

# **The Iran Nuclear Deal:**

## **How we got here and our options going forward**

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# **Outline**

**I. Iran's nuclear program**

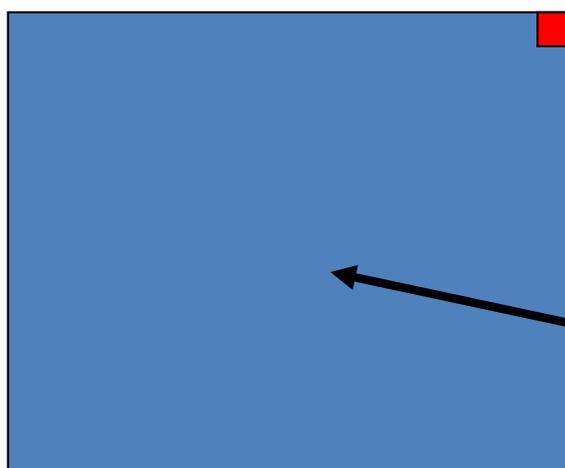
**II. The Deal**

**III. What next?**

# **I. Iran's Program**

## IRAN'S NUCLEAR PROGRAM

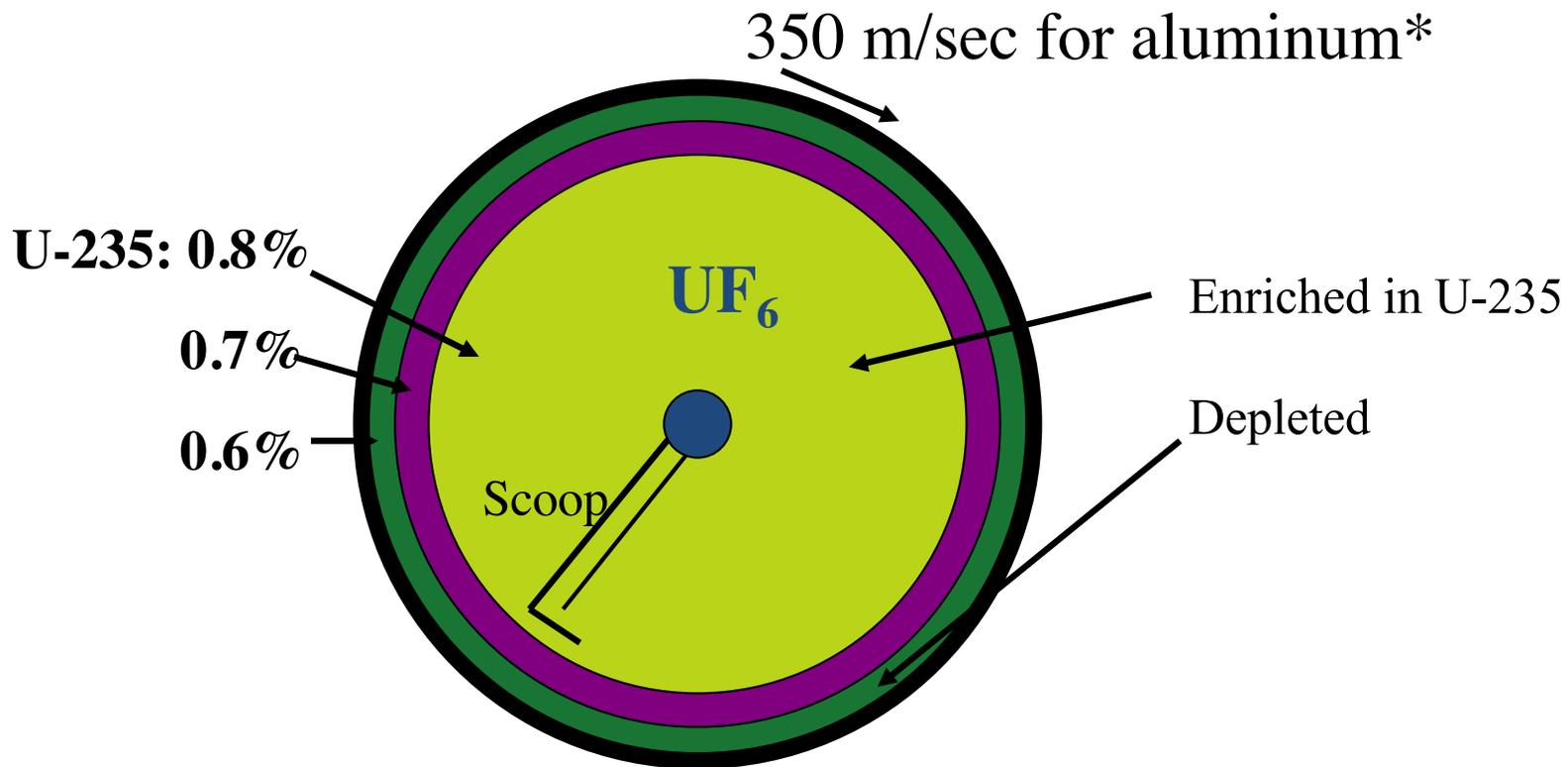
### Natural uranium: two isotopes, two routes to the bomb



← **U-235** (0.7%) will sustain a fission chain reaction *if separated*.

← **U-238** (99.3%) does not chain react but, turns into chain-reacting plutonium-239 *if you add a neutron*.

