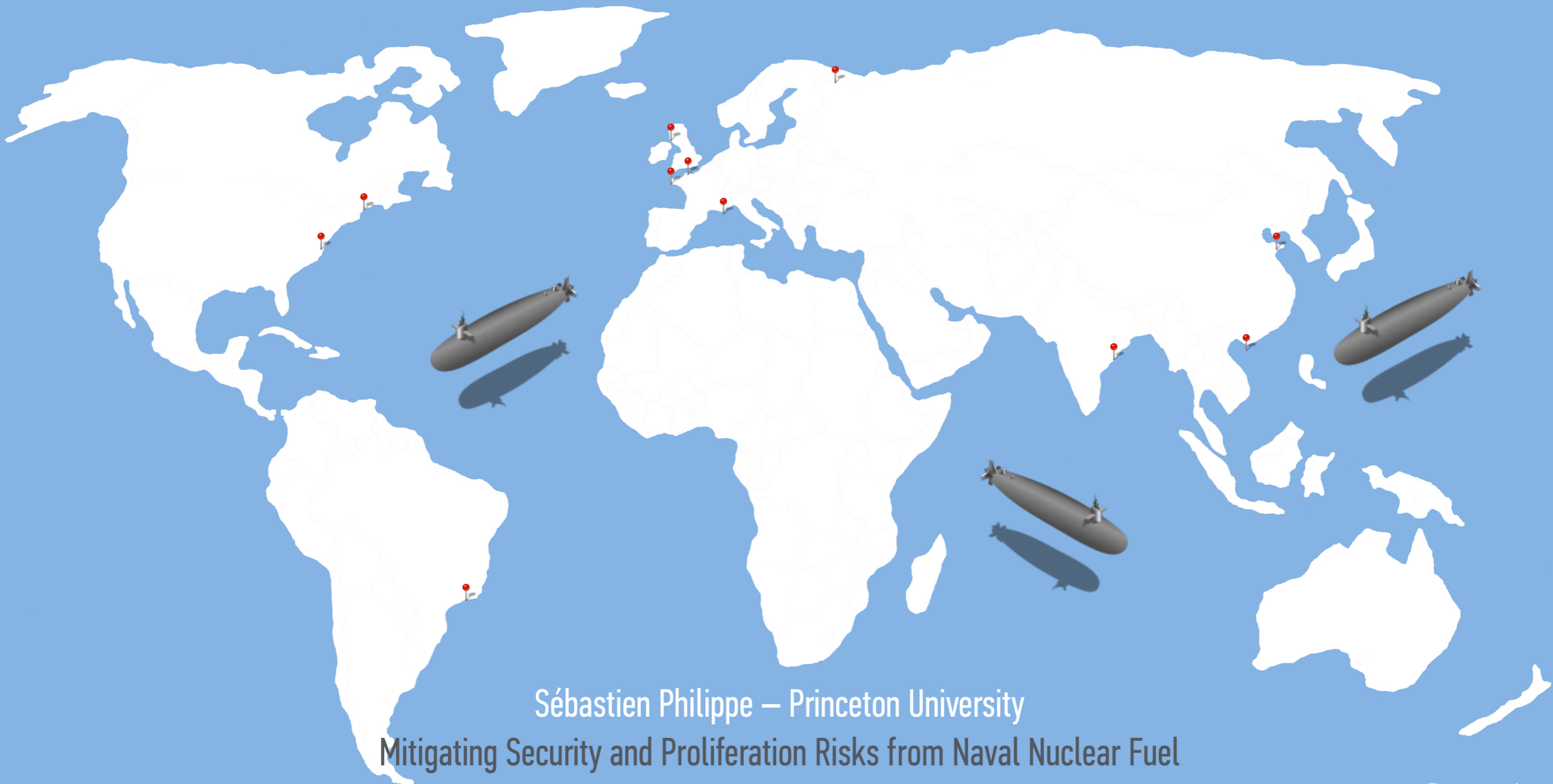


THE NAVAL NUCLEAR FUEL CYCLE

CHALLENGES AND OPPORTUNITIES FOR GOVERNANCE



Sébastien Philippe – Princeton University

Mitigating Security and Proliferation Risks from Naval Nuclear Fuel

George Washington University, August 27, 2018

Revision 1

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

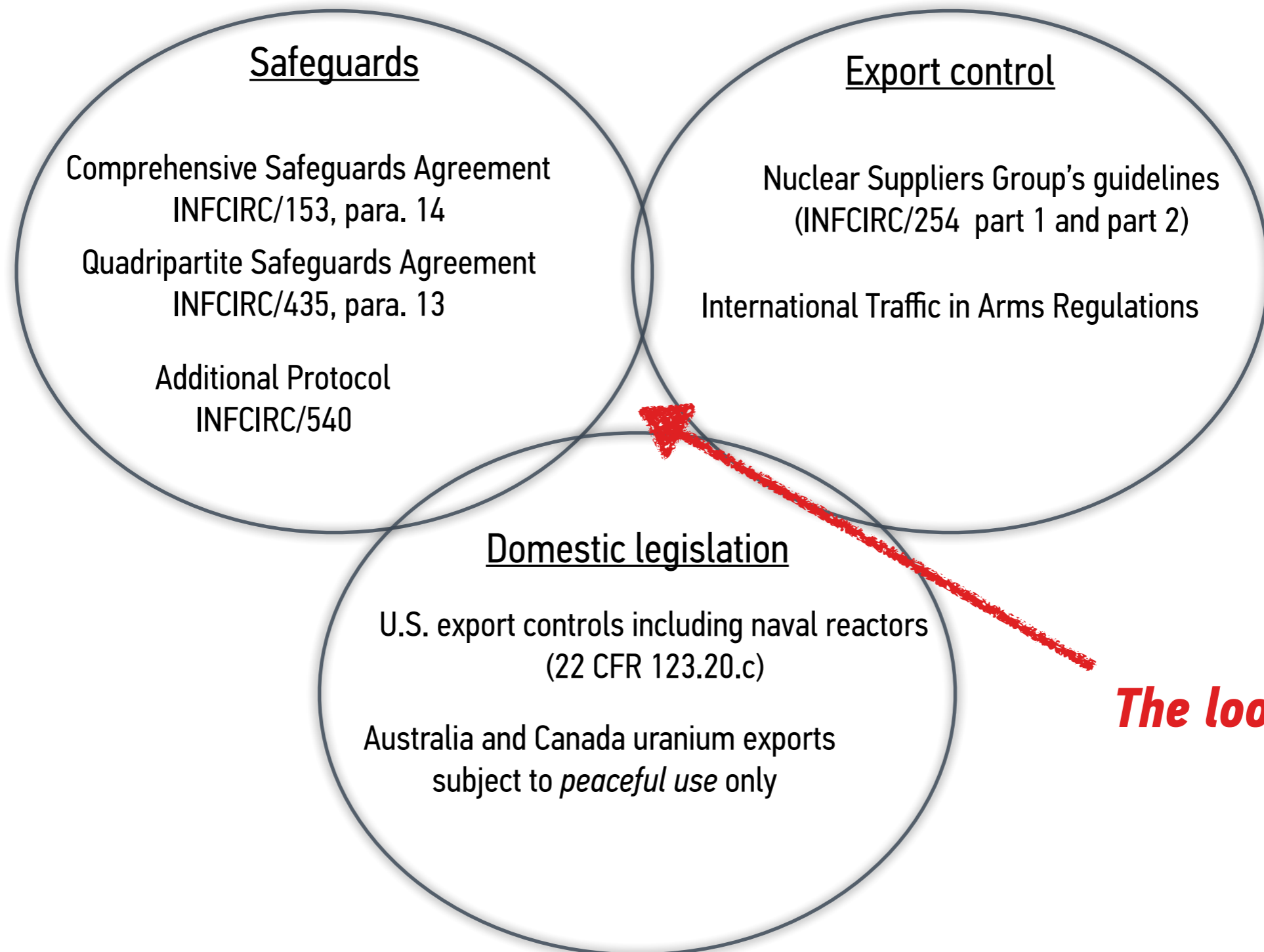
A prototype reactor (LABGENE) and a dedicated Naval Base (Itaguai) are being build

