Improving the Safeguards Approach:
Gas Centrifuge Enrichment Plants and Uranium Conversion Plants

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Office of Nuclear Safeguards & Security (NA-241)
• Next Generation Safeguards Initiative
  – Evolving challenges
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  – Unit Header Enrichment Monitoring
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• UF₆ Cylinder Tracking
• Information-Driven Inspections
Problem: The international safeguards system is being challenged by evolving proliferation threats, expanding IAEA responsibilities, the diffusion of sensitive technology via illicit networks, and a retiring safeguards workforce.

Response: The Next Generation Safeguards Initiative (NGSI) is revitalizing U.S. domestic capabilities to support the international safeguards system across five main program areas:

- Policy Development & Outreach
- Concepts and Approaches
- Technology Development
- Human Capital Development
- International Engagement

“We need more resources and authority to strengthen international inspections” – President Barack Obama in Prague, April 2009
Evolving Challenges and the International Safeguards System

**Workload**
- Growing safeguards burden
  - Number of facilities
  - SQs of material
- Evolving mandate
  - Investigation of undeclared activities
  - Proliferation networks
  - State Level Approach and more fully information driven safeguards system
- Anticipated Global nuclear renaissance

**Resources**
- Static IAEA budget and staffing levels
- Attrition among safeguards professionals both at IAEA and in the United States
- Loss of critical facilities and infrastructure (in U.S.)
Conversion plants are large, complex facilities employing batch operations

Conversion 1 and Conversion 2

- Conversion 1 plants process natural uranium material and usually involve the purification of Uranium Ore Concentrate (UOC) through to finished products such as UF\textsubscript{6} or uranium metal.
- Conversion 2 plants process enriched uranium material through to forms suitable for use in reactor fuels, usually at fuel fabrication plants.

INFCIRC/153 Para. 34 (c): “When any nuclear material of a composition and purity suitable for fuel fabrication or for being isotopically enriched leaves the plant or the process stage in which it has been produced [...] the nuclear material shall become subject to the other safeguards procedures specified in the Agreement.”

Safeguards Policy Series 18

- “uranium oxides and aqueous solutions of a composition and purity suitable for fuel fabrication or isotopic enrichment”
### NNWS with conversion plants in operation or under construction

<table>
<thead>
<tr>
<th>Country</th>
<th>Facility Name</th>
<th>Facility Type</th>
<th>Facility Status</th>
<th>Design Capacity (t HM/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>Cordoba Conversion Facility</td>
<td>Conversion to UO₂</td>
<td>In operation</td>
<td>175</td>
</tr>
<tr>
<td>Argentina</td>
<td>Pilcaniyeu Conversion Facility</td>
<td>Conversion to UF₆</td>
<td>In operation</td>
<td>62</td>
</tr>
<tr>
<td>Brazil</td>
<td>BRW Conversion</td>
<td>Conversion to UF₆</td>
<td>Under construction</td>
<td>40</td>
</tr>
<tr>
<td>Canada</td>
<td>Blind River</td>
<td>Conversion to UO₃</td>
<td>In operation</td>
<td>18000</td>
</tr>
<tr>
<td>Canada</td>
<td>Port Hope</td>
<td>Conversion to U metal</td>
<td>In operation</td>
<td>2000</td>
</tr>
<tr>
<td>Canada</td>
<td>Port Hope</td>
<td>Conversion to UF₆</td>
<td>In operation</td>
<td>12500</td>
</tr>
<tr>
<td>Canada</td>
<td>Port Hope</td>
<td>Conversion to UO₃</td>
<td>In operation</td>
<td>2800</td>
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<tr>
<td>Iran</td>
<td>Esfahan UCF</td>
<td>Conversion to UF₆ and UO₂</td>
<td>In operation</td>
<td>200</td>
</tr>
<tr>
<td>Turkey</td>
<td>CNRC Pilot Plant</td>
<td>Conversion to UO₂</td>
<td>In operation</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: IAEA Nuclear Fuel Cycle Information System
1. *Timely detection* of the **processing** of undeclared materials into pure products

2. *Timely detection* of the **diversion** of declared material
1. UO$_3$, U$_3$O$_8$, or UO$_2$ → UCl$_4$ for Electromagnetic Isotope Separation or Chemical/Ion Exchange Enrichment

