Safeguarding Uranium Enrichment: The Challenge of Large Gas-Centrifuge Facilities

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Outline

- **Overview of uranium enrichment**
- **Application of International Atomic Energy Agency (IAEA) safeguards at uranium enrichment plants**
- **Safeguards challenges presented by large gas centrifuge facilities**
- **Safeguards measures being investigated**

Overview of Uranium Enrichment

- **Existence of isotopes discovered at beginning of 20th century**

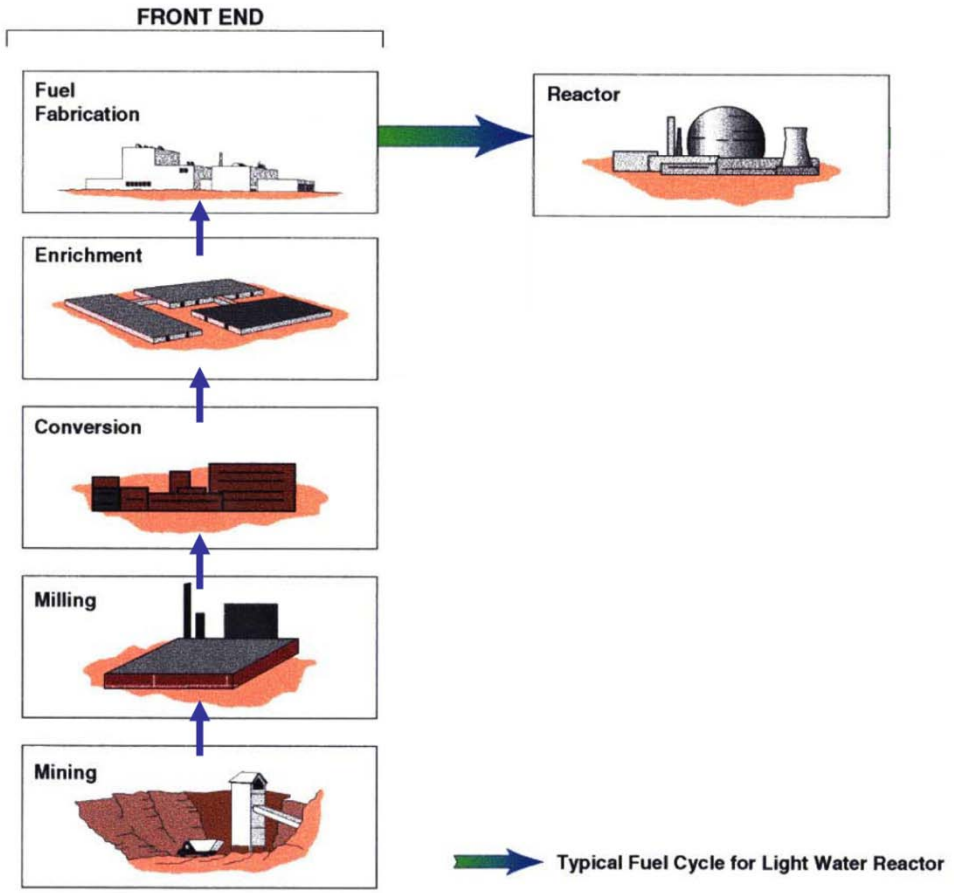
- **Early isotope separation**
  - **1920s-1930s: extremely small quantities of neon, chlorine, etc., separated using a variety of techniques (e.g., gaseous diffusion, thermal diffusion, gas centrifuge)**

Overview of Uranium Enrichment (Cont)

