SWU). The resultant SWU serves as the basis for calculating time requirements. This assessment uses the WISE calculator to determine the SWU required for enriching at various levels. The online calculator is accessible at http://www.wise-uranium.org/nfcue.html.

Gregory Jones, Nonproliferation Education Policy Center (NPEC) – Gregory Jones provided the estimated tails percentage figures for enriching to weapons-grade uranium levels for two-step and three-step batch recycling methods (starting with 3.5% LEU) at the Natanz FEP and two-step batch recycling (from 3.5%) at Natanz PFEP/Fordow FEP, where cascades are interconnected. Jones has written that the technical assumption underlying an Iranian attempt to break out using two-step batch recycling without reconfiguration (from 3.5%) may not be feasible. The alternative Iranian breakout approach he suggests, adding an intermediary step between 19.75% and 90% enrichment, is one that we have relied on in our analysis. Jones's analyses are available at http://www.npolicy.org/.

Jones has written that the process for Iran to convert the U_3O_8 enriched up to 20% created for fuel plates back to 20% enriched UF_6 gas for use in a breakout "involves dissolution by nitric acid, followed by purification by solvent extraction. These are standard processes in the nuclear industry and Iran uses them as part of its uranium ore processing...The time required from the removal of the fresh TRR fuel from safeguards to the time to produce 19.75% enriched uranium hexafluoride would be only 'days to weeks.' [citing Albert Wohlstetter et al, *Swords from Plowshares*, Chicago University Press, 1979]" The report is available at http://www.npolicy.org/article_file/Fueling_the_Tehran_Research_Reactor-Technical_Considerations_on_the_Risks_and_Benefits.pdf.

Further on this topic, Henry Sokolski, NPEC, has written that Iran could withdraw 19.75% enriched uranium from fuel plates in the form of UF_6 gas in 1-2 weeks. See http://www.nationalreview.com/corner/188387/fueling-around-iran-and-bomb/henry-sokolski.

Institute for Science and International Security (ISIS) – ISIS has contributed to a technical debate among experts regarding the feasibility of two-step and three-step batch recycling methods. ISIS analyses are available at http://isis-online.org/.

Alexander Glaser, "Characteristics of the Gas Centrifuge for Uranium Enrichment and Their Relevance for Nuclear Weapon Proliferation," *Science and Global Security* (16:1-25, 2008) – Glaser's analysis of the P-1 centrifuge—the foundation of Iran's IR-1 centrifuge program—is the basis for two-step batch recycling projections for enriching to weapons-grade uranium. A key aspect of Glaser's analysis in this paper was that 90% HEU can be produced in one step from 19.7% LEU without the need to reconfigure the arrangement of cascades. In October 2011, according to Gregory Jones, Glaser said he had "been made aware of certain phenomena that are not taken into account" in his 2008 analysis and that "We now find that the most credible scenarios involve some kind of cascade reconfiguration." See Greg Jones, "Earliest Date Possible for Iran's First Bomb," Nonproliferation Education Policy Center, December 6, 2011, http://npolicy.org/article.php?aid=1124&rid=4. For Glaser's original analysis, see http://www.princeton.edu/sgs/publications/sgs/archive/16-1-Glaser.pdf.

International Commission on Nuclear Non-Proliferation and Disarmament (ICCND) – The ICCND notes that a basic implosion-type nuclear weapon design with an explosive yield of 15 kilotons would require 15 kg of weapons-grade uranium. We use this figure as the minimum 90% HEU Iran would produce to fuel one bomb. See http://icnnd.org/Reference/reports/ent/part-ii-4.html.

Thomas B. Cochran and Christopher E. Paine, "The Amount of Plutonium and Highly-Enriched Uranium Needed for Pure Fission Nuclear Weapons," National Resources Defense Council, April 13, 1995. – Cochran and Paine assert that the "significant quantity" measurement of 25 kg weapons-grade HEU used by the IAEA greatly overestimates the amount of fissile material required to fuel a basic implosion-type nuclear explosive device. They estimate that a state with a low technical capability can produce a bomb with an explosive yield of 20 kilotons with 16 kg weapons-grade HEU. See: http://www.nrdc.org/nuclear/fissionw/fissionweapons.pdf.