2. UO$_2$ used for Plutonium production

3. UF$_4$ → U metal for Plutonium production or Atomic Vapor Laser Isotope Separation

4. UF$_6$ sent to Gas Centrifuge Enrichment or Gaseous Diffusion Plant for enrichment

Conversion Plants: Diversion Paths

Safeguards Approach and Inspection Activities for Conversion Plants

• Current:
  – design information verification (DIV) in processing and storage areas, “which may include the taking of environmental or grab samples;”
  – annual physical inventory verification (PIV);
  – interim inventory verification; mailbox declarations and short-notice random inspections (SNRI);
  – visual inspection;
  – AP Complementary Access (if appropriate)

• Activities to improve confidence in safeguards conclusions:
  – NDA of bulk containers;
  – containment and surveillance (C/S)

1. *Timely detection* of the **misuse of the facility to produce HEU** (or any UF₆ at higher-than-declared enrichment levels)

2. *Timely detection* of the **diversion of declared UF₆**

3. *Timely detection* of the **misuse of the facility to produce undeclared LEU** (at declared enrichment levels) from undeclared feed

   - Take undeclared material / enrich as feed for clandestine HEU plant
<table>
<thead>
<tr>
<th>Country</th>
<th>Facility Name</th>
<th>Facility Status</th>
<th>Design Capacity MTSWU/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>INB Resende</td>
<td>In operation</td>
<td>120</td>
</tr>
<tr>
<td>China</td>
<td>Shaanxi (Hanzhong)</td>
<td>In operation</td>
<td>1000</td>
</tr>
<tr>
<td>Germany</td>
<td>URENCO Deutschland (Gronau)</td>
<td>In operation</td>
<td>4500</td>
</tr>
<tr>
<td>France</td>
<td>George Besse II</td>
<td>In operation</td>
<td>7500</td>
</tr>
<tr>
<td>Iran</td>
<td>Natanz</td>
<td>In operation</td>
<td>?</td>
</tr>
<tr>
<td>Iran</td>
<td>Fordow</td>
<td>Installing centrifuges</td>
<td>?</td>
</tr>
<tr>
<td>Japan</td>
<td>Rokkasho</td>
<td>In operation</td>
<td>1050; planned 1500</td>
</tr>
<tr>
<td>Netherlands</td>
<td>URENCO Nederland (Almelo)</td>
<td>In operation</td>
<td>4500</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>URENCO Capenhurst</td>
<td>In operation</td>
<td>5000</td>
</tr>
</tbody>
</table>

Source: IAEA Nuclear Fuel Cycle Information System
Model Safeguards Approach for GCEPs

- Hexapartite Safeguards Project (HSP) – Based Safeguards Approach (early 1980s)
  - Annual and interim physical inventory verification (PIV) with destructive and non-destructive assay (DA and NDA)
  - Limited-frequency, unannounced access (LFUA) for cascades with visual observation and NDA (header pipe enrichment measurements [CHEM])
  - Design information verification (DIV)
  - Supplemented with containment and surveillance measures
- Post-HSP
  - Continuous enrichment measurement (CEMO) of cascade product header pipes (In use at Capenhurst from 1995 to June 2011)
  - Environmental sampling

• Additional Safeguards Measures
  – Short-notice random inspections (SNRIs) w/ mailbox declaration system
  – Header pipe enrichment monitoring
  – Load cell monitoring (with proper authentication)
  – Laser identification of UF$_6$ cylinders (L2IS) coupled with video surveillance

Next Generation Safeguards for GCEPs

- Automated cylinder identification and tracking
  - Universal ID labeling, RF tagging
  - Automated cylinder NDA (cylinder portal monitor)
- Remote, continuous attribute monitoring
  - Authenticated accountability scales w/ video surveillance
  - Continuous process load cell monitoring
  - Continuous enrichment monitoring of unit product header pipes
- Integrated surveillance (event-triggered)
  - Centralized data acquisition and analysis system
  - Unannounced, information-driven inspections
- Optimized DIV (laser-based, automated)
- Onsite DA and environmental sampling (ES) analysis/screening
Benefits of Accountancy Scale Monitoring

- Low-risk, potentially high-value implementation of continuous, unattended monitoring
- Declaration verification
  - Substitute on-site activities with continuous, automated verification
- Integration with multiple safeguards systems to establish ‘normal’ operational behavior
  - Cross-check verification with process load cells
  - Input to an attribute monitoring system and use for information-driven inspections
Benefits of Process Load Cell Monitoring