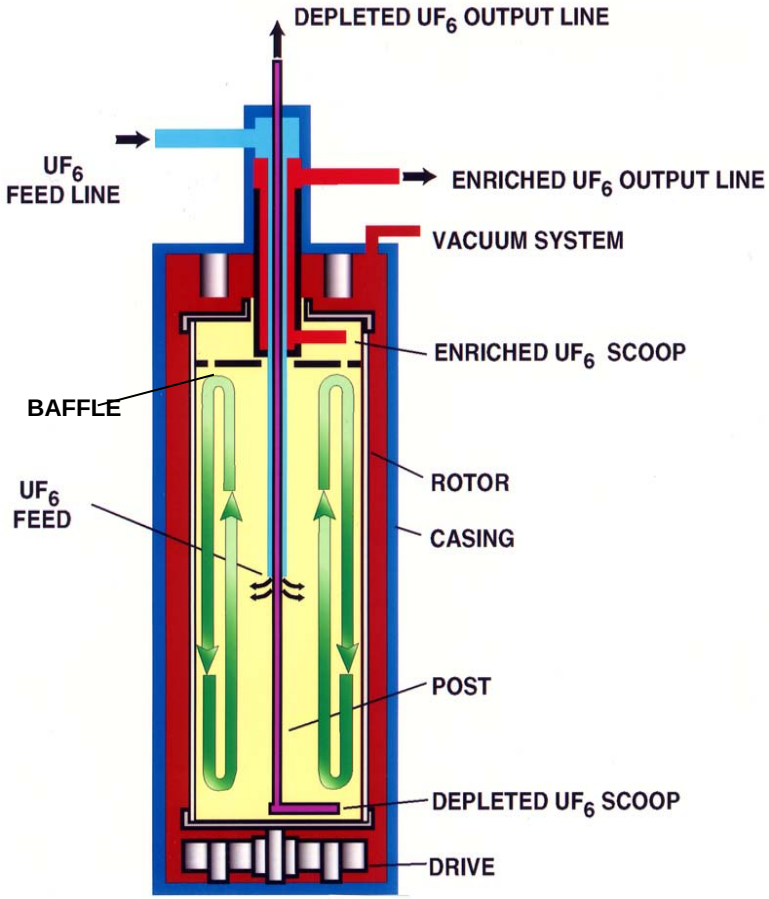
- **1940s-1950s: uranium enrichment was pursued on industrial scale for military motives**
- **Gaseous diffusion plants in U.S., Russia, England, France, and China**

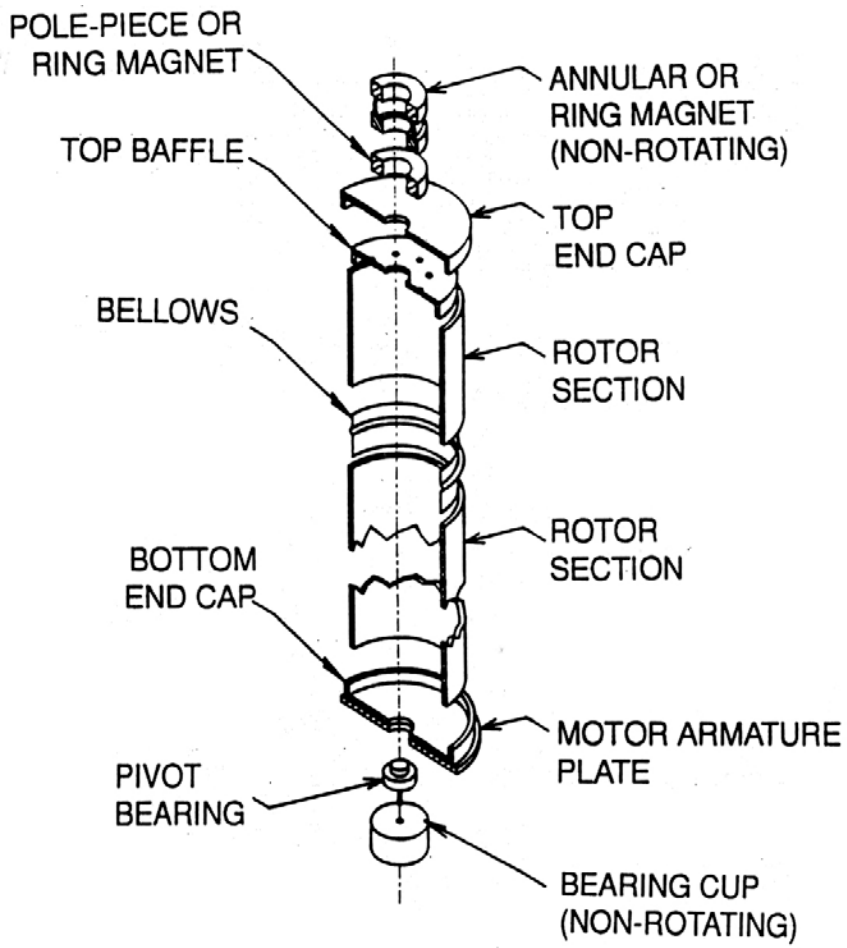
Overview of Uranium Enrichment (Cont)

- **1960s-1980s: Focus shifted to peaceful uses**
- **Gas centrifuge programs emerged in U.S., Russia, England, Germany, Netherlands, and Japan**