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

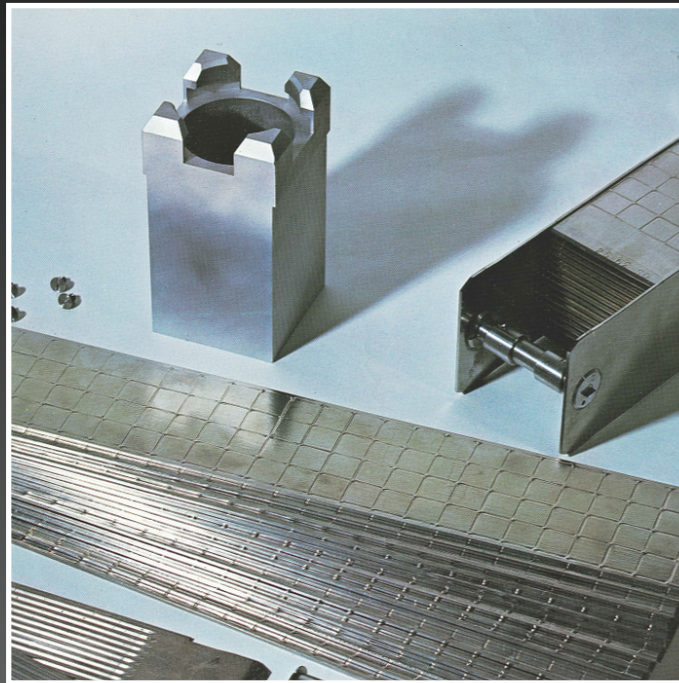
RELEVANT TO THE NAVAL NUCLEAR FUEL CYCLE



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

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

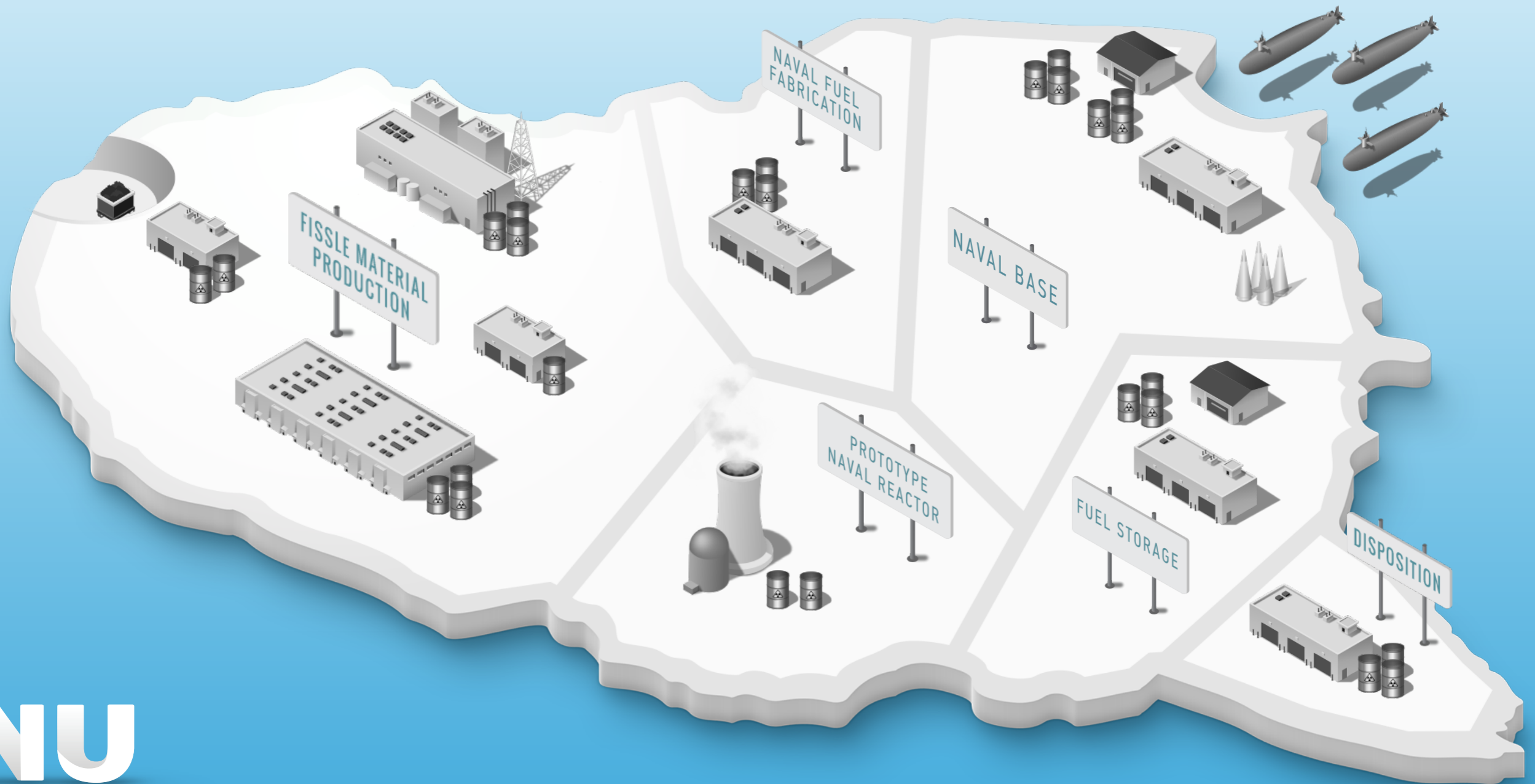


PRECEDENTS AND SECRECY ISSUE

- 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

Laura Rockwood, “Naval Nuclear Propulsion and IAEA Safeguards,” *Federation of American Scientists Issue Brief*, August 2017.

