Detectability of Uranium Enrichment

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Revision 4

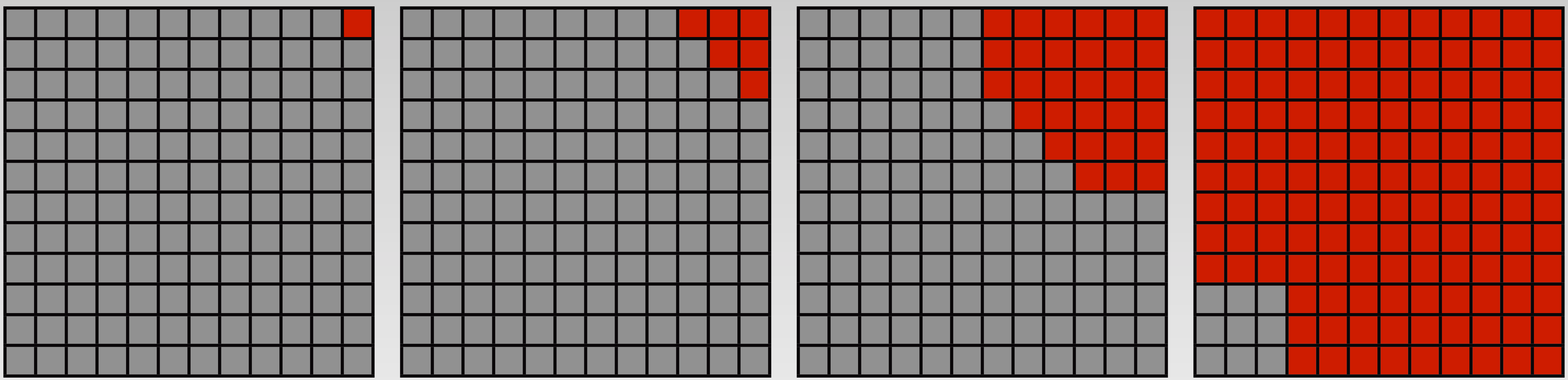
Background

What is Uranium Enrichment?

Enriched Uranium

(visually)

HEU
(weapon-usable)