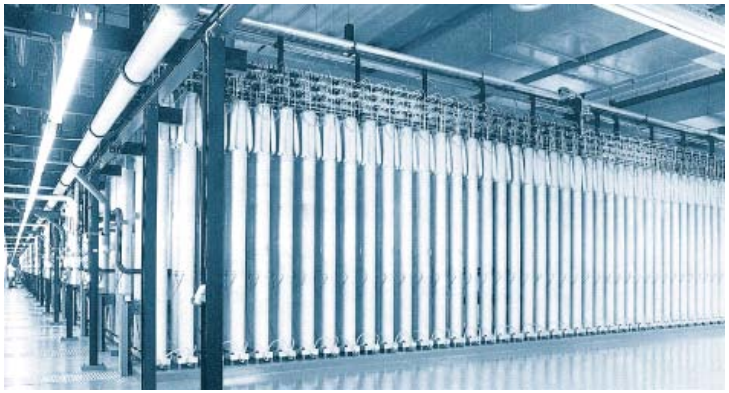


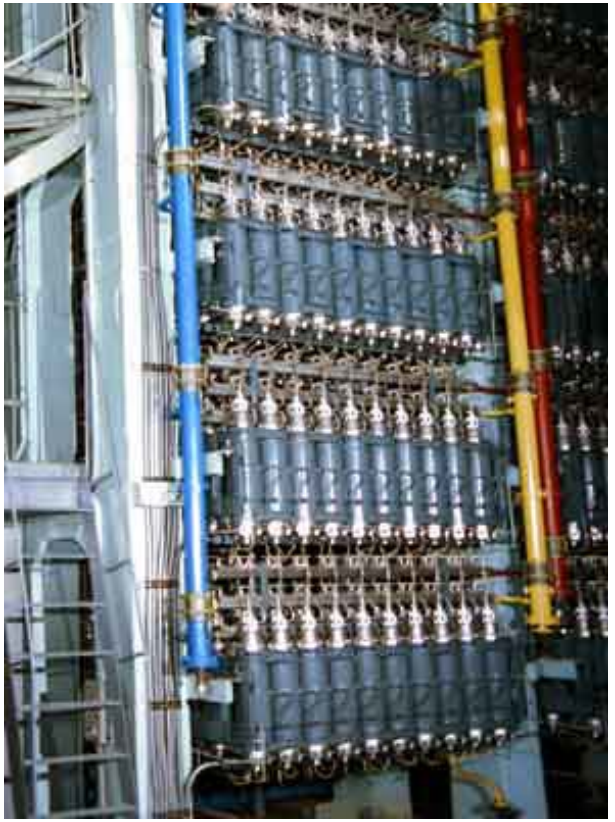
Schematic of a Gas Centrifuge



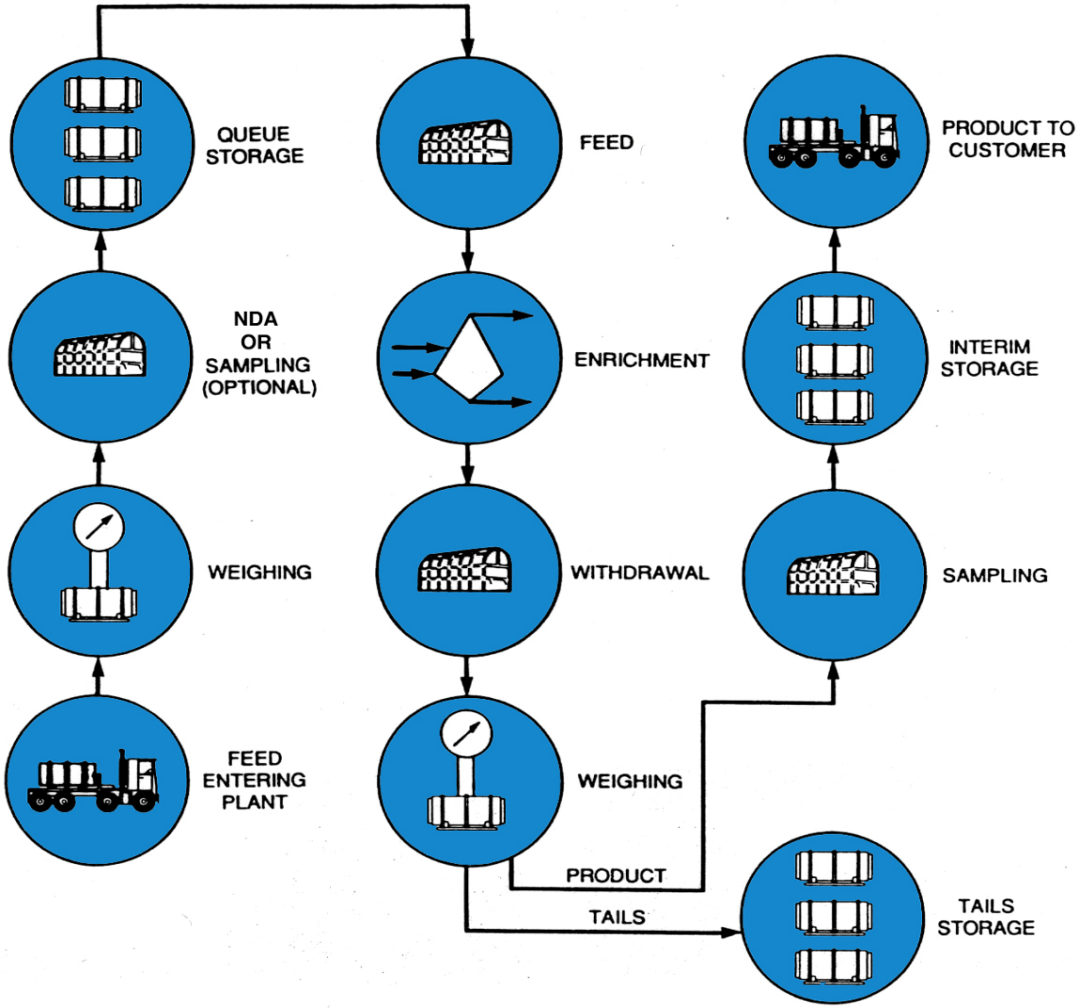


Examples of Gas Centrifuge Cascades

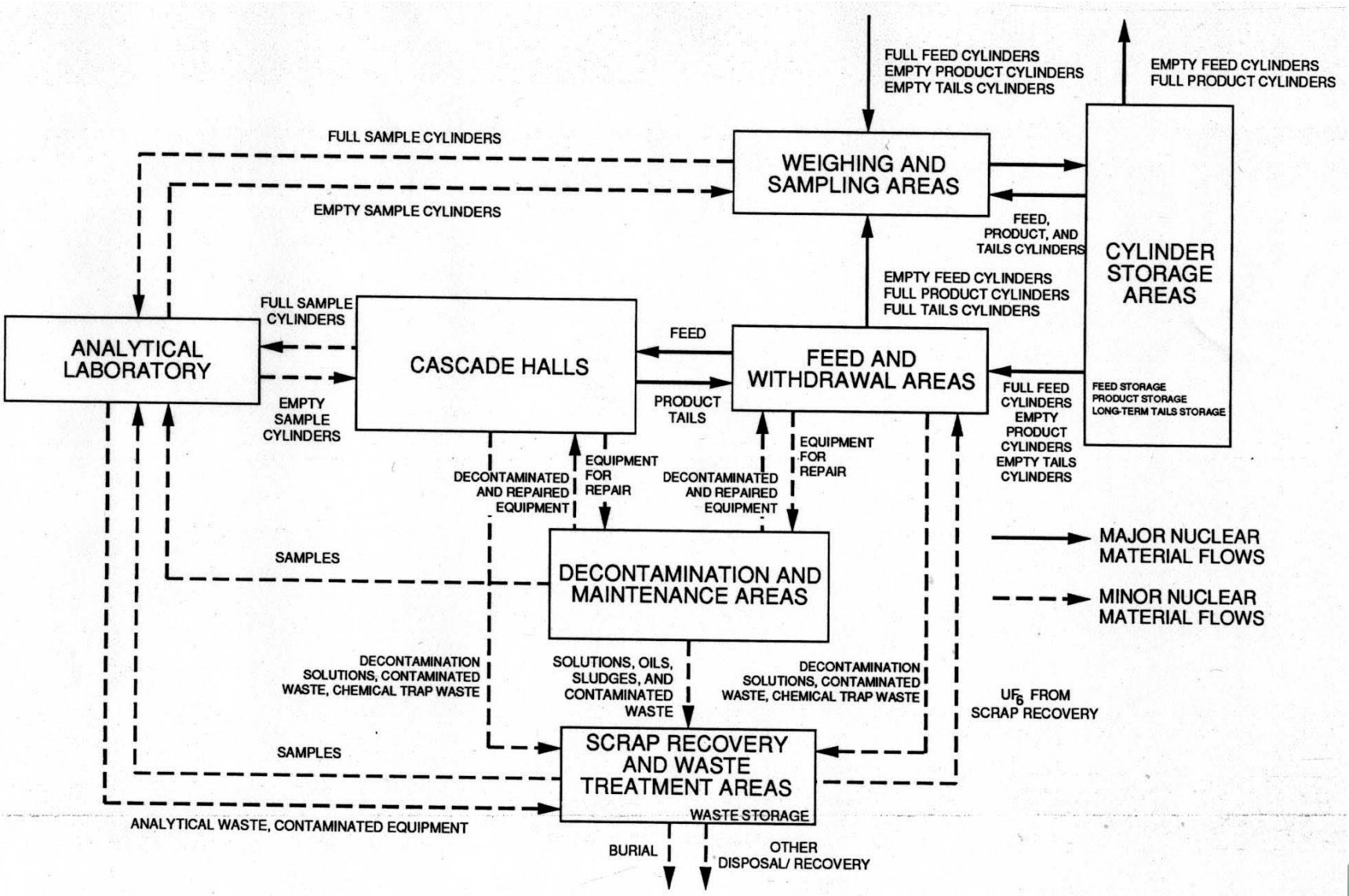




Typical Operations at a UF_6-based Enrichment Plant



Typical Material Flows



Large-scale Enrichment Facilities

Plant Name	Operator	Separative Capacity (t-SWU/year)
George Besse I, Tricastin, France	CEA	10,800: Gaseous Diffusion
Gronau, Germany	Urenco	2,750: Gas Centrifuge (still expanding)
Rokhasho, Japan	JNFL	1,050: Gas centrifuge
Almelo, Netherlands	Urenco	4,400: Gas centrifuge (still expanding)
Capenhurst, UK	Urenco	5,000: Gas centrifuge