The Military Naval Nuclear Fuel Cycle






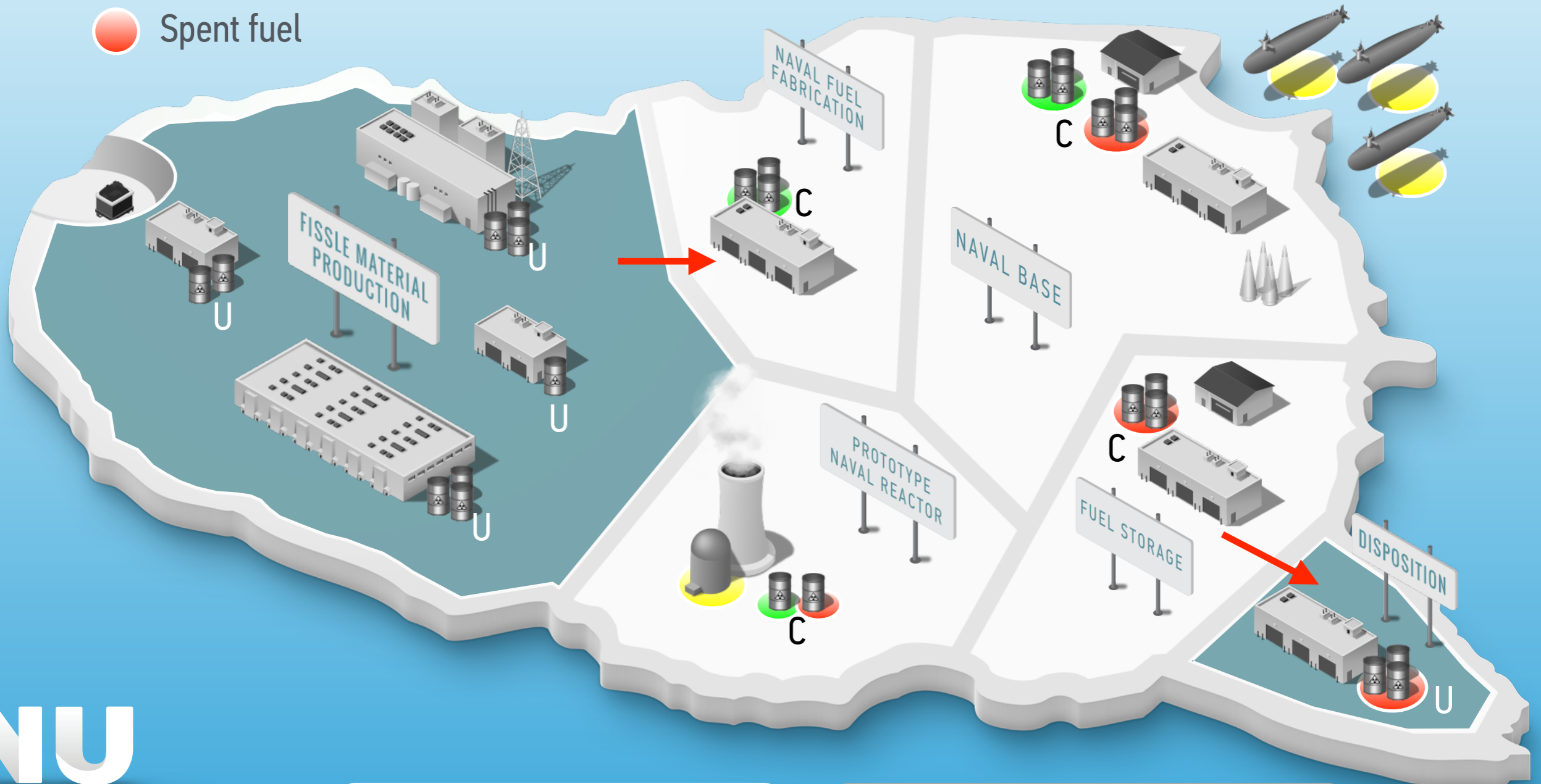
NU

www.verification.nu

Adapted from revision 3

The Scope of the Verification Challenge

-  Fresh fuel
-  Fuel in reactor
-  Spent fuel



NU

www.verification.nu

Adapted from revision 3

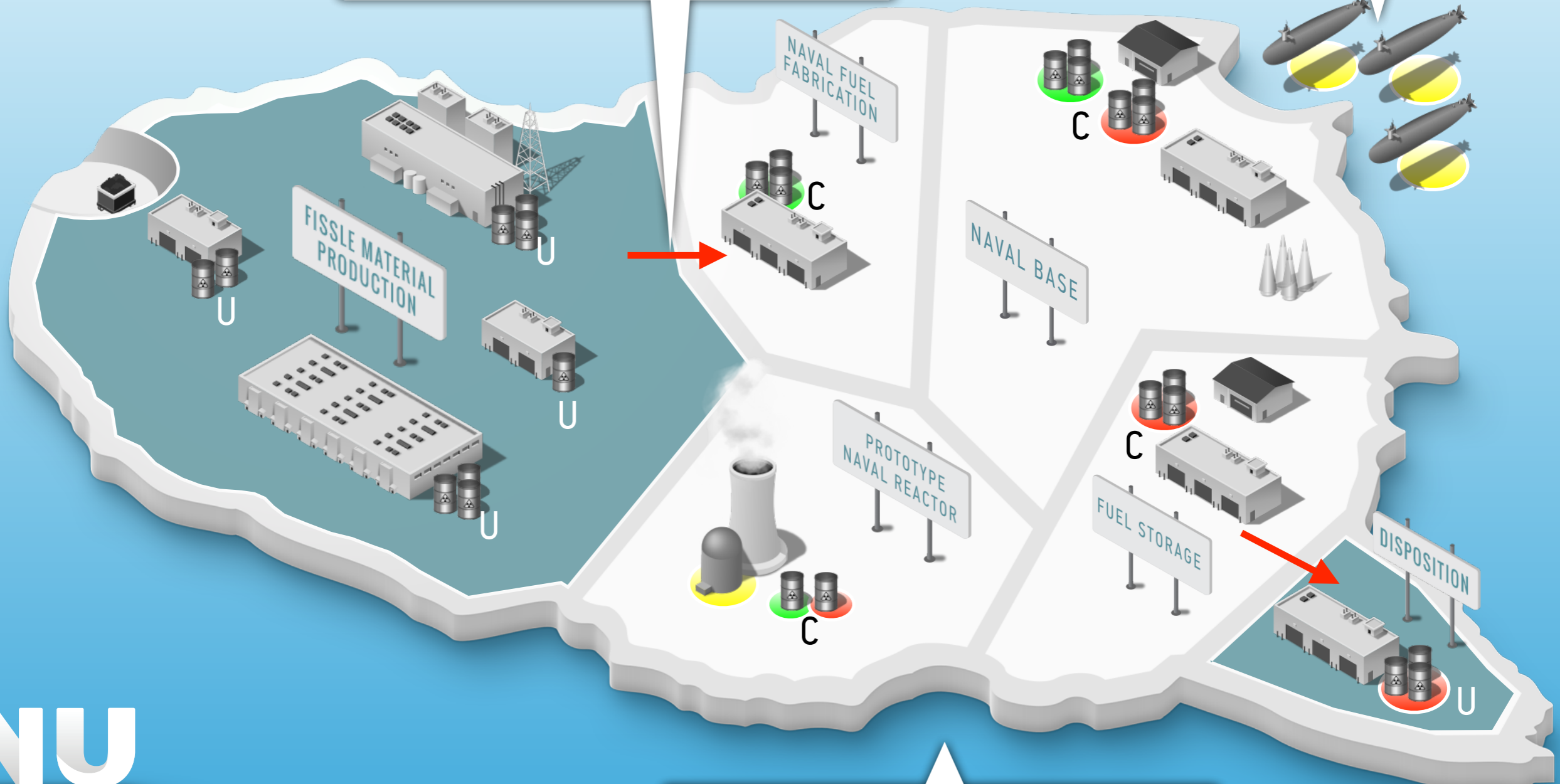
Standard NPT Safeguards

Require New Arrangements

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

SECURITY BASELINE AND SAFEGUARDS MODEL WILL DICTATE WHAT IS POSSIBLE



SECURITY (AND KNOWLEDGE) BASELINE

What do we know about military naval reactors? About naval fuel?

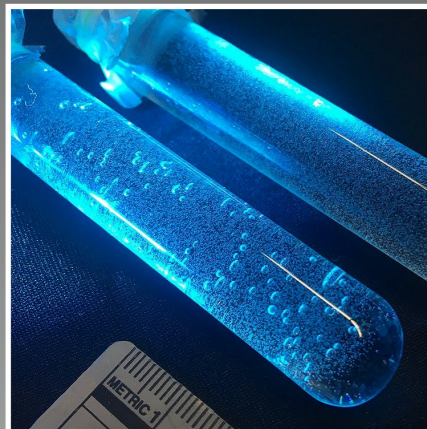
What is secret? What do we need to know for effective safeguards and verification?



SAFEGUARDS MODEL: NEW ARRANGEMENTS BEYOND INFCIRC/153

Containment and Surveillance Approach combined with Managed Access

Commitment to no export and cap the size of the naval stockpile