# Gas centrifuge enrichment starting with natural U

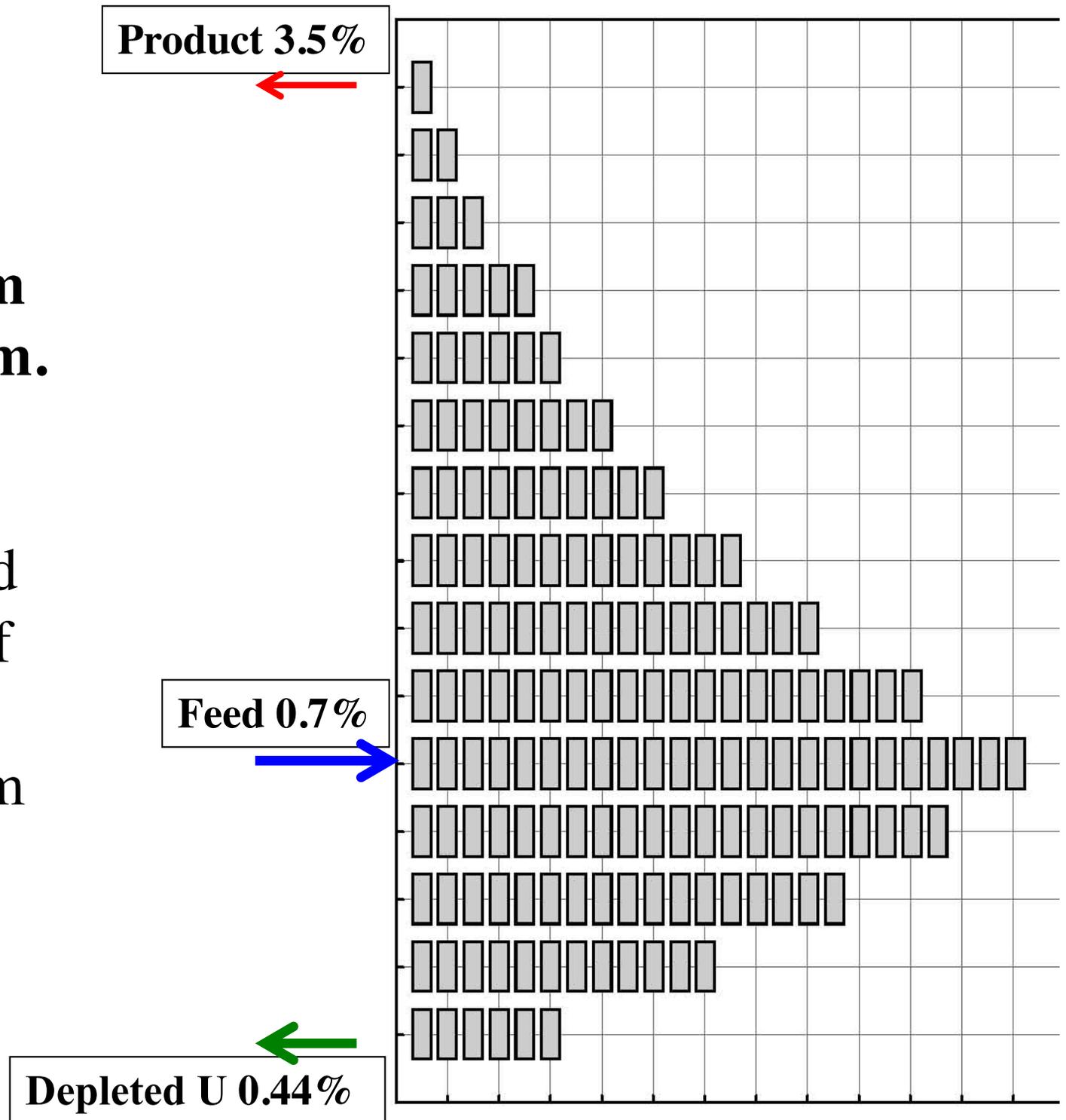


\*Maraging steel or carbon fiber have higher tensile strength to density ratios and therefore higher spinning speeds.

# 164-machine *cascade* for producing 3.5 enriched U from natural uranium.

A bigger cascade  
with ~5000 IR-1  
centrifuges could  
produce 25 kg of  
U-235 in 90%  
enriched uranium  
(one weapon  
equivalent) per  
year

(Alex Glaser)



**Above-ground pilot plant**



**Underground centrifuge halls being covered up**

# Natanz Uranium Enrichment Plant in 2002

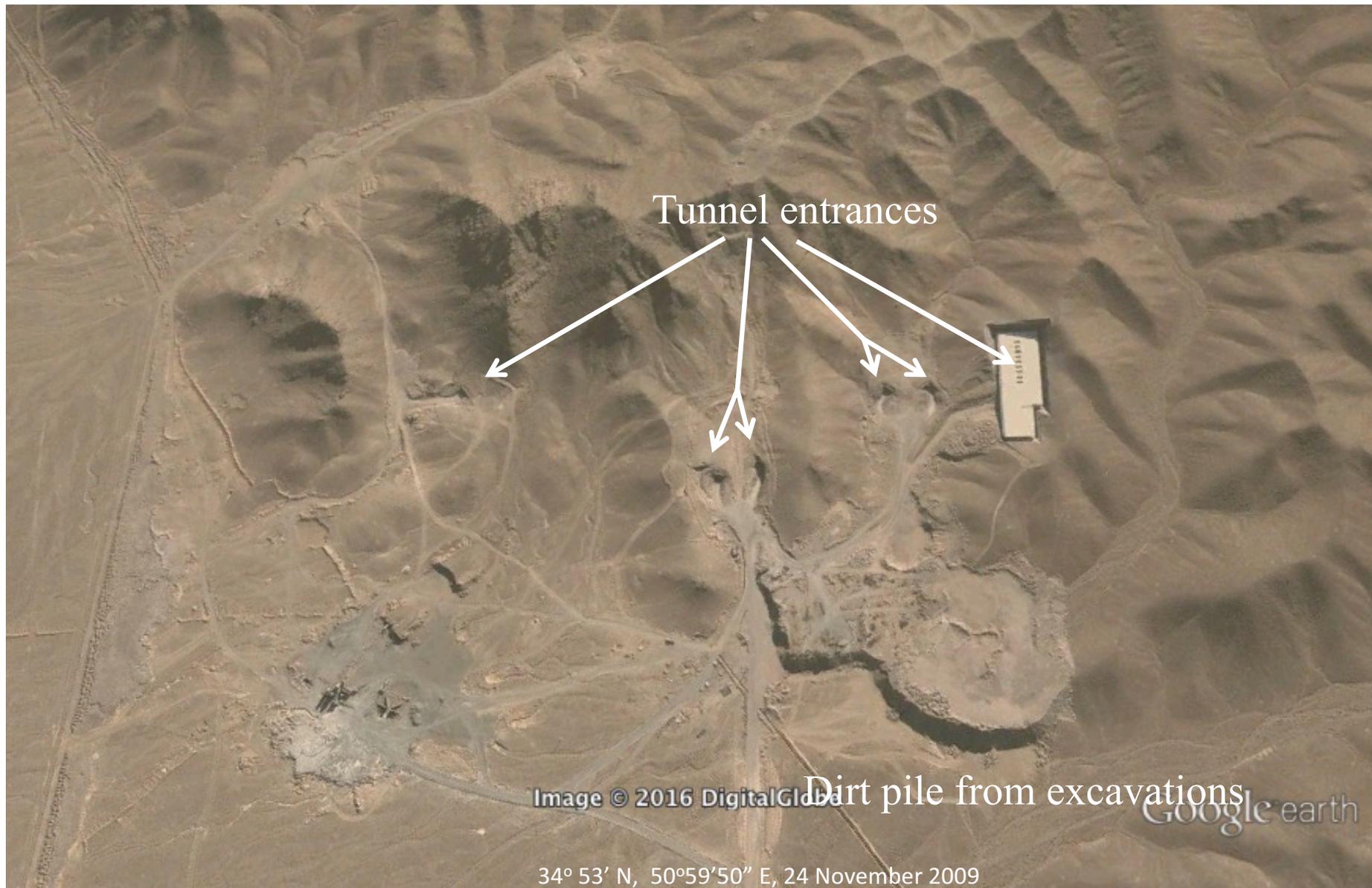
33°43'30"N, 51°43'30", <http://isis-online.org/isis-reports/imagery/category/iran/>

**Former Iranian President Ahmadinejad inspecting  
P1 (Pakistan 1) Centrifuges in Natanz Pilot Plant (2008)  
(~1 Separative Work Unit [SWU] per year)**



# Fordow underground enrichment plant, revealed in 2009

Designed for 2700 centrifuges. Began producing ~20% enriched uranium from ~3.5% enriched feed.



