The Nuclear Forensics International Technical Working Group (ITWG) was formed in 1995 to foster cooperation in combating illicit trafficking

- To deter illicit nuclear trafficking, nuclear forensics laboratories have been cooperating on common technical strategies and databases
- The initial organizational meeting for the ITWG (ITWG-0) was held at LLNL in 1995
- The Nuclear Smuggling ITWG was chartered by the G-8 in 1996
- The ITWG’s objective is to provide cooperative and effective technical solutions to governments who request assistance
- The ITWG works closely with the IAEA to provide requesting states with assistance as well as with logistical support
Exercises and round robins have been a key ITWG activity from its beginning

1999: Round Robin 1; plutonium oxide powder
2003: Round Robin 2; HEU oxide powder
2010: Round Robin 3; HEU metal
2014: CMX-4; LEU oxide powder & pellets

Poster from 2nd ITWG Round Robin

Devised as learning experiences—not performance tests

CMX-4 Exercise Scenario

a) Country A International Airport

On a tip from a confidential informant, a passenger scheduled to fly out of Country A International Airport to Frankfurt, Germany is targeted for questioning/interdiction.
Exercise Scenario

Suspect apprehended – Leads investigators to residence

The suspect passenger is stopped by airport authorities for alleged “simple possession” of a radioactive substance without proper documentation...

Exercise scenario

b) Suspect’s Residence, Country A

In a separate search of the subject’s residence in Country A, authorities located and took into evidence a dense radioactive object, suspected to be a nuclear fuel pellet, such as one that would be used for nuclear power generation...
Exercise scenario

**c) Abandoned warehouse, Frankfurt, Germany**

Uranium pellets have previously been seized by authorities 5 years prior at an abandoned warehouse in Frankfurt, Germany.

Sample ES3

Are these pellets similar to what was found in country A?

Sample Opening at LLNL

- Establish chain-of-custody
- Photo documentation
- Initial physical measurements (mass, dimensions)
Material Seizures Overview (Fictional scenario)

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Form</th>
<th>Interdiction location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES1</td>
<td>Powder</td>
<td>Country A International Airport</td>
</tr>
<tr>
<td>ES2</td>
<td>Fuel pellet</td>
<td>Suspect’s Residence, Country A</td>
</tr>
<tr>
<td>ES3</td>
<td>Fuel pellet</td>
<td>Frankfurt, Germany</td>
</tr>
</tbody>
</table>

Metal canister with exercise samples
ES-1 powder sample
ES-2 pellet sample

Questions to be answered . . .

1. Do the seized materials contain uranium?

2. What is the mass & enrichment level?

3. Do they originate from the same facility/process/batch?

Outside scope of exercise
### Physical Dimensions

**Figure 1.** Diameter A.
**Figure 2.** Diameter B (rotated 90 degrees azimuthal relative to A).
**Figure 3.** Diameter measurements were made at top and bottom of each pellet.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>ES-2</td>
<td>0.362 ± 0.001</td>
<td>0.361 ± 0.001</td>
<td>0.360 ± 0.001</td>
<td>0.359 ± 0.001</td>
<td>0.144 ± 0.001</td>
</tr>
<tr>
<td>ES-3</td>
<td>0.358 ± 0.001</td>
<td>0.358 ± 0.001</td>
<td>0.357 ± 0.001</td>
<td>0.356 ± 0.001</td>
<td>0.142 ± 0.001</td>
</tr>
</tbody>
</table>

- Physical dimensions of ES-2 and ES-3 were found to be the same within uncertainty.
- Both pellets seemed slightly tapered.

### Optical Microscopy

**ES-2 Fuel Pellet**

- Both pellets had this vertical line on the side. Possible artifact from the pellet mold?

This pellet seemed more "distressed" than the other - more chips, cracks, oxidation, etc.

Available within 24 hours
Optical Microscopy
ES-3 Fuel Pellet

Available within 24 hours

U Assay by Gamma spectrometry

Preliminary values for the mass of U per mass of sample were determined to be

\((0.88\pm0.04)\,\text{g/g}\) (2σ) for the pellets and \((0.85\pm0.06)\,\text{g/g}\) (2σ) for the powder.

(UO\(_2\) is 0.88 g/g.)

There was no evidence of \(^{237}\text{Np}, \, ^{241}\text{Am}, \, \text{Pu}\), or residual fission products in the preliminary spectra. Longer counting would be conducted later to place better limits on undetected species.

Available within 24 hours
U Isotopes using Gamma Spectrometry

What's the samples' enrichment?

![Graph showing U isotopes](image)

1. Do the seized materials contain U?

YES!
All Samples are LEU
### Mass Spectrometry - Isotopic Composition Results

Can we determine the enrichment more precisely?

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>$^{234}\text{U}/^{238}\text{U}$ $+/-$ 2σ</th>
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<th>$^{236}\text{U}/^{238}\text{U}$ $+/-$ 2σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES1</td>
<td>0.0002527 0.0000009</td>
<td>0.02981 0.000003</td>
<td>0.0001862 0.0000017</td>
</tr>
<tr>
<td>ES2</td>
<td>0.0002526 0.0000009</td>
<td>0.02981 0.000003</td>
<td>0.0001857 0.0000014</td>
</tr>
<tr>
<td>ES3</td>
<td>0.0001923 0.0000007</td>
<td>0.02248 0.000002</td>
<td>0.0000009 0.0000007</td>
</tr>
</tbody>
</table>

2. What is the enrichment level?

- ES1 and ES2 overlapping
- Available within a few days.

2.2 and 2.9 % U-235
Radiochronometry

Are they from the same batch?

Chemical Composition/Structure: X-ray Diffraction (XRD) Results

**ES1**
- Black powder intercepted in Texas
- Phases identified: α-U₃O₈ – 46%
- Uraninite (UO₂) – 54%

**ES2**
- Pellet intercepted in Texas
- Phases identified: Uraninite (UO₂) – 100%

**ES3**
- Pellet intercepted in Frankfurt
- Phases identified: Uraninite (UO₂) – 100%

Example spectrum from ES1
ES1 and E2: same facility, batch, process
ES3: same facility, not same batch or process
In summary

The “Reveal”

- Consisted of two separate batches of high-fired, low enriched uranium oxide (LEU UO₂) pellets:
  - One Batch (A) was enriched 12 February 2002 (2.2% 235U).
  - Another Batch (B) was enriched to 2.9% 235U - produced sometime between 2002 and 2007.

- Pellets were originally produced as targets in the production of medical radioisotopes.

ES1 (powder) came from Batch B - crushed and partially oxidized in a tube furnace.
ES2 (pellet) came from Batch B.
ES3 (pellet) came from Batch A.
The “Reveal”

- **Enrichment:** 2.9%
- **Mass:** ~ 2.4g
- **Pellet was first ground in a bench top mill, then...**

...heated in a tube furnace to oxidize.