VERIFICATION APPROACHES AND SECURITY

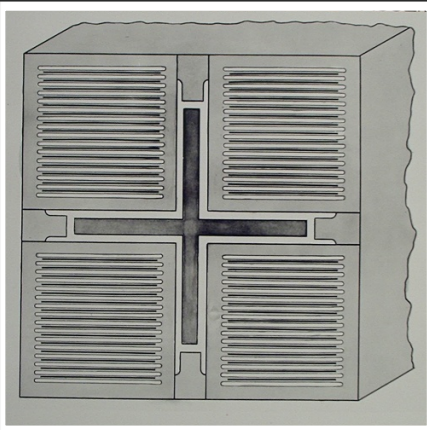
How can we deal with sensitive information? Can we make useful measurements?

What needs to be developed? Can we work out a test bed?

Sebastien Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle," *Journal of Nuclear Materials Management*, Vol. XLII, No.3, 2014, 40-52.

SECRECY BASELINE

MILITARY NAVAL REACTORS AND ASSOCIATED TECHNOLOGIES ARE USUALLY CLASSIFIED



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?



MANUFACTURING PROCESSES AND FACILITIES

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



SENSITIVE OPERATIONAL INFORMATION

How can we conduct on-site inspections while not revealing operational information?

MANAGED ACCESS! (e.g. New START...)

Sources: Westinghouse Inc (top), Nuclear Fuel Service Inc. (center) and DCNS/Marinha do Brasil (bottom)

HOW MUCH URANIUM ARE WE TALKING ABOUT?