Tunnel entrances

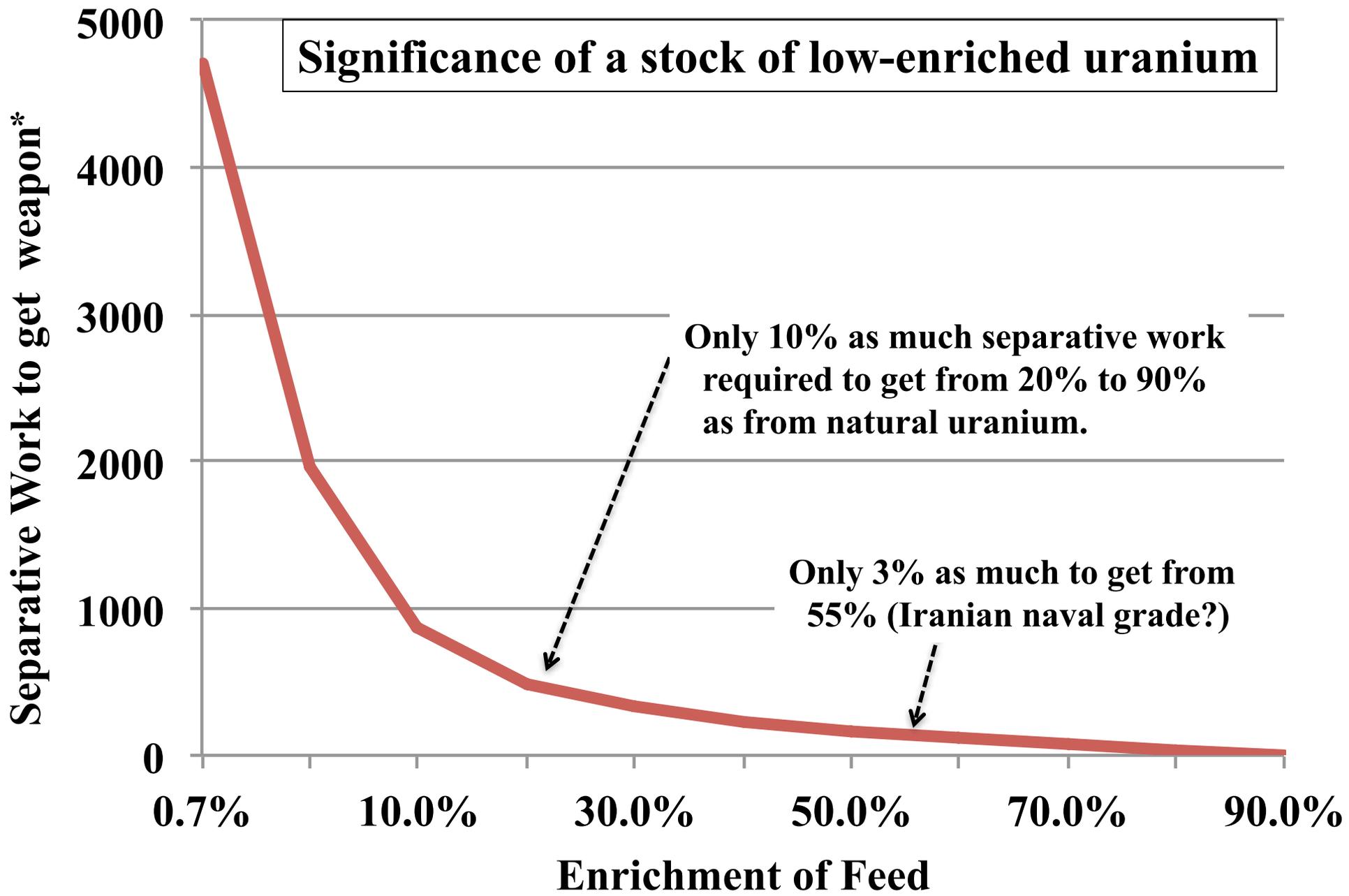
Dirt pile from excavations

Image © 2016 Digital Globe

Google earth

34° 53' N, 50°59'50" E, 24 November 2009

**Significance of a stock of low-enriched uranium**

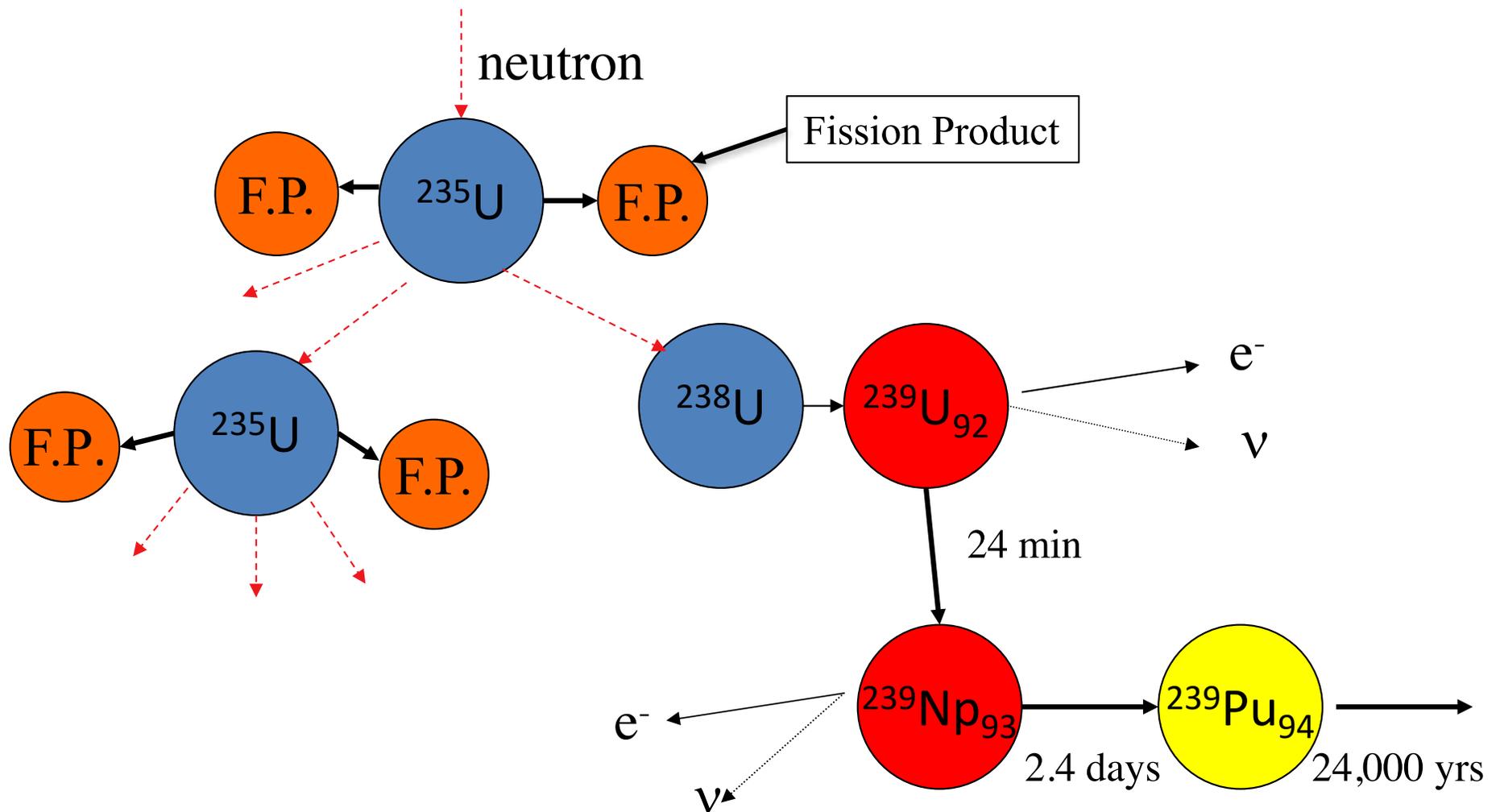


Only 10% as much separative work required to get from 20% to 90% as from natural uranium.

Only 3% as much to get from 55% (Iranian naval grade?)

\*IAEA defines “significant quantity” as 90% enriched uranium containing 25 kg U-235

# The second route to the bomb: Making plutonium in a nuclear reactor (~ 1 atom of Pu per atom of U-235 fissioned in natural-uranium-fueled reactor)



# Arak heavy water plant (2005)

(34°22'14" N, 49°14'27E)



**D<sub>2</sub>O doesn't absorb as many neutrons as H<sub>2</sub>O, so you can make a reactor with natural un-enriched uranium (0.7% U-235) fuel in a tank of heavy water.**

**D<sub>2</sub>O made by bubbling H<sub>2</sub>S through hot and cold water tanks and taking advantage of the temperature dependence of the D exchange reaction.**

**Arak 40 MWt reactor (2015). Basically same design as India's Cirus reactor but no plant for plutonium recovery. 