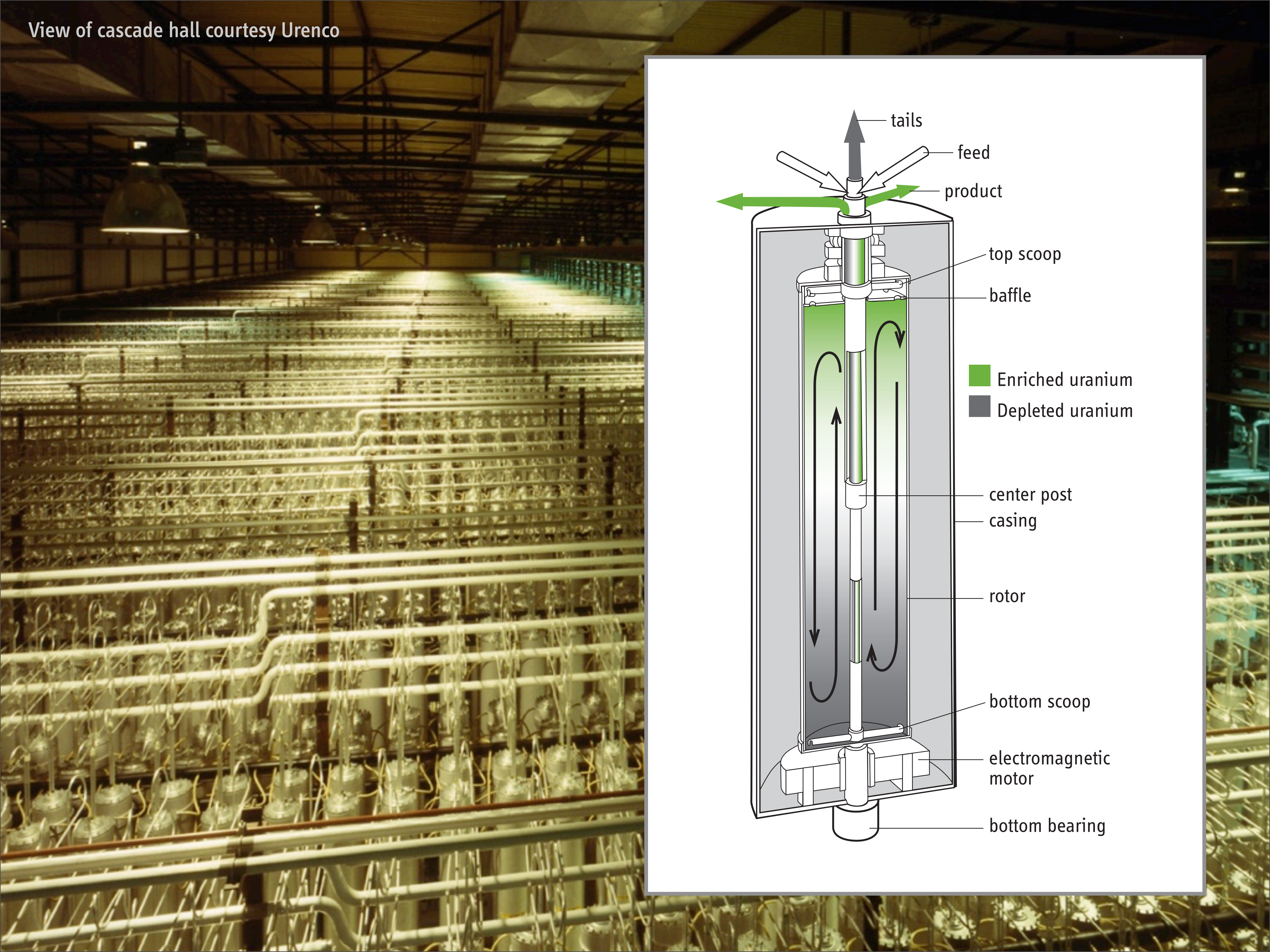
Natural uranium
0.7% U-235

Low-enriched uranium
typically 3-5%,
but less than 20% U-235

Highly enriched uranium
20% U-235 and above

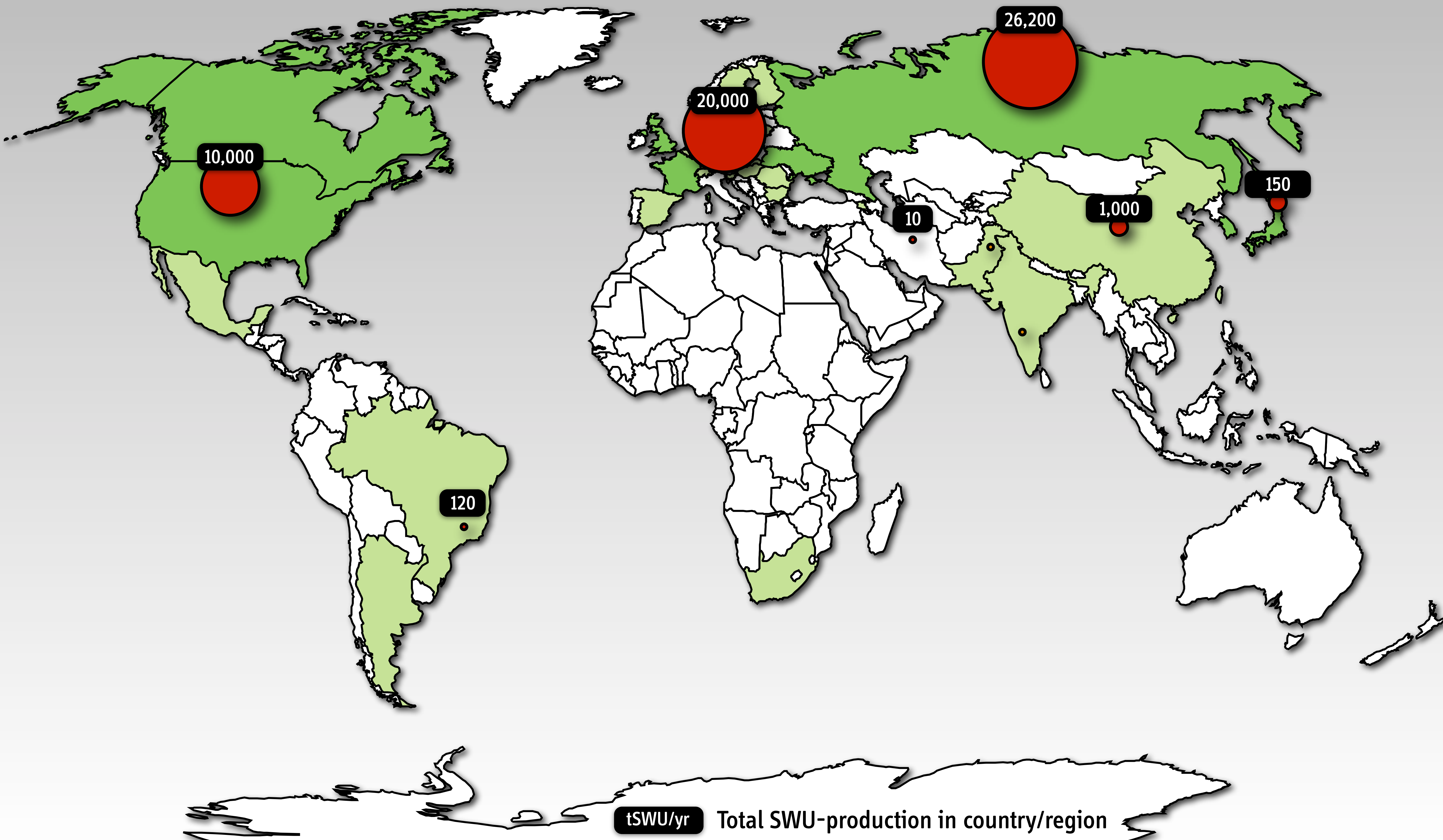
Weapon-grade uranium
more than 90% U-235

Uranium
- U-235
- U-238


View of cascade hall courtesy Urenco
tails
feed
product
top scoop
baffle
Enriched uranium
Depleted uranium
center post
casing
rotor
bottom scoop
electromagnetic motor
bottom bearing

Global Enrichment Capacities, 2010

(14 operational plants in 10 countries, not including two military plants)



Why Centrifuges are Different

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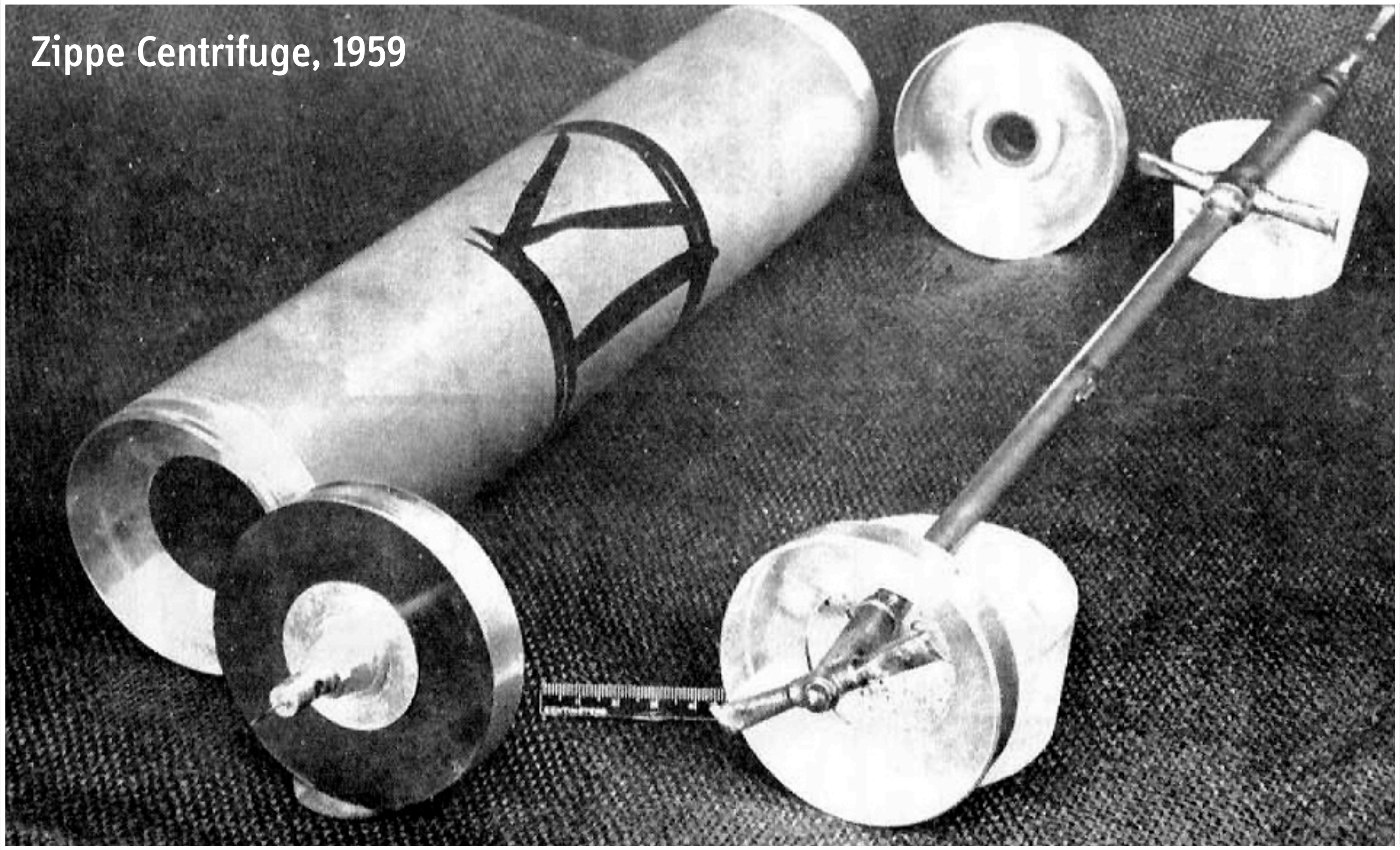