4 plants, Russia	Rosatom	2,500 – 12,800: Gas centrifuge (>27,000 total and expanding)
Paducah, Ohio	USEC	11,300: Gaseous Diffusion

Introduction to IAEA Safeguards

- **Provides international assurances on voluntary declarations made by members through various treaties**
- **Established in 1957**
- **151 member states**
- **~2,300 professional and support staff**
- **Applies safeguards to >600 facilities**
- **Applies safeguards to ~1000 tonnes of material**
- **~2000 inspection in 2008**
- **~110M Euro (~$150M) budget for safeguards**

IAEA Safeguards Objectives

- **Objectives of IAEA safeguards at uranium enrichment plants:**
  - **Timely detection of the diversion of UF_6**
  - **Timely detection of the misuse of the facility to produce undeclared product (at declared enrichment levels) from undeclared feed**
  - **Timely detection of the misuse of the facility to produce UF_6 at higher than declared enrichment level – in particular, HEU**

IAEA Safeguards Measures

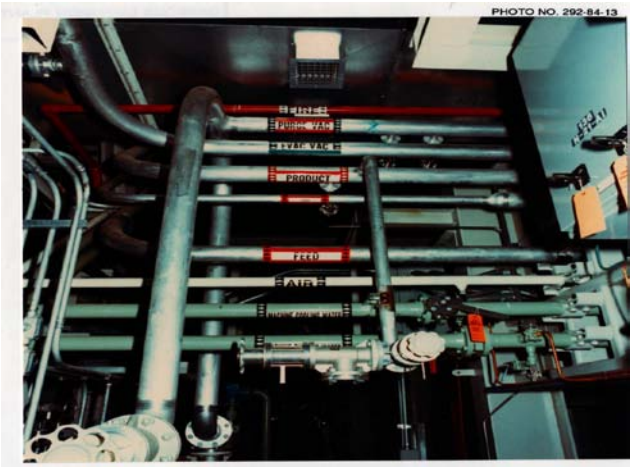
- **Nuclear material accountancy**
- **Containment and surveillance (C/S)**
- **Inspection**

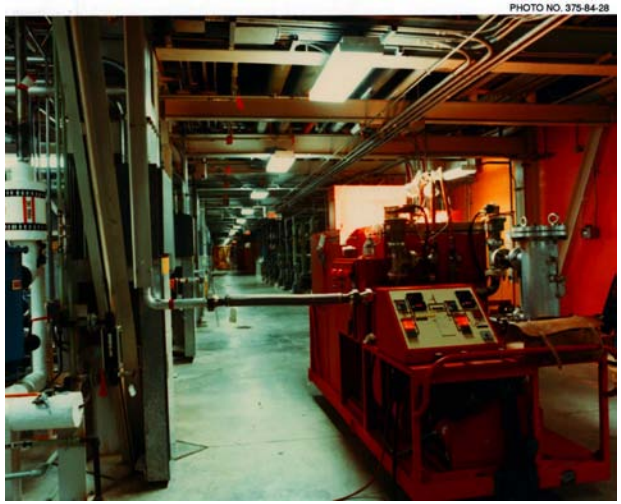
Safeguards Challenges at Enrichment Plants

- **No current means to independently verify actual separative capacity**
- **Many aspects of cascade design and operation are classified or proprietary**
- **IAEA budgetary constraints**
- **Necessity to minimize impact on operations**