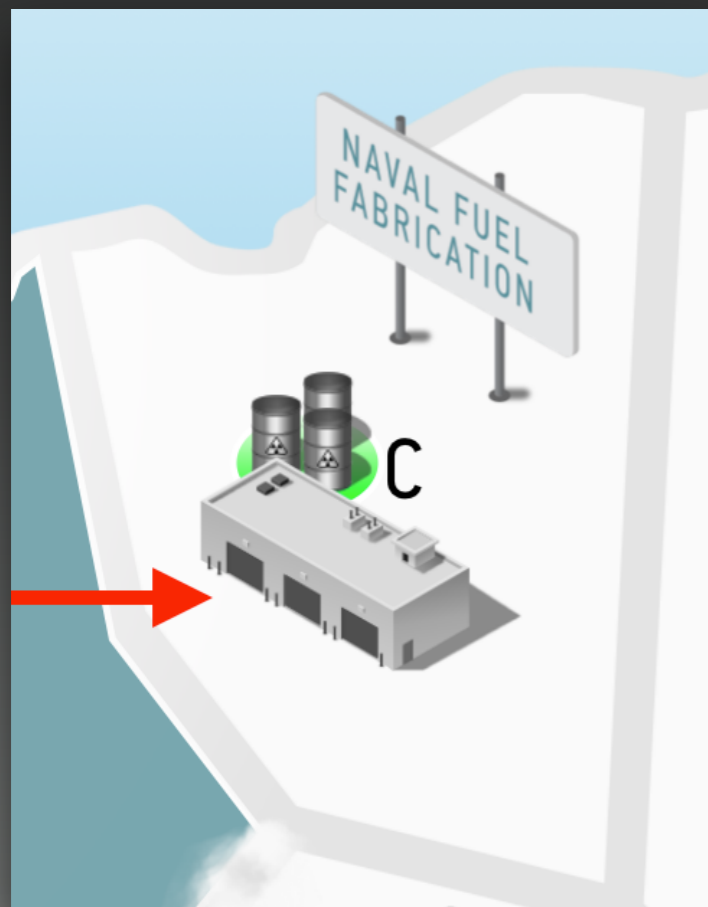
1959 U.S. HEU TRANSFER FOR 1ST FRENCH PROTOTYPE REACTOR

Calculation of U²³⁵ required for prototype nuclear submarine propulsion plant

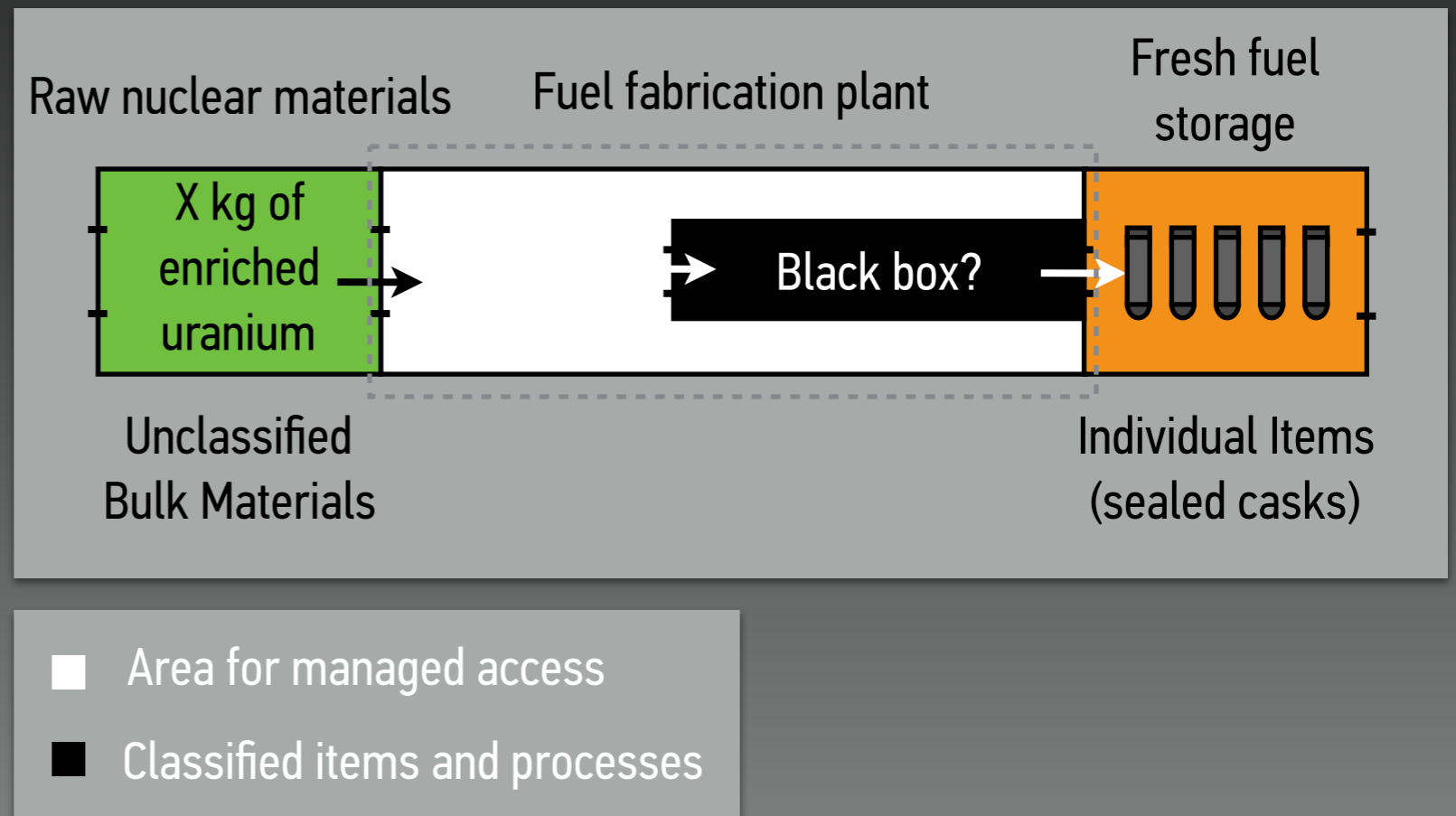
	Slightly enriched		Highly enriched	
	French	United States	French	United States
Core, kg. U ²³⁵	120	120	40	40
Core life, months.....	24	24	6	6
Burnup, percent U ²³⁵ /core.....	25	25	20	20
Processing losses, percent U ²³⁵ /core.....	6	5	15	3
Years operation.....	10	7	10	7
Kg. U²³⁵:				
Burnup.....	150	105	160	112
Processing loss.....	36	21	126	18
Cores on hand near end of 10 years.....		300		160
Total.....	186	426	286	290