Characteristics of centrifuge technology relevant to nuclear proliferation

Rapid Breakout and Clandestine Option


200 meters
Fuel
Enrichment
Plant
(FEP)
(FEP)
The Natanz Site in Iran (2007)

Iran’s Second Enrichment Site, near Qom

(Fordow Plant, revealed in September 2009 at 34.885 N, 50.996 E)

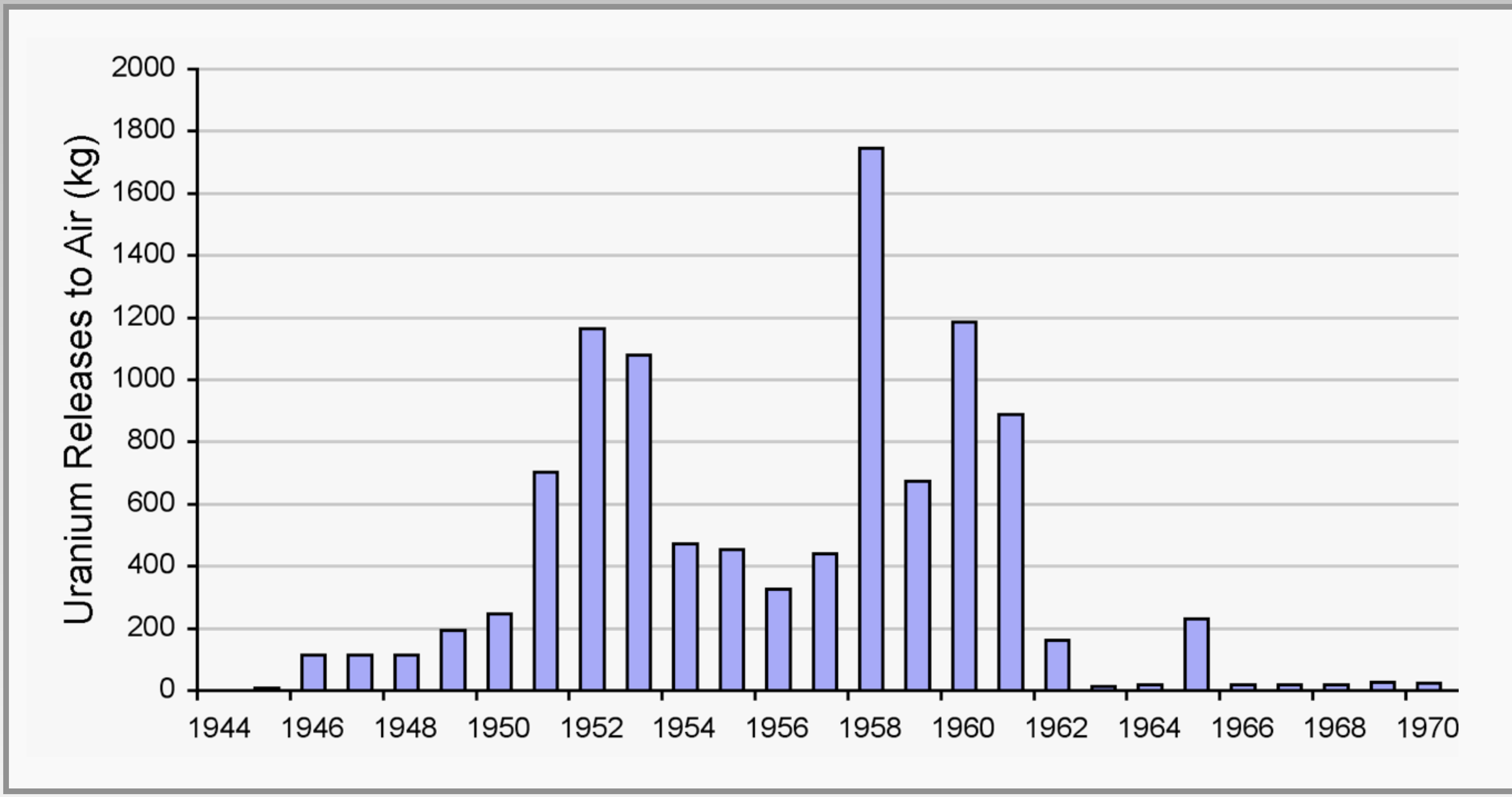
Detectability of Uranium Enrichment

	Satellite Imagery		Environmental Monitoring	
	Visible	Thermal	Standoff	Wide-Area
Gaseous Diffusion	Yes	Yes	?	?
Calutron/EMIS	No	Yes	?	?
Centrifuge	No	No	?	?

Emissions from Enrichment Plants

and Strategies to Detect Them

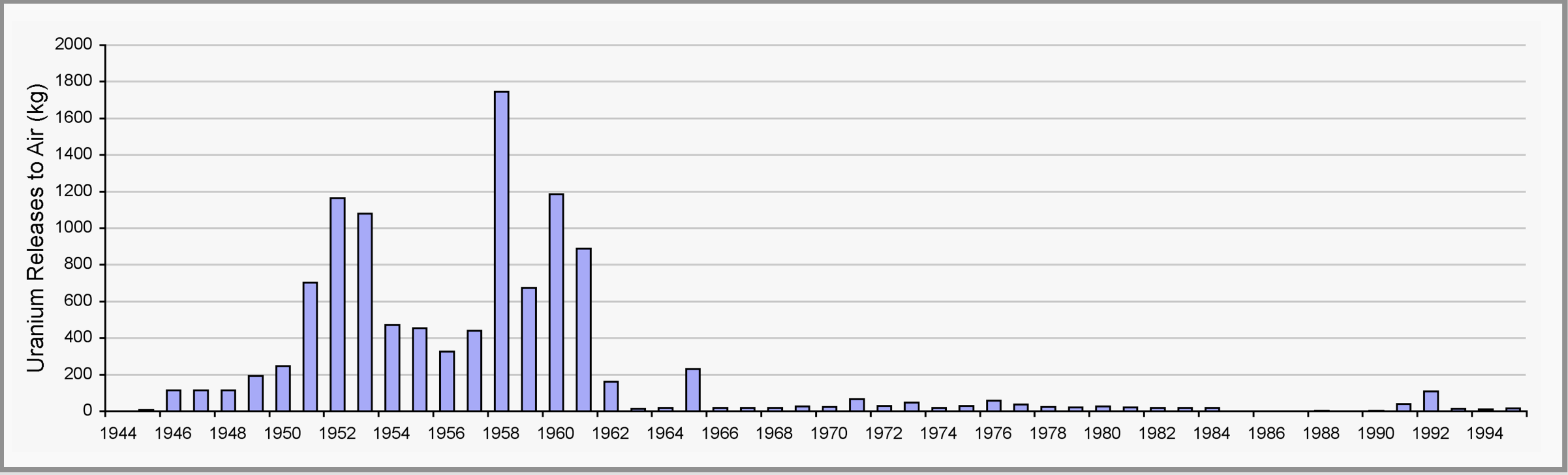
Some Old (Large) Plants Had Substantial Uranium Emissions