• Direct measurement of mass of material processed
  – Increased confidence of no undeclared feeds, no excess production
• Currently, no monitoring of feeds and withdrawals between inspections
• Could close UF₆ material balance more frequently
• Cross-check verified with accountancy scales: number of cylinders processed, full/empty weights, etc.
• Eliminate need for cylinder switchover during PIV
Benefits of Unit Header Enrichment Monitoring

• Timely detection of HEU production
• Near-real-time $^{235}$U balance when integrated with process load cells
• Unit headers, *not* cascade headers
  – Fewer per plant
  – Higher pressure
  – Less-sensitive locations
  – flexibility in installation
  – Reduces maintenance time due to elimination of cadmium source

CEMO - 1995 to June 2011

AEM at Capenhurst E23 plant (UK)
• Importance of “trust” in SGs data
• Some sources cannot be authenticated in the traditional sense (practically)
• At-the-source authentication
  – Transmission over un-trusted networks
• Cross-check verification
  – Simple, rules-based consistency checks
  – Linked back to a “trusted” (authenticated) source
  – More cost effective
Remote Monitoring

- Replacing on-site activities, fewer “days in the field”
- Lowering operator burden
  - e.g., quicker cylinder release times
- Operator concerns
  - Allowing unfiltered data off-site
  - Drawing conclusions without operator feedback
  - “False alarms”
Remote Monitoring (cont.)

• Possible solution: information-driven inspections
  – Using remote monitoring data to optimize on-site inspection activities and schedule
  – A realization of information-driven safeguards
  – Randomization (from operator perspective) with fewer inspections
  – Three options proposed:
    1. Full remote transmission and remote analysis
    2. Single system go/no-go
    3. Aggregate go/no-go
  • Actual implementation some combination of these
  • Selection based on information sensitivity and automated analysis capabilities
1. Transmission of all transmissible unattended monitoring data to IAEA HQ
2. Manual or software analysis of data at HQ to determine optimal inspection schedule

1. Each safeguards system generates its own go/no-go signal  
   (similar to CEMO, except thresholds can be milder)
2. All go/no-go signals transmitted to IAEA HQ
3. Set of signals viewed as a whole to determine optimal inspection schedule

1. All unattended monitoring systems deliver data to onsite aggregator for automated analysis
2. Aggregator/analyzer generates whole-plant go/no-go or “risk” score for transmission to HQ
3. Go/no-go or risk score observed over time to determine optimal inspection schedule

Safeguards-by-Design

- An approach in which “international safeguards are fully integrated into the design process of a new nuclear facility from the initial planning through design, construction, operation, and decommissioning”
  - Avoid costly redesign and retrofits
  - Make implementation of SGs more effective and efficient
- DOE supporting preparation of “model” SBD guidance documents, including for GCEPs
  - IAEA SGs objectives for facility
  - Best practices/lessons learned
  - Advanced concepts for novel instrumentation and designs
• Limit ingress/egress paths
• Simplify process pipework and ensure flow measurement points are accessible to inspectors
• Locate drums and UF₆ cylinders with inspector access in mind
  – Design storage and handling areas to facilitate easy access

• Extensive effort expended in locating and identifying cylinders
• Universal cylinder identification system
  – Reduced effort for both operators and inspectors
• Detection of “undeclared” cylinders
• Automated identification technologies
  – Barcodes, laser “fingerprinting”, RF-tagging
  – automated software to compare operator inventory lists with inspector observations
• Informal definition: Using unattended monitoring data to optimize inspection schedules and activities
• *Not* using unattended monitoring data to draw safeguards conclusions
• A realization of Information-Driven Safeguards
• Continuing to make inspections more effective and efficient:
  – Inspection evolution: Scheduled inspections → SNRIs → Information-Driven inspections
  – Fewer inspections
  – Maintaining the deterrent effect of inspector presence
  – Meeting timeliness goals
• “Random” from operator’s perspective
• Information-driven inspections using unattended monitoring data are the logical evolution of inspection planning

• Continuous monitoring systems can be used for information-driven inspections while meeting operator requirements and reducing operator burden: fewer, better inspections

• Any such system must be designed to effectively protect sensitive information
QUESTIONS?