1 gm of fission produced ~1 MWt-day and ~1 gram of plutonium.  $(40 \text{ MWt}) \times (200 \text{ days}) \sim 8 \text{ kg}$  (~ 1 bomb).**



## **II. The Deal**

# **A short history of the Iran nuclear crisis**

**2002:** Iran's nuclear program became public.

**2003:** IAEA demanded that Iran **stop enrichment & plutonium-separation activities** until it concluded an investigation. Iran complied.

**2003-5:** **France, Germany and UK negotiated** with Iran but G.W. Bush insisted "not a centrifuge will spin in Iran." Negotiations failed.

**2005-2013:** President Ahmadinejad elected and **restarted enrichment program. IAEA reported Iran to the UN Security Council. As U.S. and UN ramped up sanctions, Iran built up its enrichment capacity and the Arak reactor. Three times Israel's Prime Minister Netanyahu proposed attacks on Iran's nuclear facilities.**

**2008:** **President Obama elected, willing to compromise with Iran.**

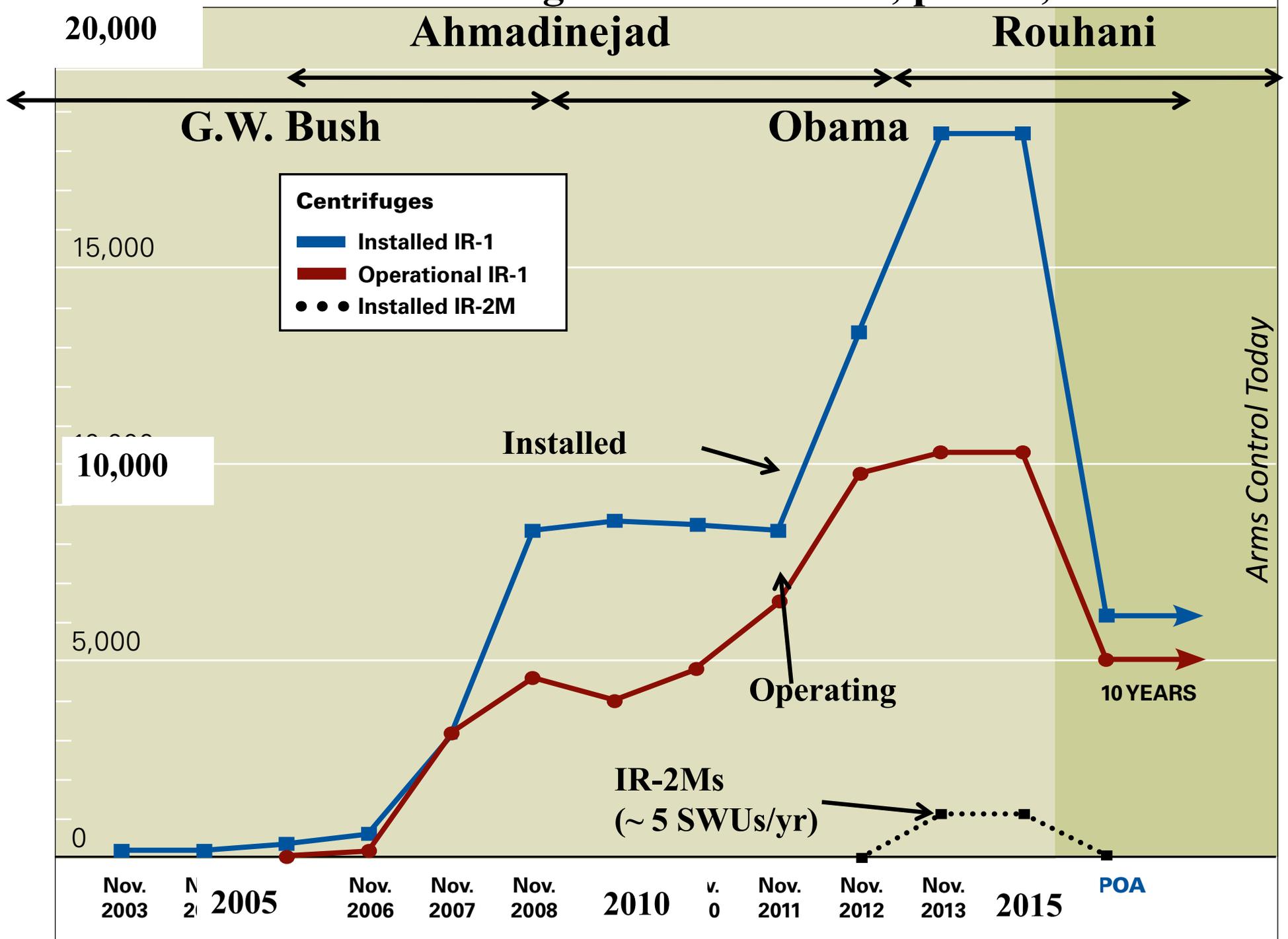
**August 2013:** **President Rouhani elected, promising a deal.**