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

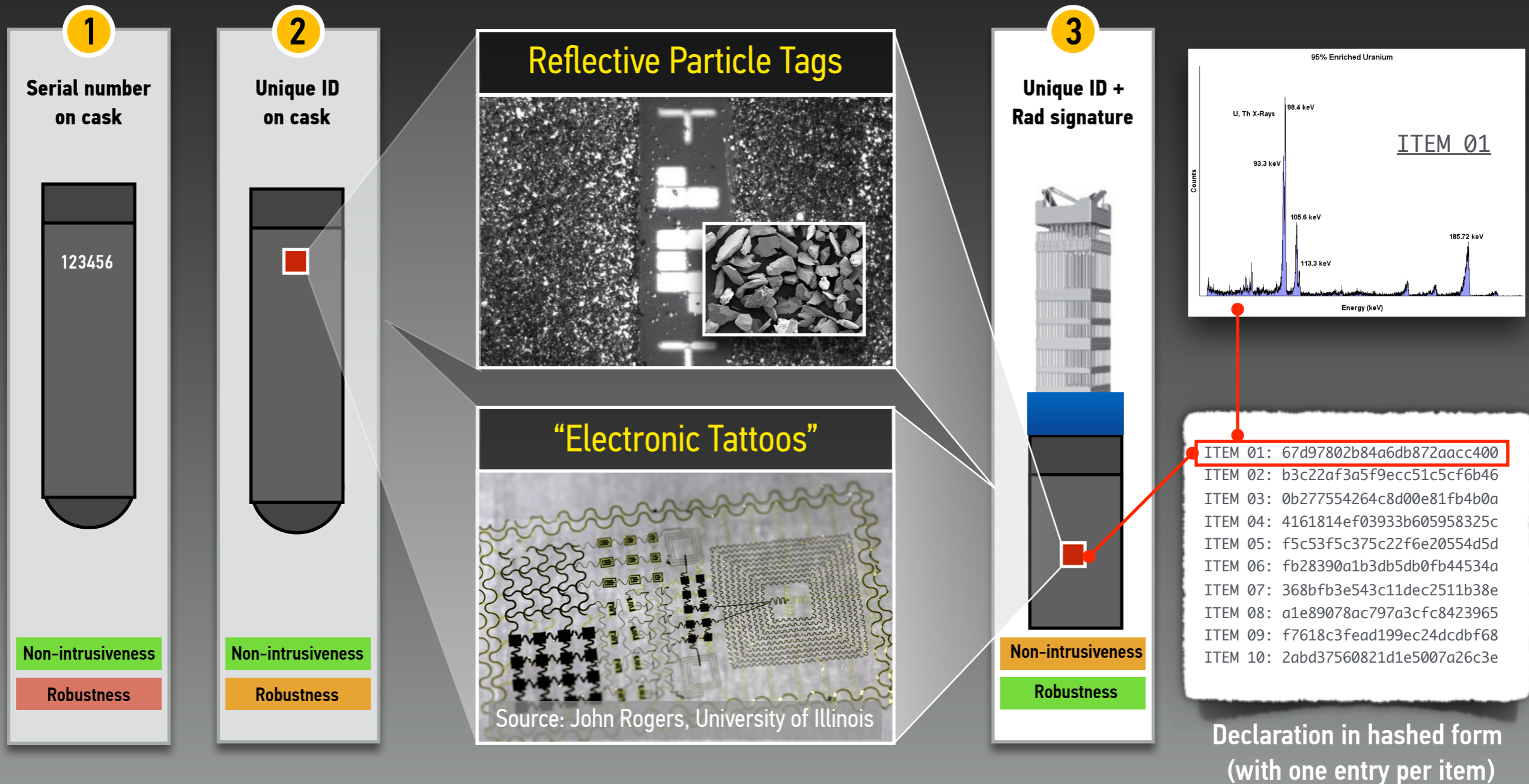


Bottom line: Everything coming out of the facility can be inspected unless it is in a special declared cask.

Sebastien Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle," *Journal of Nuclear Materials Management*, Vol. XLII, No.3, 2014, 40-52.