Indicators Associated with HEU Production

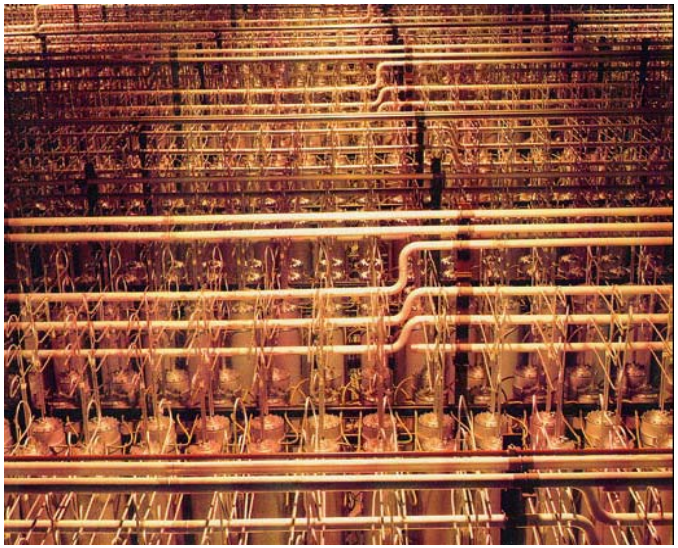
- **Reduced throughput**
- **Portable feed and withdrawal equipment/stations in cascade area**
- **Extra UF_6 cylinders in cascade area**
- **Valve settings**
- **Piping reconfigurations (e.g., inter-cascade piping, feed/ withdrawal points)**
- **Radiation signatures indicating HEU**
- **Ratios of minor isotopes**

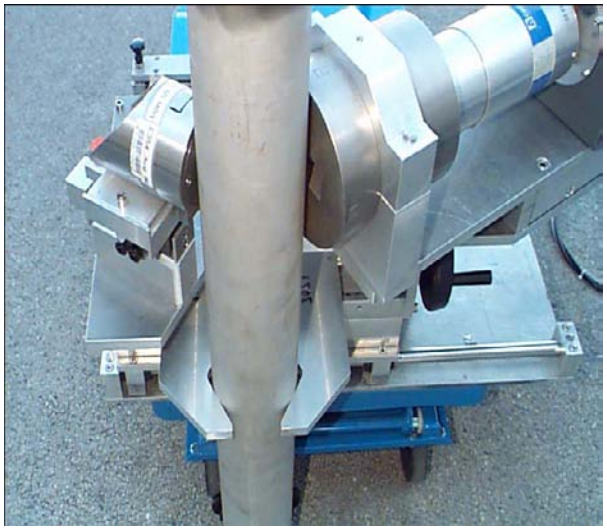




Initial Cascade Area Inspection Activities

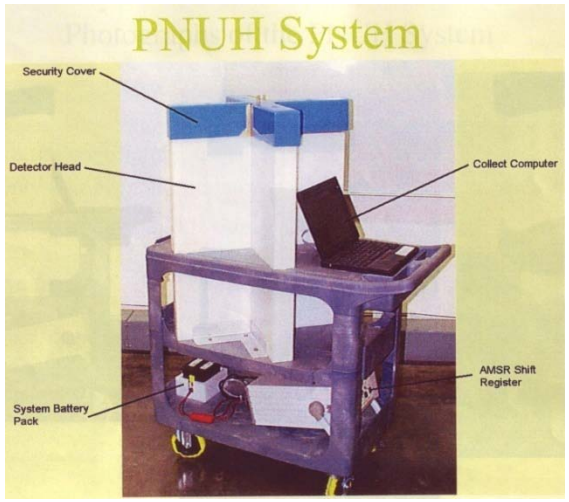
- **Limited-Frequency, Unannounced Access (LFUA) – 1980s**
  - **Visual observation**
  - **Radiation monitoring and NDA measurements**
  - **Sampling**
  - **Application and verification of seals**

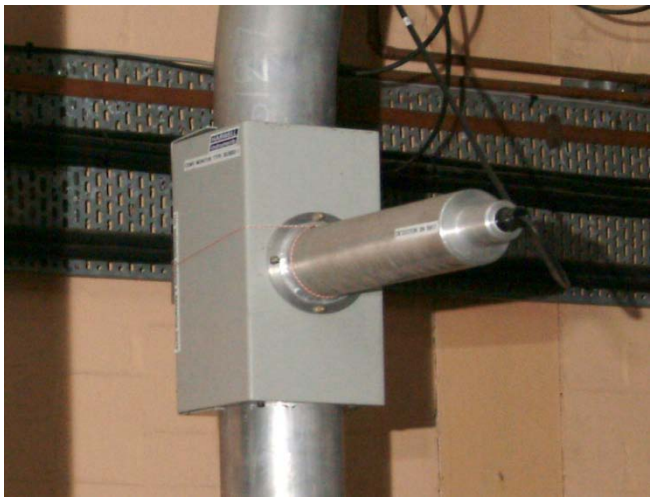




Additional Cascade Area Inspection Techniques

- **Added since early 1990s**
  - **Environmental sampling**
  - **Continuous on-line enrichment monitors**
  - **Portable neutron uranium hold-up counter**