## **The two sides' "red lines"**

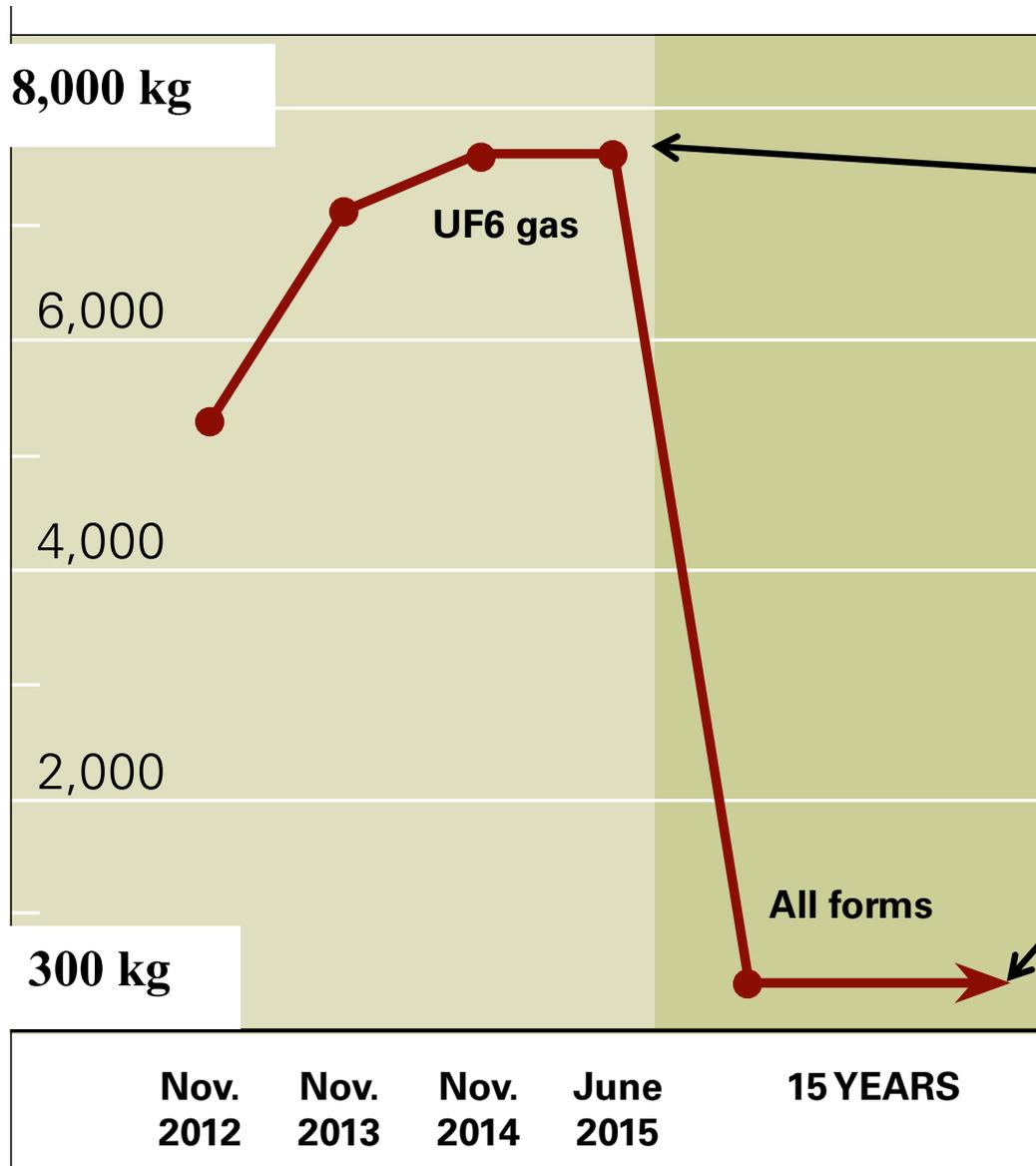
**Iran** insisted that it would not give up either its enrichment program or its Arak reactor.

**President Obama** insisted that a deal would have to put Iran at least a year away from making enough highly enriched uranium or separating enough plutonium to make a bomb.

# Number of installed centrifuges: Iran escalates, pauses, the deal



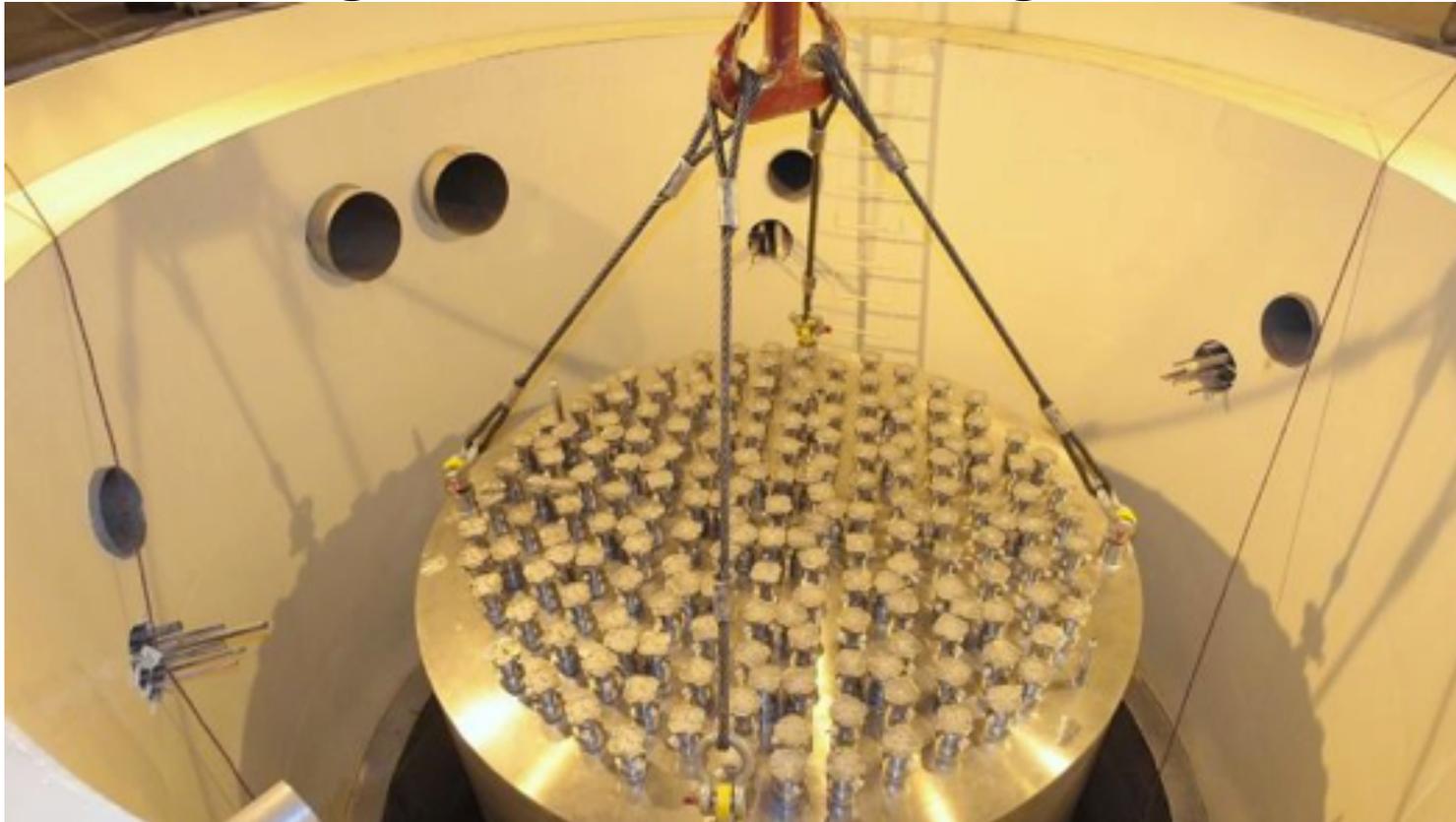
**Iran's pre-enriched uranium reduced to 300 kg UF<sub>6</sub>.**  
*This allowed Iran to keep 2.5 times as many centrifuges because 2.5x more required to produce a bomb quantity of 90% enriched uranium from natural uranium than from 3.5% enriched uranium.*