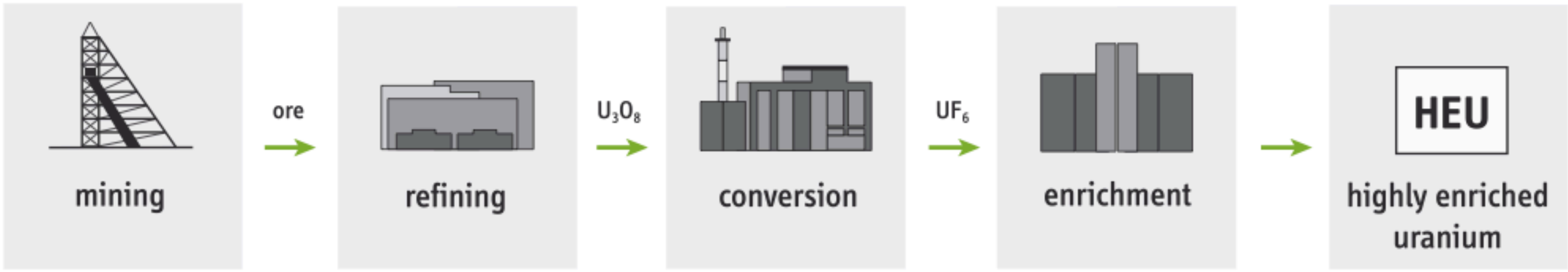


Historical emissions to air from Oak Ridge K-25 Site

Source: Uranium Releases from the Oak Ridge Reservation, DRAFT Task 6 Report, February 1997

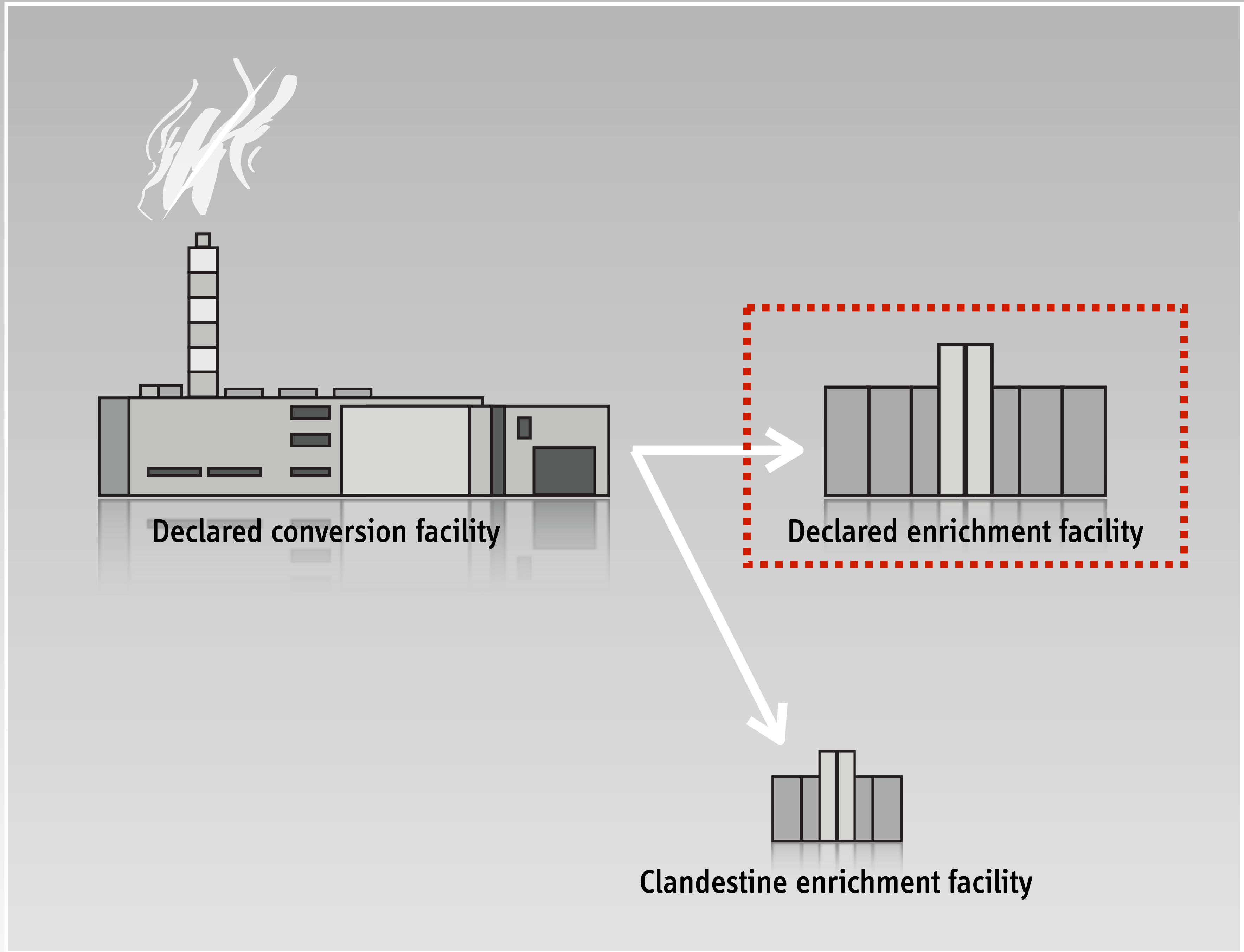
Enrichment Plant Operators Have Reduced Emissions Dramatically Over Time