Global Enrichment Capacity is Expanding

- **Advanced Centrifuge Plant in U.S. (USEC) – 3,800 t-SWU**
- **URENCO USA (Urenco) – 3,000 to 5,900 t-SWU**
- **George Besse II in France (Areva) – 7,500+ t-SWU**
- **Eagle Rock in U.S (Areva) – 3,300 t-SWU**
- **Global Laser Enrichment (GE-Hitachi) – 3,000-6,000 t-SWU**

Current Safeguards Challenges

- **Still no means to independently verify actual separative capacity**
- **Many aspects continue to be classified or proprietary**
- **Continued IAEA budgetary constraints**
- **Large-capacity plants make LFUA inspections difficult**
  - **More cascades to verify**
  - **Operationally more flexible & automated**
  - **<.2% capacity of 3,000 t-SWU plant needed to produce 1 significant quantity**

Recent Events Influencing IAEA Safeguards Approach

- **Meetings among technology holders**
  - **IAEA hosted meeting in Vienna (April 2005)**
  - **DOE hosted meeting at ORNL (July 2008)**
  - **Urenco hosted meeting in U.K. (Dec. 2009)**
- **IAEA developed "Model Safeguards Approach" (2006)**

IAEA Needs

- **Needs identified during April 2005 technology holder meeting**
  - **Short-notice random inspections**
  - **Continuous monitoring of operations**
  - **Shared use of operator data**
  - **Continuous item monitoring**
  - **On-site analytical capabilities**

Safeguards Measures Being Investigated

- **Continuous, unattended UF_6 verification**
  - **Cylinder tracking**
  - **Process scale monitoring**
  - **Enrichment monitoring**
  - **Accountancy scale monitoring**
- **Portable analytical instruments**
- **New design information verification (DIV) tools**

Cylinder Tracking

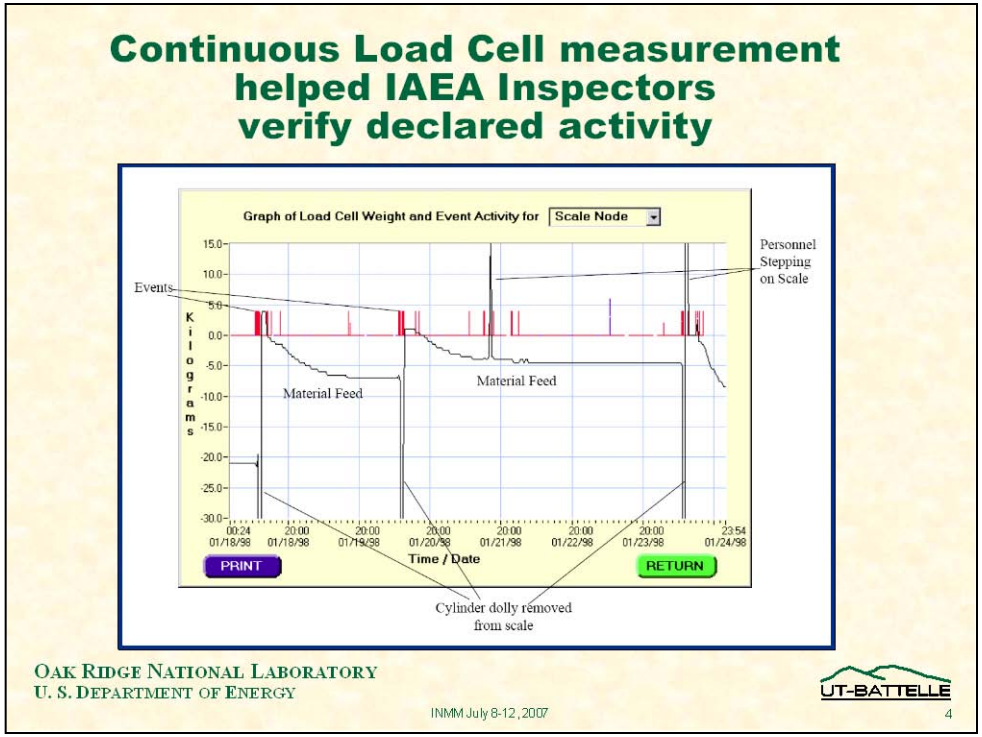
Enhanced tools for inventorying of UF_6 cylinders