VERIFYING NUMERICAL LIMITS OF DECLARED ITEMS

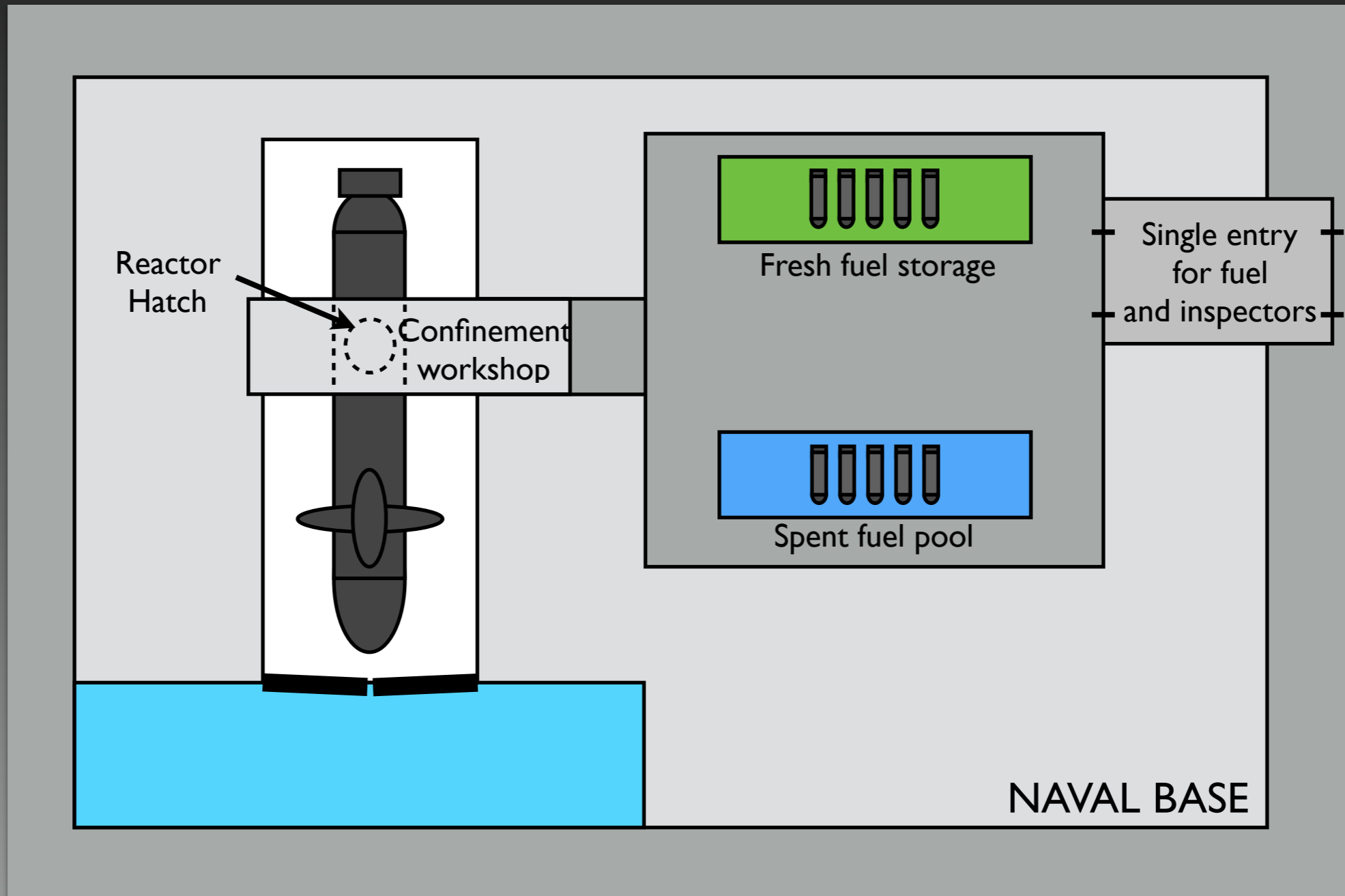
FRESH FUEL TAGGING OPTIONS



Reflective particle tag concept: A. Gonzales, *Reflective Particle Tag for Arms Control and Safeguards Authentication*, Sandia National Laboratories, 2004

THE NAVAL BASE IS ANOTHER CRITICAL POINT

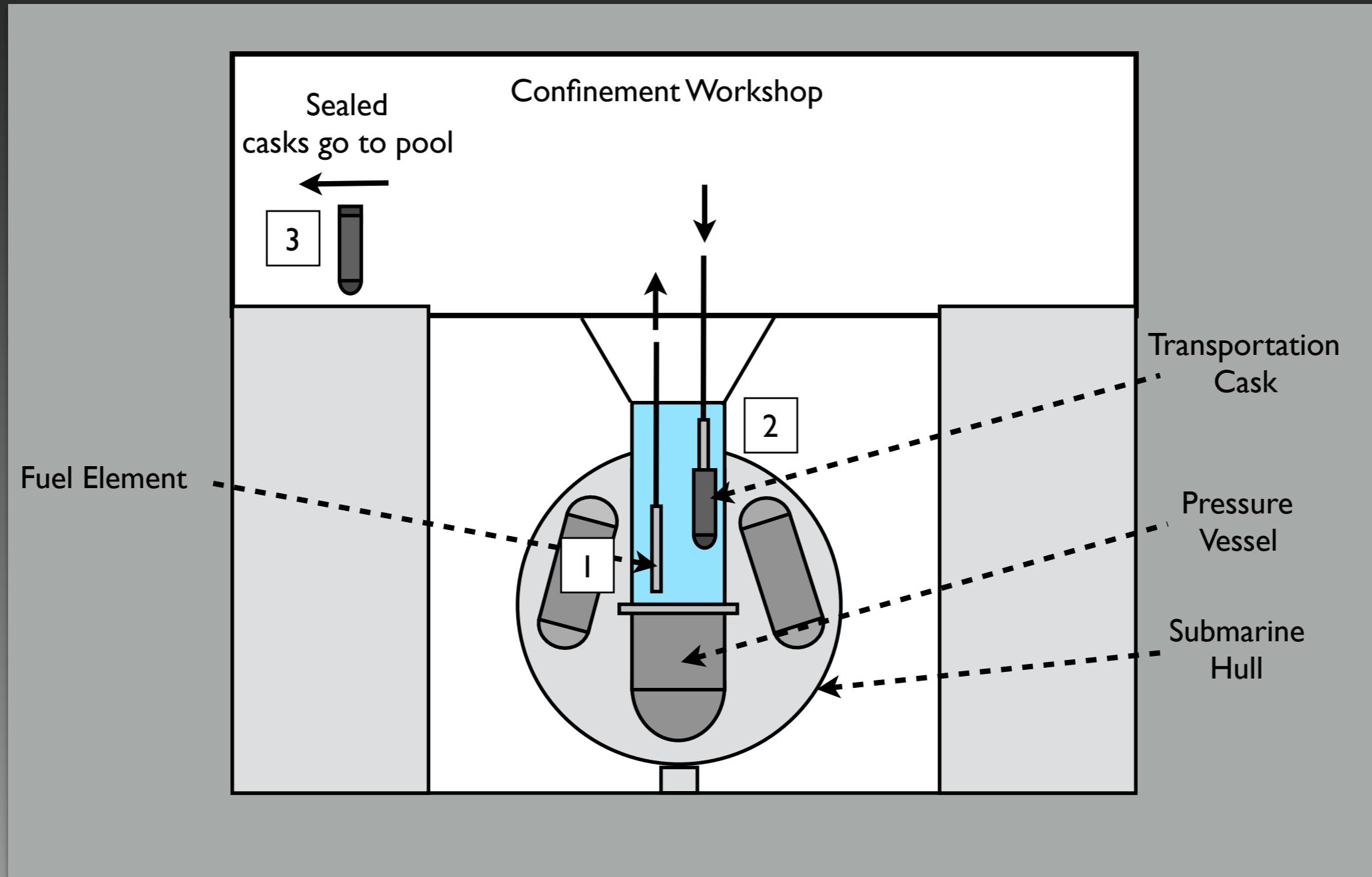
HOW TO CONFIRM FUEL ELEMENTS WERE INSTALLED IN THE REACTOR?