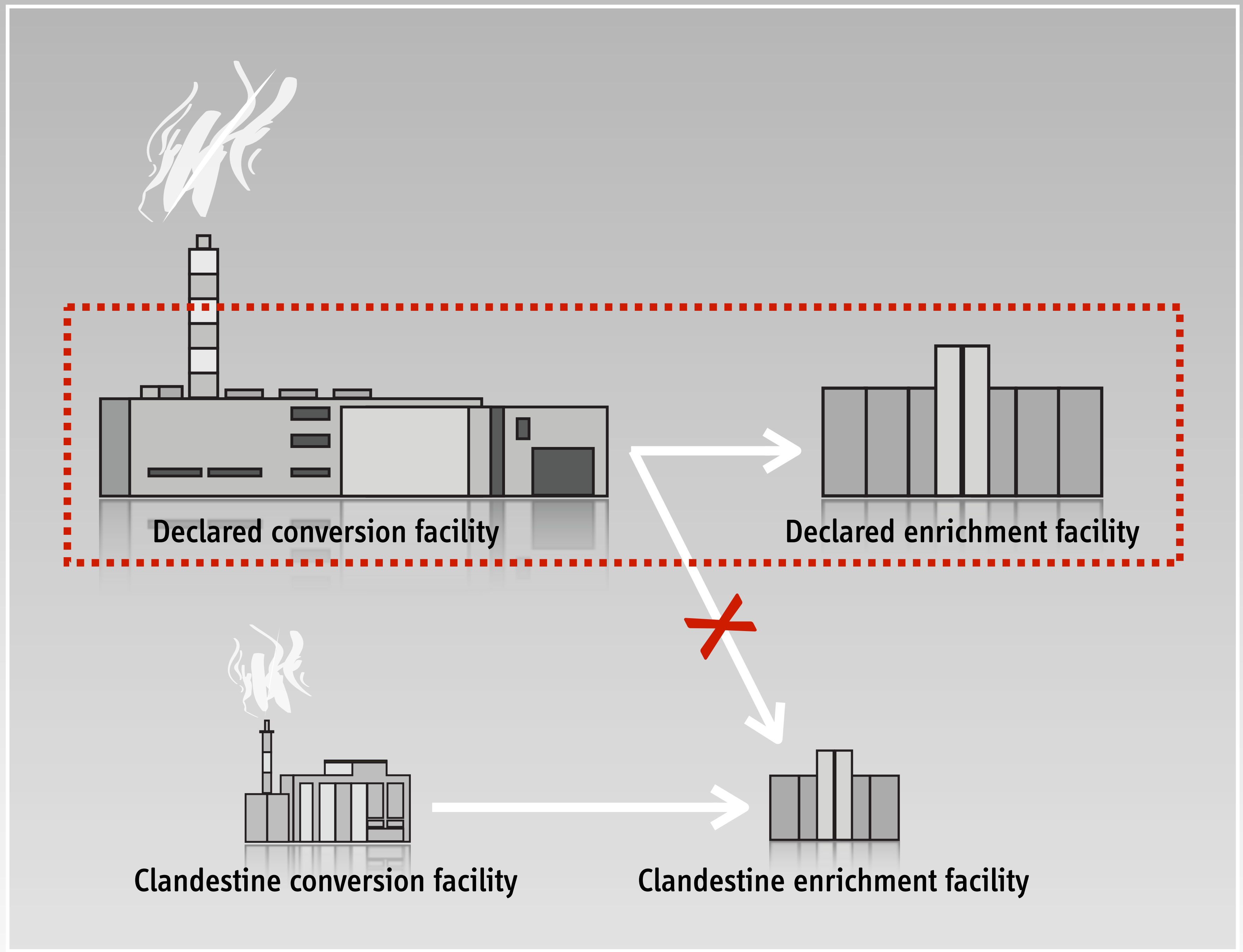


Uranium Enrichment Pathway

Alternative Detection Scheme



Alternative Detection Scheme



Estimated Levels of Total Uranium Released from an Enrichment Program

(sized to support a small weapons program)

	Uranium Emissions (Best Estimate)
Gaseous Diffusion	4 kg/yr
Calutron/EMIS	90 kg/yr
Centrifuge	1 kg/yr
Conversion (UF_6 production)	5 kg/yr

(Considerable uncertainties in all these estimates; and possibly much lower for centrifuge plant)

David Albright and Lauren Barbour, "Source Terms for Uranium Enrichment Plants"
IAEA Use of Wide Area Environmental Sampling in the Detection of Undeclared Nuclear Activities
STR-321, International Atomic Energy Agency, Vienna, 27 August 1999

What Are We Looking For?

UF_6 (gaseous) + 2 H_2O $\longrightarrow$ UO_2F_2 (particulate) + 4 HF (gaseous)

Existing natural background of uranium, but presence of uranium molecules (UF_6 and UO_2F_2) can point to anthropogenic origin

UF_6 reacts quickly with water molecules

(and is probably already removed inside the plant or very soon after emission)

UO_2F_2 is a particulate, stable

Little experimental data appears to be available on the atmospheric lifetime of UO_2F_2

HF is emitted from many other industrial processes

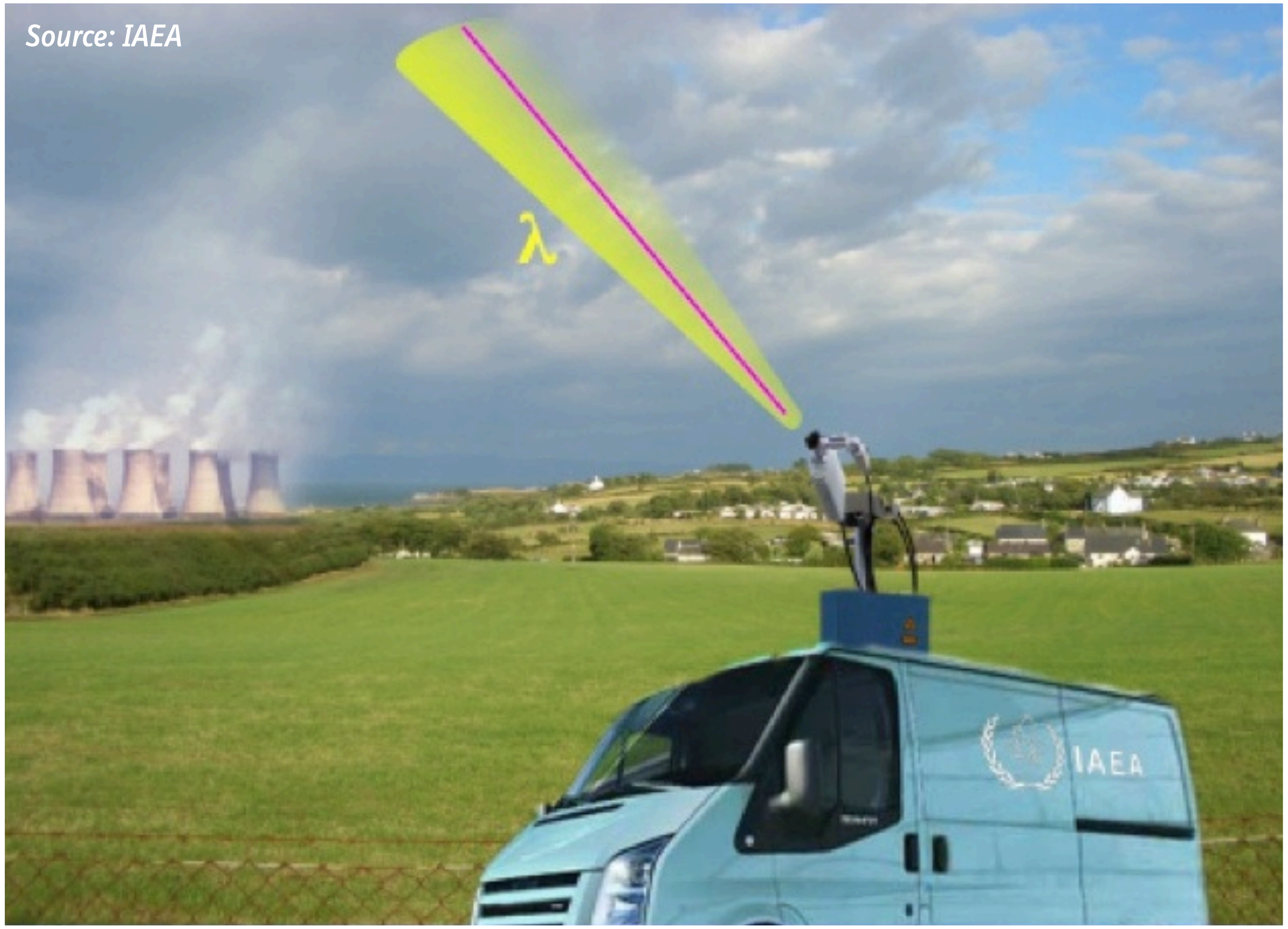
(but could help "ringing in" a suspected enrichment site)