Enough LEU feed to produce  
~5 bomb quantities of 90%  
enriched uranium.

~ 1/5 of LEU feed to produce  
one bomb quantity of HEU.

## **“Calandria” of the *Arak* Reactor being lowered into its biological shield**



Calandria containing fuel in cooling channels to be replaced by smaller one.

***Core will be converted from natural (0.7% U-235) to 3.5% enriched uranium***  
while keeping amount of U-235 constant, reducing amount of U-238 (and  
therefore plutonium produced) by  $(0.7\%/3.5\% = 0.2)$

***Power will be reduced from 40 to 20 Megawatts reducing Pu production by  
another factor of 2.*** Overall, 1/10 as much plutonium produced in a year.

# The leaders

Ayatollah Khameni, President Rouhani



Foreign Minister  
Zarif

**Hard-liners are furious. Iranian hard-liners, *including Khameni* want Rouhani to be a one-term President. Election *19 May*.**

**What next?**

**Deal starts to phase out after 10 years**

## **Not just an Iran problem**

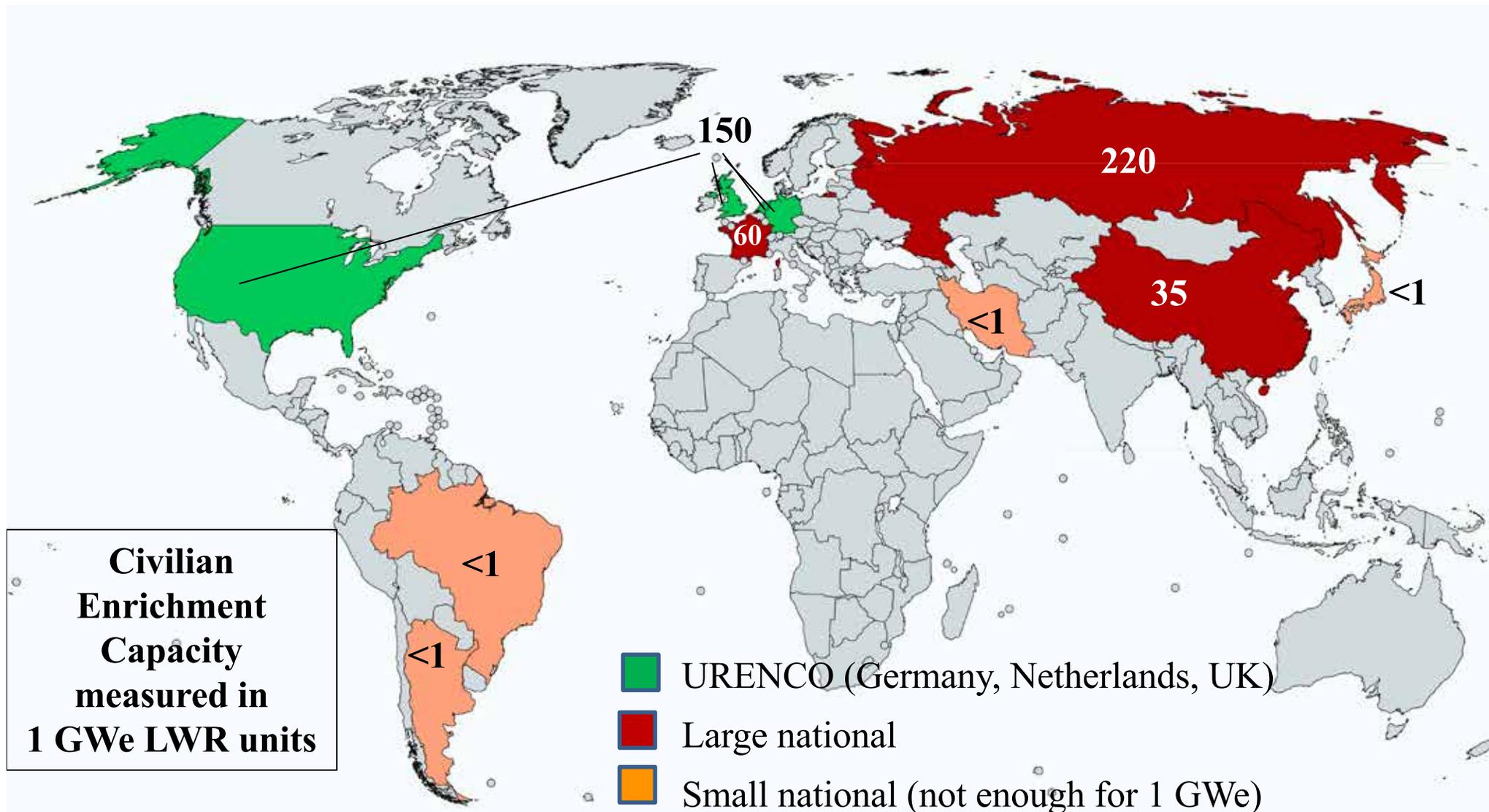
Any national enrichment or reprocessing (plutonium-separation) program is a nuclear-weapon proliferation problem.

We have had to confront Argentinean, Brazilian, Japanese, Pakistani, South African enrichment programs in the 1970s. North Korea in the 1990s. Iran today.

We had to confront Indian, Japanese, South Korean, Swedish, Taiwanese reprocessing programs in the 1960s and 1970s – and South Korea again today.

