ALL AT SEA?
THE NUCLEAR NONPROLIFERATION AND DISARMAMENT CHALLENGES OF NAVAL REACTORS

SIX COUNTRIES INCLUDING THE 5 NPT NWS ARE OPERATING NAVAL REACTORS
The US, UK, Russia and India use HEU in their naval reactors
France and China use LEU

NAVAL REACTORS ACCOUNT FOR MORE THAN HALF OF GLOBAL HEU USE
And represent most of the global stockpile of HEU for non-weapons use
Prospects for conversion to LEU in the US and Russia are dim

BRAZIL COULD BE THE FIRST NNWS TO DEVELOP A NUCLEAR SUBMARINE
A prototype reactor (LABGENE) and a dedicated Naval Base (Itaguai) are being build
Present a new challenge for the NPT verification regime (Article 14, of INFCIRC/153)

Sources: Marine Nationale (top), Wikimedia, (center) and Brazilian Navy (bottom)
CURRENT LEGAL FRAMEWORK

RELEVANT TO THE NAVAL NUCLEAR FUEL CYCLE

**Safeguards**
- Comprehensive Safeguards Agreement INFCIRC/153, para. 14
- Quadripartite Safeguards Agreement INFCIRC/435, para. 13
- Additional Protocol INFCIRC/540

**Export control**
- Nuclear Suppliers Group’s guidelines (INFCIRC/254 part 1 and part 2)
- International Traffic in Arms Regulations

**Domestic legislation**
- U.S. export controls including naval reactors (22 CFR 123.20.c)
- Australia and Canada uranium exports subject to *peaceful use* only

*The loophole?*
THE NAVAL FUEL CYCLE AND IAEA SAFEGUARDS

INFCIRC/153, PAR 14 — NON-APPLICATION OF SAFEGUARDS IN NON-PEACEFUL ACTIVITIES

WITHDRAWAL OF NUCLEAR MATERIALS FROM SAFEGUARDS

- Limited to non-proscribed military activities (e.g. propulsion)
- Cannot involve nuclear material subject to “no military use”
- Requires negotiation of an arrangement with IAEA including: reporting on total quantity and composition, and of any exports; defining points of withdrawal and reapplication of routine safeguards

PRECEDEMTS AND SECRECY ISSUE

- Australia (1978): asked IAEA to confirm the involvement of the Board of Governors in any state decision to trigger article 14
- Canada (1980s): asked about exporting UF₆ to NWS and import submarine cores back; also considered a military-to-military approach to bypass CSA
- Under paragraph 14, the IAEA has no right to classified information

Sources: CEA (top), Canadian Navy (bottom)

The Military Naval Nuclear Fuel Cycle
The Scope of the Verification Challenge

- Fresh fuel
- Fuel in reactor
- Spent fuel

Standard NPT Safeguards

Require New Arrangements

Adapted from revision 3
Where to Start From?

- INITIAL DECLARATION -
  X kg of U at x% 235
  Y kg of U at y% 235

NUMBER OF VESSELS

- INITIAL DECLARATION -
  FACILITIES AND LOCATIONS
VERIFYING NON-DIVERSION OF NAVAL FUEL

SECRECY BASELINE AND SAFEGUARDS MODEL WILL DICTATE WHAT IS POSSIBLE

SECRECY (AND KNOWLEDGE) BASELINE

What do we know about military naval reactors? About naval fuel?
What is secret? What do we need to know for effective safeguards and verification?

SAFEGUARDS MODEL: NEW ARRANGEMENTS BEYOND INFCIRC/153

Containment and Surveillance Approach combined with Manages Access
Commitment to no export and cap the size of the naval stockpile

VERIFICATION APPROACHES AND SECRECY

How can we deal with sensitive information? Can we make useful measurements?
What needs to be developed? Can we work out a test bed?

SECRECY BASELINE

MILITARY NAVAL REACTORS AND ASSOCIATED TECHNOLOGIES ARE USUALLY CLASSIFIED

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**REACTOR AND FUEL DESIGN INFORMATION**

What does naval fuel look like? Are fuel elements standard?
Can we know the U-235 content? Can we make measurements on fuel elements?

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**MANUFACTURING PROCESSES AND FACILITIES**

Is the manufacturing process secret? To what extend? Can we conduct inspections at the fuel fabrication plant?

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**SENSITIVE OPERATIONAL INFORMATION**

How can we conduct on-site inspections while not revealing operational information?
MANAGED ACCESS! (e.g. New START...)

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Sources: Westinghouse Inc (top), Nuclear Fuel Service Inc. (center) and DCNS/Marinha do Brasil (bottom)
### HOW MUCH URANIUM ARE WE TALKING ABOUT?

#### 1959 U.S. HEU TRANSFER FOR 1ST FRENCH PROTOTYPE Reactor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Slightly enriched</th>
<th>Highly enriched</th>
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<tbody>
<tr>
<td></td>
<td>French</td>
<td>United States</td>
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<tr>
<td>Core, kg. U²³⁵</td>
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<td>120</td>
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<td>Core life, months</td>
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<td>24</td>
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<tr>
<td>Burnup, percent U²³⁵/core</td>
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<tr>
<td>Processing losses, percent U²³⁵/core</td>
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<td>5</td>
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<tr>
<td>Years operation</td>
<td>10</td>
<td>7</td>
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<tr>
<td>Kg. U²³⁵</td>
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<td>105</td>
</tr>
<tr>
<td>Burnup</td>
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<td>21</td>
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<tr>
<td>Processing loss</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Cores on hand near end of 10 years</td>
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<td></td>
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<tr>
<td>Total</td>
<td>186</td>
<td>426</td>
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</tbody>
</table>

Source: US Senate hearings on US/FR agreement 1959
FUEL FABRICATION IS A CRITICAL POINT
FROM BULK MATERIAL TO SINGLE ITEMS IN CLASSIFIED FORM

Source: author

Bottom line: Everything coming out of the facility can be inspected unless it is in a special declared cask.

VERIFYING NUMERICAL LIMITS OF DECLARED ITEMS

FRESH FUEL TAGGING OPTIONS


Serial number on cask

Unique ID on cask

Unique ID + Rad signature

"Electronic Tattoos"

Source: John Rogers, University of Illinois

Declaration in hashed form (with one entry per item)
THE NAVAL BASE IS ANOTHER CRITICAL POINT

HOW TO CONFIRM FUEL ELEMENTS WERE INSTALLED IN THE REACTOR?

THE NAVAL BASE IS ANOTHER CRITICAL POINT

HOW TO CONFIRM FUEL ELEMENTS WERE INSTALLED IN THE REACTOR?


TOWARDS A TEST-BED FOR SAFEGUARDS?
WITH BRAZIL'S LABGENE LAND-BASED PROTOTYPE REACTOR

Source: Brazilian navy.
LOOKING FORWARD
A TENTATIVE RESEARCH AGENDA TO SUPPORT VERIFICATION OF THE NAVAL FUEL CYCLE

LABGENE AS VERIFICATION/SAFEGUARDS TEST BED
Brazil’s prototype reactor could be used as a test bed for fuel element tracking and verification while testing techniques protecting sensitive information.

LAUNCH R&D REVIEW AND PROGRAM ON VERIFICATION
Review past concepts from arms control and warhead verification.
Develop new concepts (zero-knowledge, unique objects for tags...)

PROMOTE REACTOR CONVERSION TO LEU AS THE NORM
Switching to LEU would greatly diminish the risks associated with naval fuel.
A ban on the production of HEU could also help in that direction.

Sources: Marinha do Brasil (top), Author. (center) and NNSA (bottom)