Detectability of Uranium Enrichment

	Satellite Imagery		Environmental Sampling	
	Visible	Thermal	Standoff	Wide-Area
Gaseous Diffusion	Yes	Yes	(Likely)	(Unlikely)
Calutron/EMIS	No	Yes	Yes	(Unlikely)
Centrifuge	No	No	(Unlikely)	No
Conversion	No	No	(Likely)	Large-scale only

Laser-Based Standoff Detection

1. Selective excitation of target species (molecule) with laser tuned to appropriate optical frequency
2. Detection of emitted or backscattered light by a suitable optical collection device



- **DIAL**
  Differential Absorption
  Light Detection and Ranging (LIDAR)
- **TDSL**
  Tunable Diode Laser Spectroscopy
- ...

- **Radar-REMPI**
  Radar Resonance Enhanced
  Multi-Photon Ionization

Some of these technologies are being investigated by the IAEA's Novel Technologies Project and/or supported by Member State Support Programs

Some Interim Findings

Plants emit particularly in the early stages of development

Network-based Wide Area Environmental Monitoring (WAEM) is unrealistic for centrifuge uranium enrichment and uranium conversion

Standoff detection may have potential

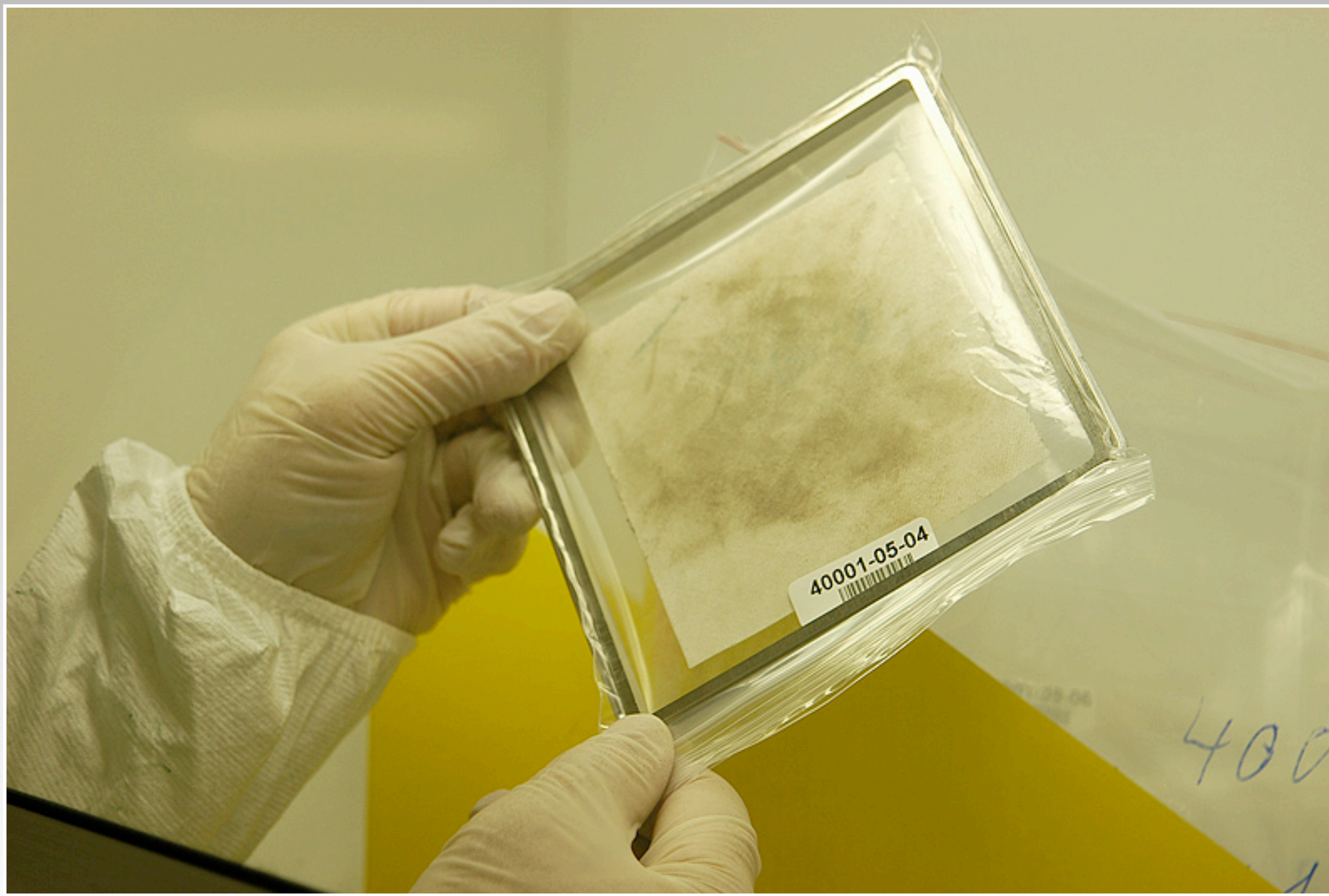
Research and development (including field tests) of technologies needed