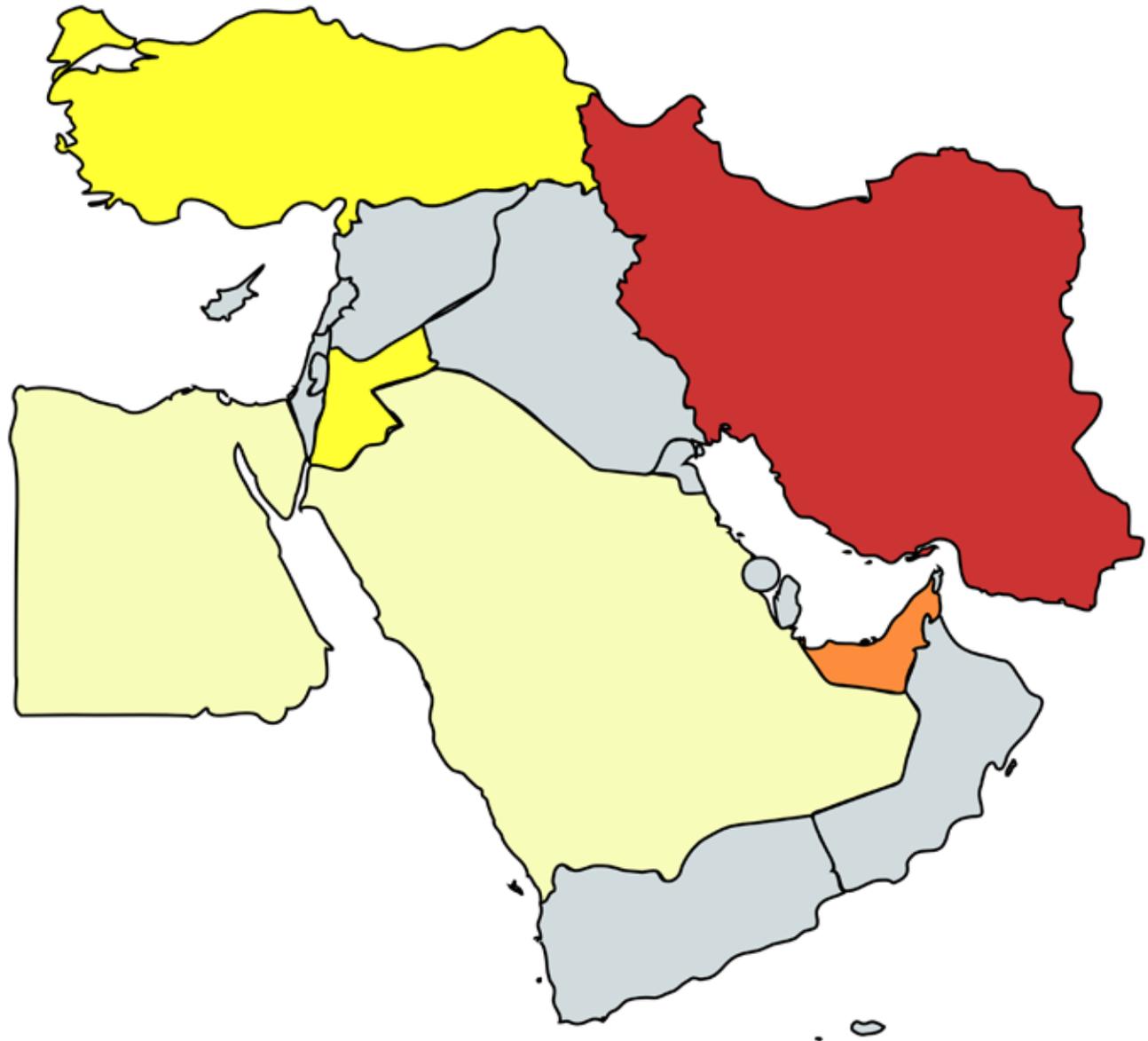
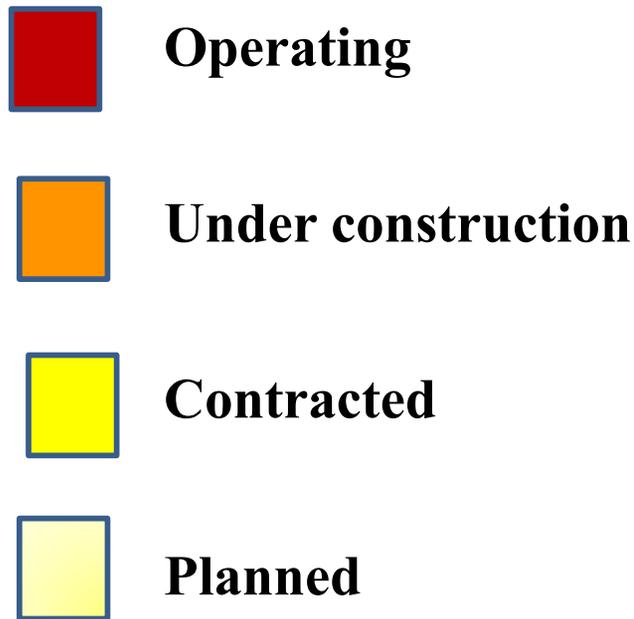
**We need a generic solution.**

**Enrichment.** Today, *global civilian enrichment dominated by three nuclear-weapon states and URENCO, a multinational (Germany-Netherlands-UK)*  
*U.S. and UK have URENCO – not national – enrichment plants.*  
Small plants are not economic and suspect.

