Timely Verification at Large-scale Gas Centrifuge Enrichment Plants

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Ann Arbor, MI
What do ongoing trends in gas centrifuge enrichment technology mean for IAEA safeguards?

What can the IAEA do to keep pace with these trends?
**BACKGROUND**

**WHERE ARE THE GOALPOSTS?**

Comprehensive Safeguards Agreements (NNWS), Voluntary Offer Agreements (NWS)

**HSP**

- Goals: Detect diversion of declared material AND facility misuse
- Traditional item-based safeguards measures
- Limited Frequency Unannounced Access (LFUA) to cascade halls


**RMA**

Revised Model Approach (2006)
- Additional goal: Detect excess LEU production using undeclared material
- Short-notice random inspections (SNRIs) to feed/withdrawal areas to verify that only declared material is fed

**CONSORTIUM for VERIFICATION TECHNOLOGY**
WHAT HAS CHANGED SINCE 2006?

Pre-Fukushima: Construction of new GCEPs, Expansion of existing ones
• New plants: URENCO USA (4.7 MSWU), Georges-Besse II (7.5 MSWU)
• Expansions: Gronau UTA II (2.4 MSWU), Almelo expansion (1.8 MSWU)

Post-Fukushima: 60 MSWU supply glut accumulates
• This LEU is somewhere... not necessarily in UF₆, however.

Bottom line: More capacity per site, More LEU in storage
What IAEA safeguards issues do these dynamics raise?
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Timely detection of HEU production
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- Timely detection of HEU production
- Efficiency of traditional SG measures
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Timely detection of HEU production

Efficiency of traditional SG measures
What might an HEU production scenario look like at a modern commercial GCEP?
SIMULATING A MISUSE SCENARIO

SMITH, LEBRUN & LABELLA, JNMM 2013:

<table>
<thead>
<tr>
<th></th>
<th>#</th>
<th>tSWU/year</th>
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</thead>
<tbody>
<tr>
<td>GCEP</td>
<td>1</td>
<td>4000</td>
</tr>
<tr>
<td>Units/GCEP</td>
<td>8</td>
<td>500</td>
</tr>
<tr>
<td>Cascades/Unit</td>
<td>10</td>
<td>50</td>
</tr>
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</table>

Further assumed here:

- 1000 Centrifuges/Cascade: 50 kgSWU/yr
- 11 enriching stages, 4 stripping stages
- Max enrichment = 5%
- 10 g U/centrifuge
- Separation factor $\gamma = R'/R'' = 1.44$
VISUALIZING A MISUSE SCENARIO

A NOTIONAL (5-CASCADE) PRODUCTION UNIT:

Feed and Withdrawal Stations

Feed

Feed

Tails

Tails

Product

Header Connection Area, with Unit Headers

Cascade Hall, with Cascade Headers
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A NOTIONAL (5-CASCADE) PRODUCTION UNIT:

Cascade Hall, with Cascade Headers

Feed and Withdrawal Stations

- Feed 5.1%
- Feed 5.1%
- Tails 4.4%
- Tails 4.4%
- Product 94.1%

Header Connection Area, with Unit Headers

Cascade Hall, with Cascade Headers
IS IT WORTH RESHAPING CASCADES?

IN THIS CASE, PROBABLY NOT.

**TRADEOFFS OF NO RESHAPING**

Pros: Expedient, Simple, Additional enrichment gain from off-normal stage cuts

Cons: Some loss of nominal SWU capacity

**3 CASCADE GROUPS (2 IN MODIFIED UNIT)**

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<tr>
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<th>Product Enrichment</th>
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<tbody>
<tr>
<td>Original</td>
<td>0.72%</td>
<td>5.11%</td>
<td>0.29%</td>
<td>50</td>
</tr>
<tr>
<td>Mid Group</td>
<td>5.11%</td>
<td>34.0%</td>
<td>2.29%</td>
<td>49.5</td>
</tr>
<tr>
<td>Top</td>
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<td>94.1%</td>
<td>28.1%</td>
<td>28.4</td>
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EQUILIBRATION IS QUICK.

5% → 34%

9 cascades
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EQUILIBRATION IS QUICK.

5% → 34%
9 cascades

34% → 94%
1 cascade
PRODUCTION RATE ESTIMATES

**MODE 1:**
No LEU sitting around

While continuously producing LEU in unmodified units:

- 1 modified unit: ~0.5 SQ/day
- 2 modified units: ~1.0 SQ/day
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Time for a weekend breakout?
What measures can the IAEA apply to detect HEU production in a timely manner?
DETECTING HEU PRODUCTION

**Long-standing Measures**

- LFUA Inspections
- Environmental Sampling
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**Newer Unattended Measures (some under development)**
- Online Enrichment Monitor (OLEM)
- Authenticated Load Cell Monitoring (LCM)
- Unattended Cylinder Verification Station (UCVS)
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**Future Measures**
- Unattended means for detecting piping reconfiguration in real time
- Unattended detection of hidden feed/withdrawal points

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Detecting reconfiguration itself
UNATTENDED MEASURES FOR REAL-TIME RECONFIGURATION DETECTION

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Open path gas detection systems for HF (more research needed?)
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- Electronic, remote-indicating seals on potentially significant sampling ports
- IAEA surveillance cameras at cascade hall access points, and/or on sampling ports
- Open path gas detection systems for HF (more research needed?)
- Unattended NDA for detecting HEU presence in process areas
  Detector arrays are expensive. How about a roving roomba detector?
FINAL THOUGHTS ON TECHNOLOGY
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Potential synergies of new systems with operator needs should be exploited.
- HF Detection -> Safety
- Seals on sampling ports -> Insider threat mitigation
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The Challenge:

• New challenges to safeguards verification have arisen in the last decade, including timely detection of HEU production.
• Starting from a normal production scenario, production of an SQ of weapons-grade HEU could take place, conservatively, within a few days.
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• Starting from a normal production scenario, production of an SQ of weapons-grade HEU could take place, conservatively, within a few days

Potential Solutions:

• Unattended systems offer some improvements to detection timeliness for HEU production
• Unattended safeguards measures for detecting reconfiguration of piping and undeclared feed/withdrawal could pay further dividends.