Also: Facility-specific source terms, environmental behavior of relevant molecules, and background levels are poorly understood or documented

“Indirect Detection”

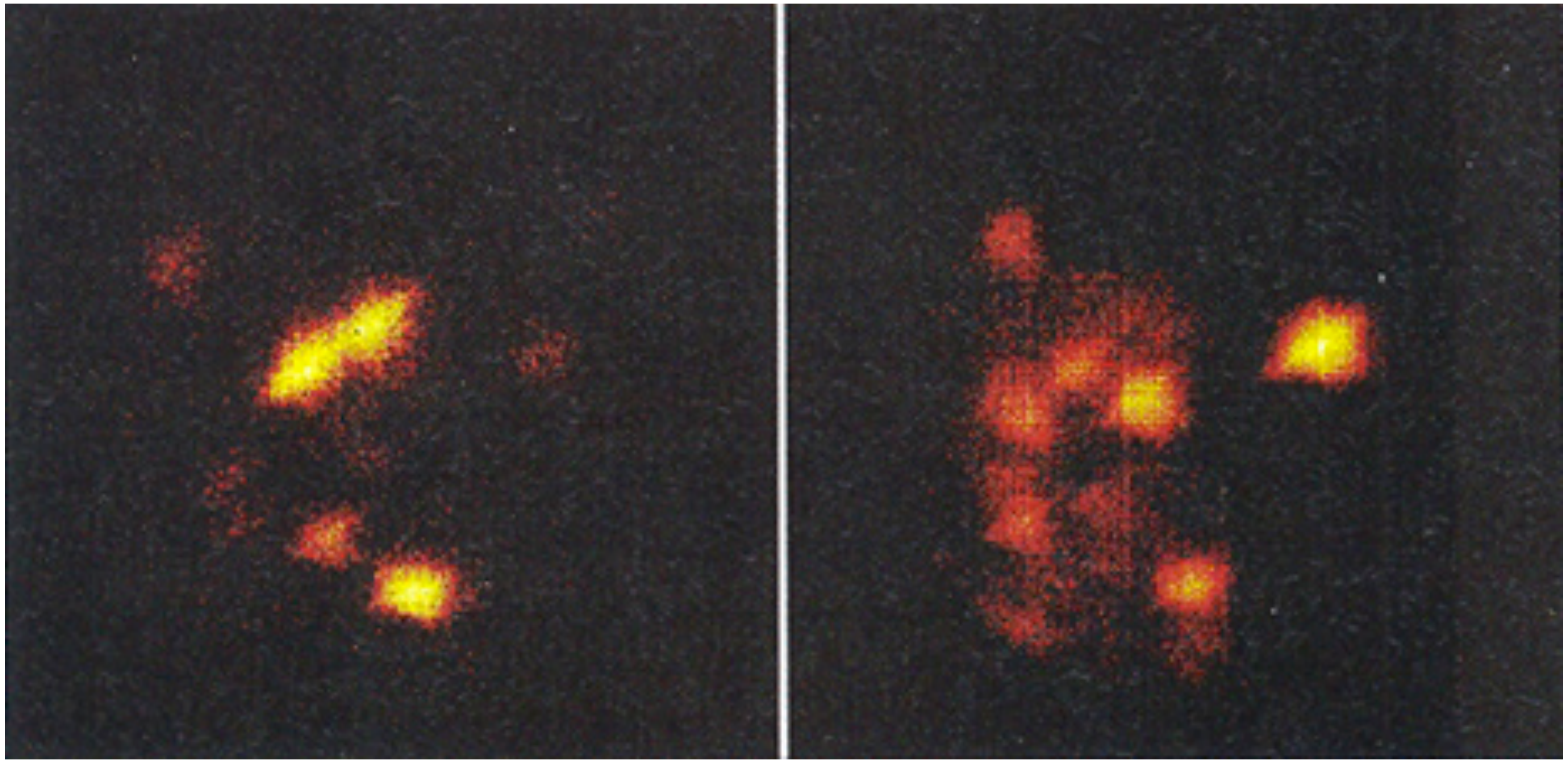
(with Nuclear Forensics Methods)

Environmental Swipe Sampling



Environmental Swipe Sampling

Images of micron-sized particles of uranium-oxide made with a Secondary Ion Mass Spectrometer



U-235 Concentration

U-238 Concentration

Detection of Clandestine Enrichment Via Vagabonding Particles?

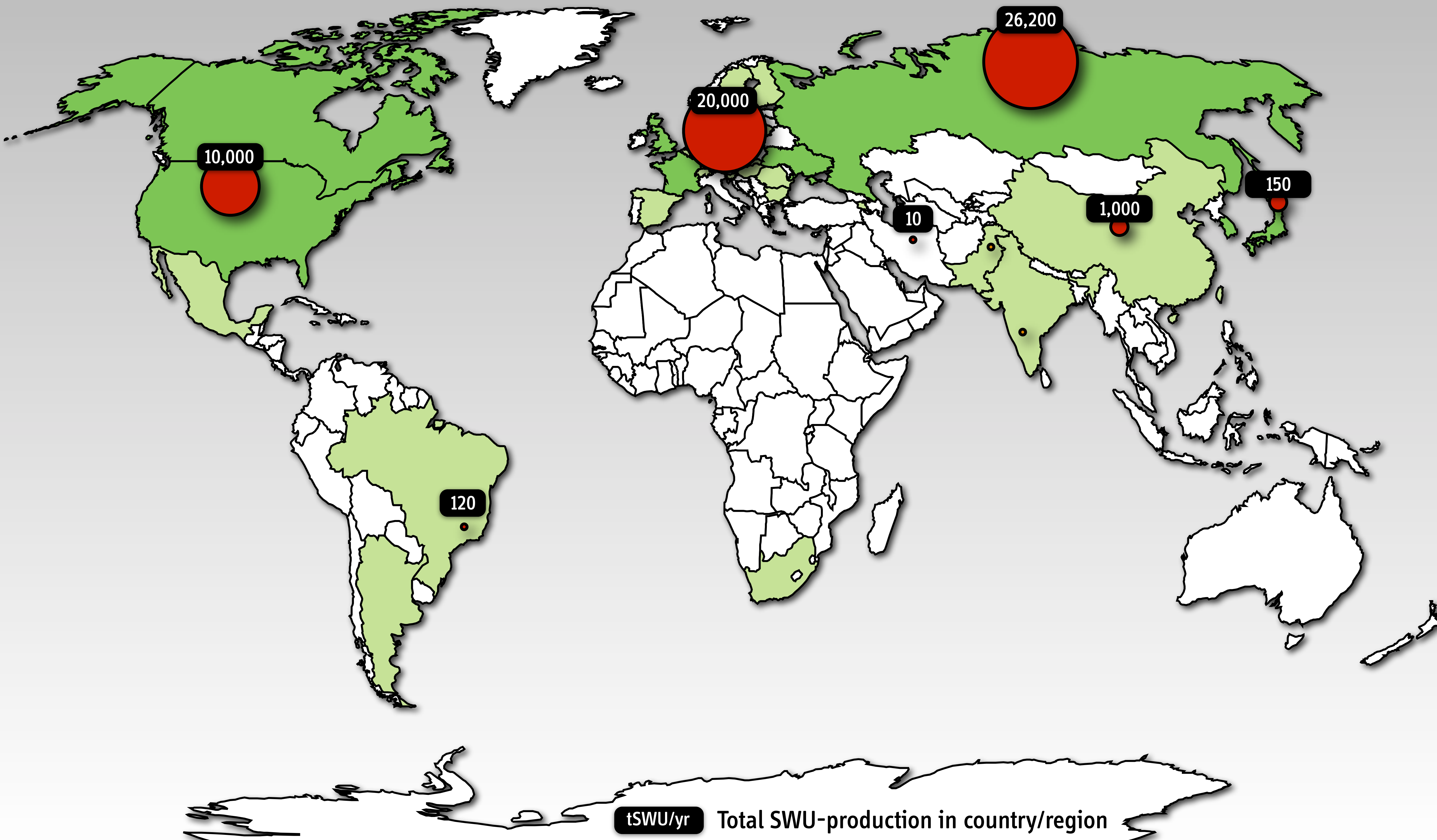
18,000 pages of documents and production records from North Korea's Yongbyon nuclear complex being handed over in May 2008 as part of the Six Party Process