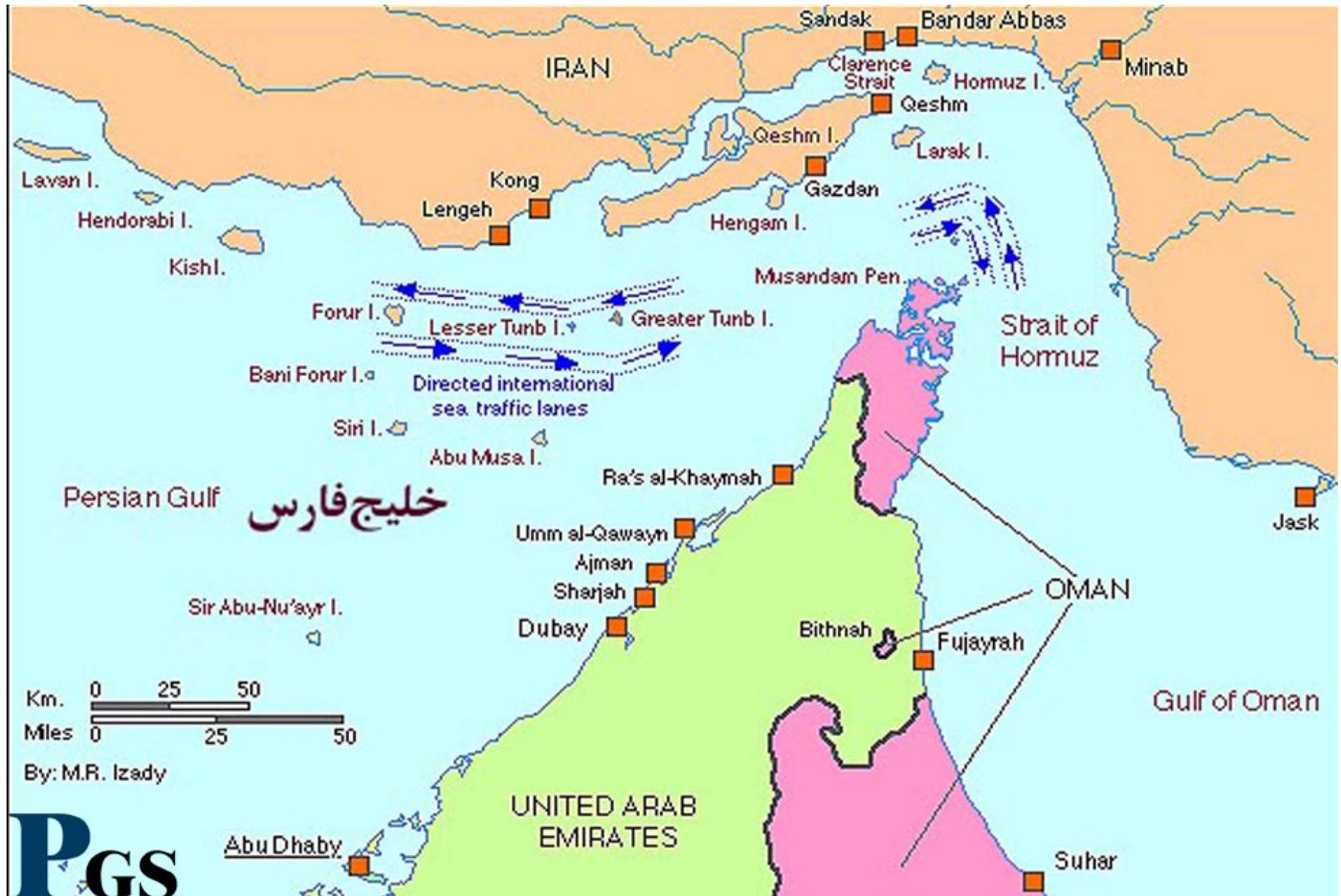


**Uneconomic and destabilizing if every country with a nuclear power plant, has an enrichment plant.  
Limit uranium enrichment to multinational plants?**

**Status of nuclear power reactors in Middle East**



# Would a multinational enrichment plant on a populated island in the Persian Gulf be less threatening to Iran's neighbors?

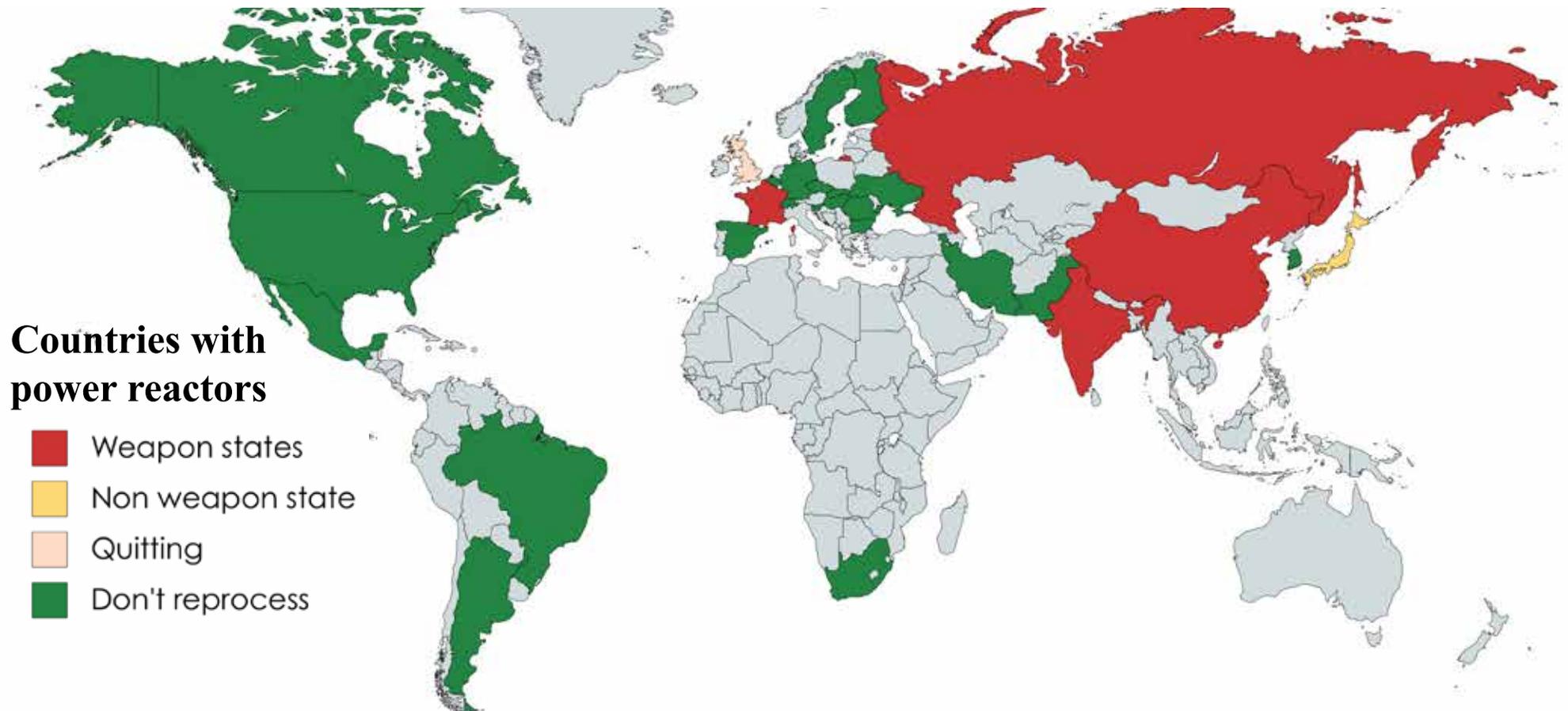


# Ban reprocessing in Middle East and later everywhere else?

A large reprocessing plant separates out enough plutonium for 1000 bombs a year. Civilian reprocessing uneconomic but dying a slow death because of powerful lobbies in China, France, India, Japan and Russia.

U.S. has opposed spread of reprocessing since 1974 when India used an Atoms for Peace reprocessing program to obtain plutonium for a weapons program.

Fortunately, Iran not currently interested in reprocessing.



# **A Persian Gulf Nuclear-Weapon Free Zone Could Be the Core of a future Middle East NWFZ and Stronger Global Constraints on Nuclear-weapon Materials**



**But it all may fall apart  
if both Iran and the U.S. have hardline Presidents**

	<b>Iran's President</b>	<b>U.S. President</b>	
2002-2005	Mohammed Khatami	George W. Bush	Dove-Hawk
2005-2008	Mahmoud Ahmadinejad	George W. Bush	Hawk-Hawk
2009-2013)	Mahmoud Ahmadinejad	Barack Obama	Hawk-Dove
2013-2016	Hassan Rouhani	Barack Obama	<i>Dove-Dove</i>
2017-2020	?	Donald Trump	? – ?

**Iran's Presidential election is this May 19<sup>th</sup>. Extra high stakes since the Supreme Leader (78) may have to be replaced during the next Iranian President's term.**