Sebastien Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle," *Journal of Nuclear Materials Management*, Vol. XLII, No.3, 2014, 40-52.

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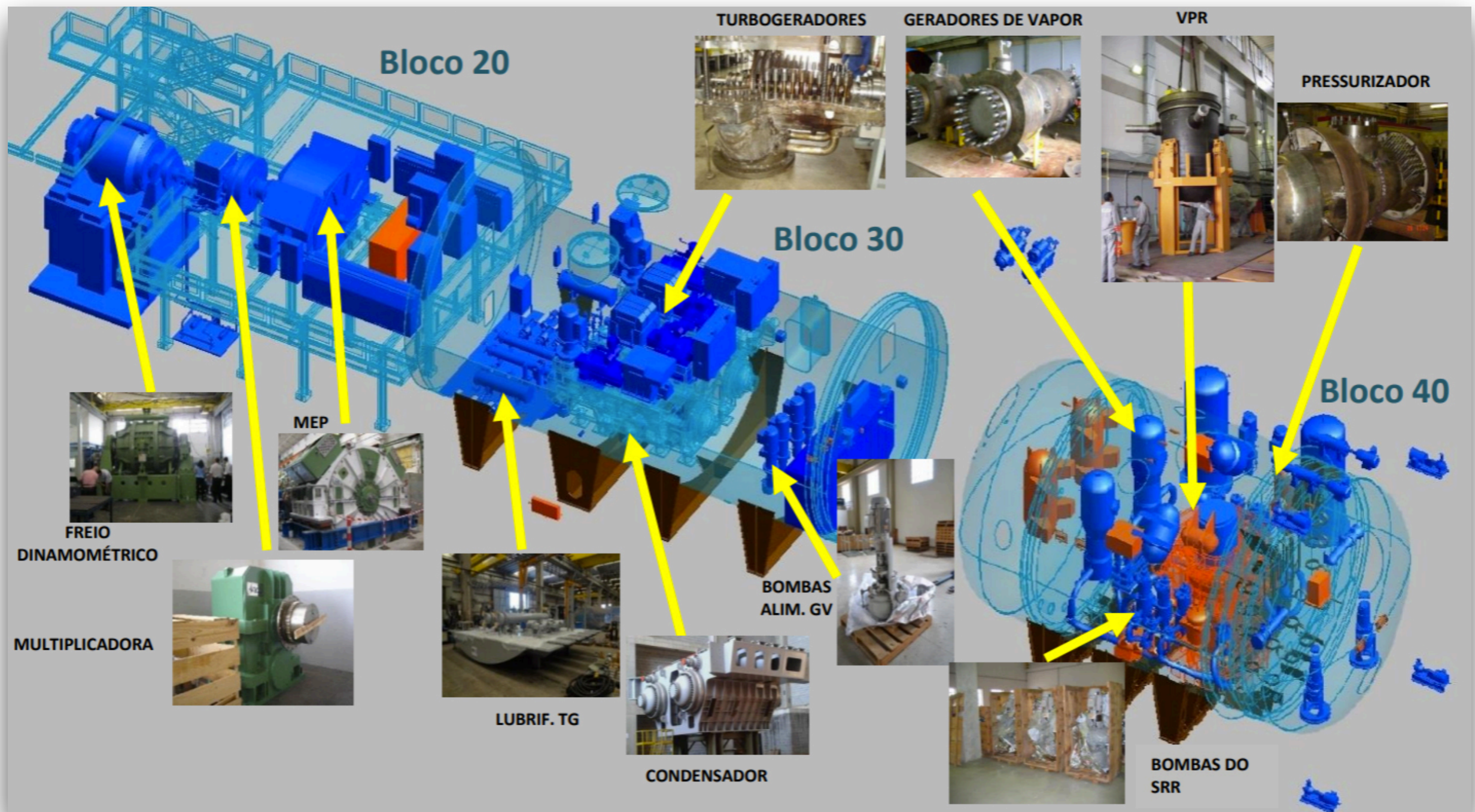


Sebastien Philippe, "Safeguarding the Military Naval Nuclear Fuel Cycle," *Journal of Nuclear Materials Management*, Vol. XLII, No.3, 2014, 40-52.

Adapted from Charles Fribourg, "Navires à Propulsion Nucléaire," *Techniques de l'Ingénieur*, BN3141, 2002.

TOWARDS A TEST-BED FOR SAFEGUARDS?

WITH BRAZIL'S LABGENE LAND-BASED PROTOTYPE REACTOR



Source: Brazilian navy.

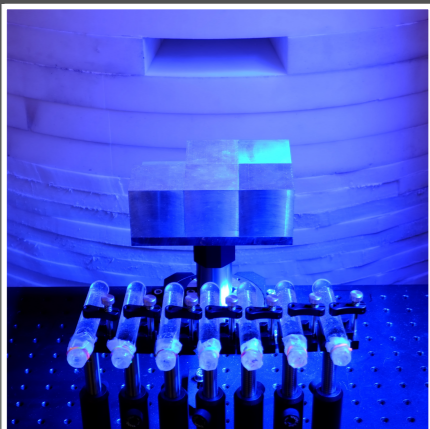
LOOKING FORWARD

A TENTATIVE RESEARCH AGENDA TO SUPPORT VERIFICATION OF THE NAVAL FUEL CYCLE



LABGENE AS VERIFICATION/SAFEGUARDS TEST BED

Brazil's prototype reactor could be use 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...)



**Conceptual
Research and
Development Plan
for Low-Enriched
Uranium Naval Fuel**

PROMOTE REACTORS USING 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)*