Reportedly, HEU particles were later found on some of these documents

A New Framework for the Nuclear Fuel Cycle?

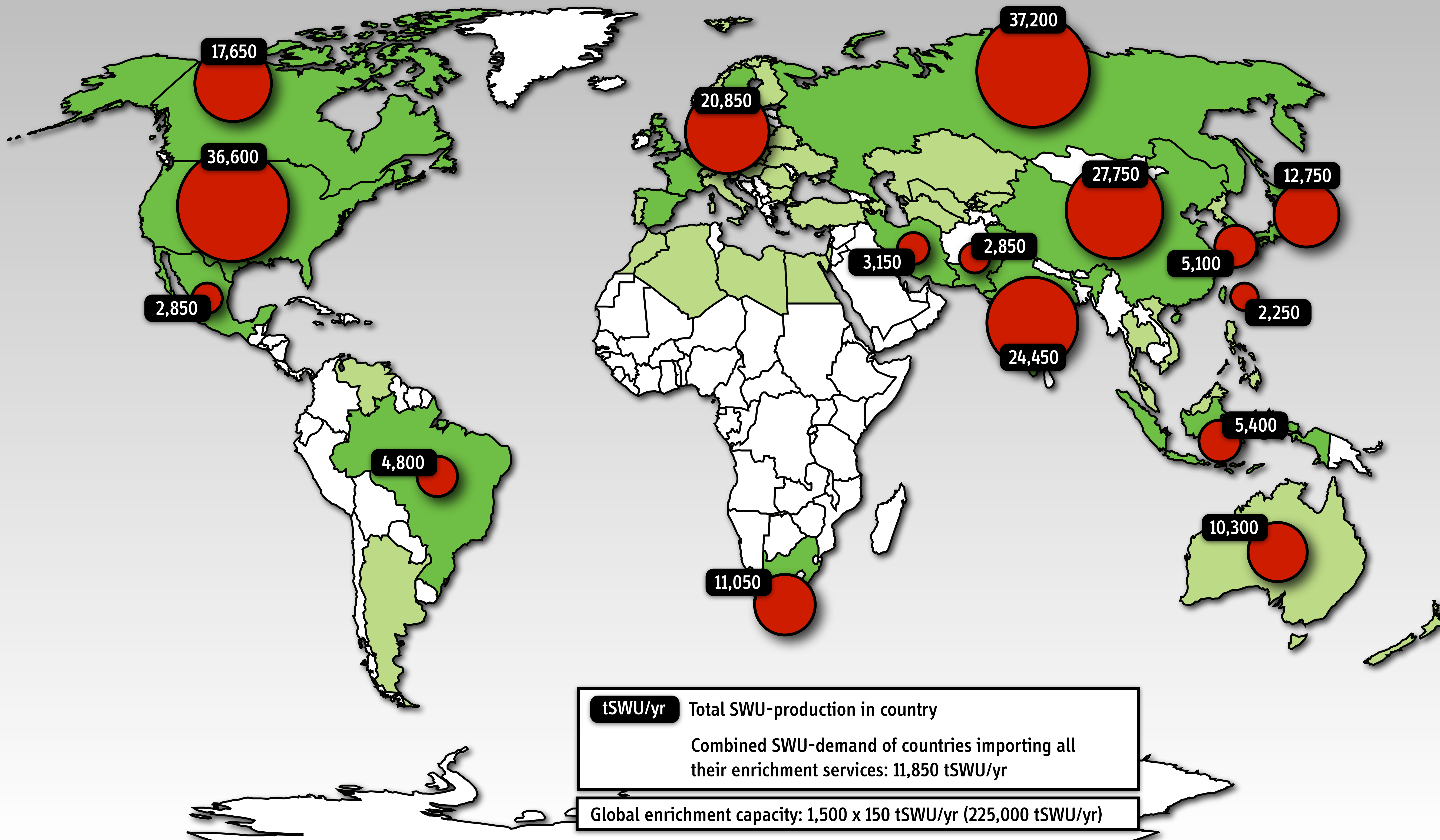
Global Enrichment Capacities, 2010

(14 operational plants in 10 countries, not including two military plants)



Enrichment Demand and Distribution

(for 1500 GWe Global Nuclear Expansion Scenario based on light-water reactors)



Preventing the Further Spread and Assuring Peaceful Use

Preventing Further Spread	• Tighten export controls (further)
	• Increase the ability to detect undeclared facilities
	• Encourage multilateral approaches to the nuclear fuel cycle
Assuring Peaceful Use	• Increase the effectiveness of IAEA safeguards
	• Revisit alternative "proliferation-resistant" technologies

Multilateral approaches involving joint ownership of enrichment plants
(using centrifuge technology on a "black-box" basis)
could help reduce concerns about clandestine enrichment programs

Concluding Remarks

Remote detection of uranium enrichment is extremely challenging

Network-based Wide Area Environmental Monitoring (WAEM) is unrealistic

Some Standoff Detection methods have potential and could play and important role for future safeguards and treaty-verification purposes

Further research and development (including field tests) of technologies is needed

Technical solutions alone will not provide 100-percent confidence in the absence of clandestine nuclear facilities

IAEA is moving towards "integrated safeguards" for states with Additional Protocol

Beneficial and/or necessary in the longer term:
Moving away from research, development, and deployment of sensitive nuclear technologies under national control