Continuous Feed & Withdrawal Area Verification

Continuous monitoring of feed and withdrawal operations

Continuous UF_6 Flow Verification

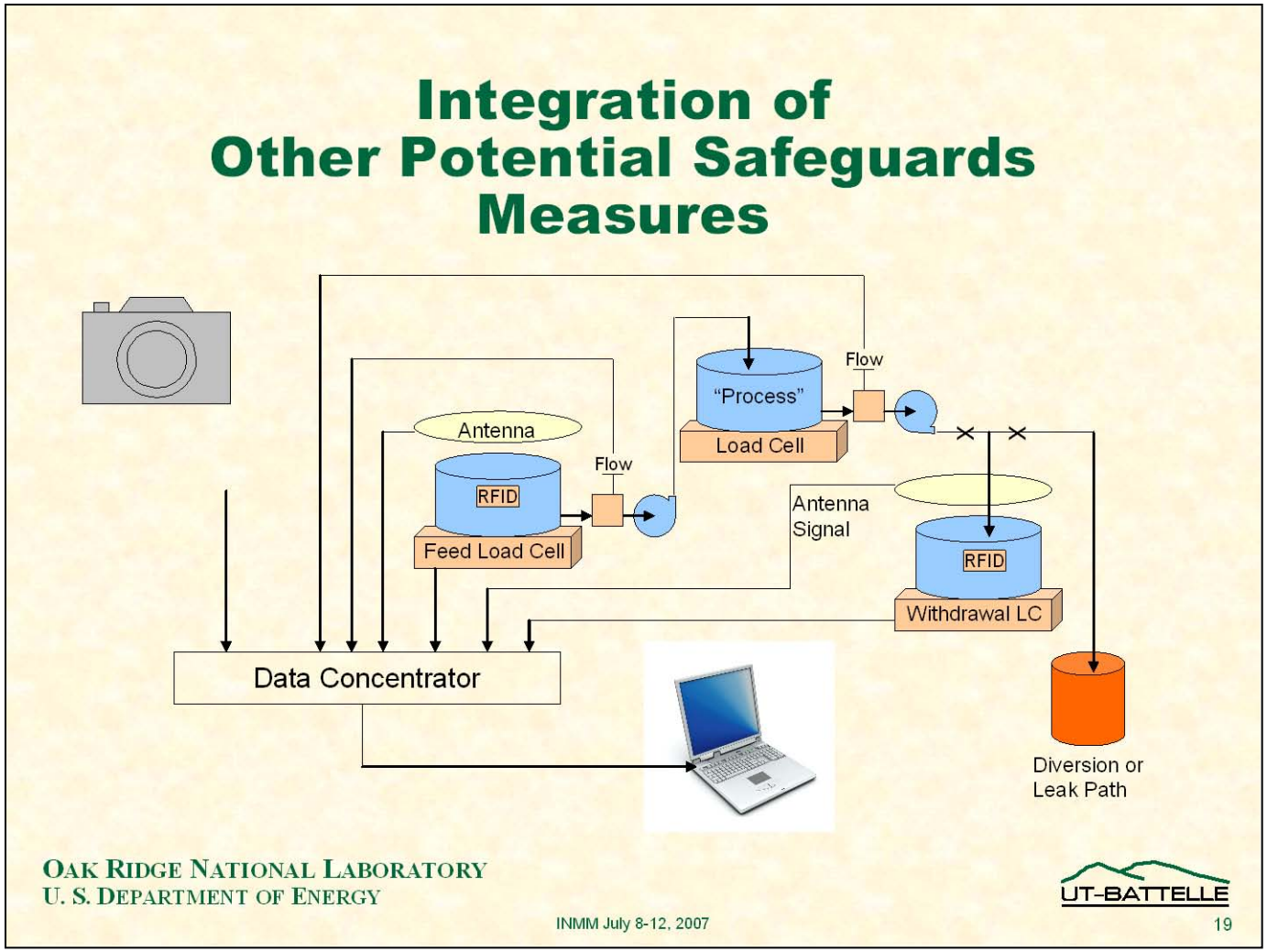
Continuous monitoring of process load cells in feed and withdrawal areas



DIV Instruments

- **3 dimensional – DIV systems to identify changes in piping**
- **Gamma and neutron imaging to identify changes in material flows**

Integration of Safeguards Measures



Smaller Enrichment Facilities

- **New safeguards measures should be applicable to smaller enrichment facilities:**
  - **Natanz, Iran: ~100 t-SWU/year**
  - **Resende, Brazil: ~120 t-SWU/year**

Final Thoughts

- **The increase in separative capacity of current plants and the start of construction of future large-capacity plants has reinvigorated the safeguards community to evaluate the effectiveness of the IAEA safeguards approach**
- **The IAEA has already established a new model safeguards approach and is investigating additional novel tools and techniques**
- **Several member states (including the U.S.) are evaluating new safeguards measures (based on current technology) to better address the verification of process flows**
- **These new measures will likely be applied globally and strengthen IAEA safeguards at all enrichment facilities**