# Decommissioning of nuclear submarines in Brazil

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# SUMMARY

- Nuclear (powered) submarine overview;
- Nuclear submarine decommissioning considerations;
- Foreign nuclear submarine decommissioning process; and
- Brazilian nuclear submarine decommissioning studies.

OPEN SOURCES INFORMATION

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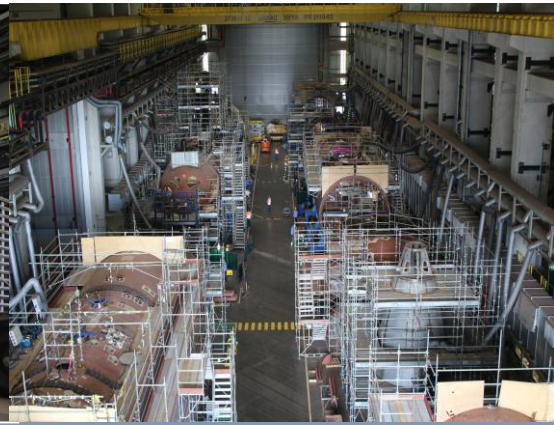
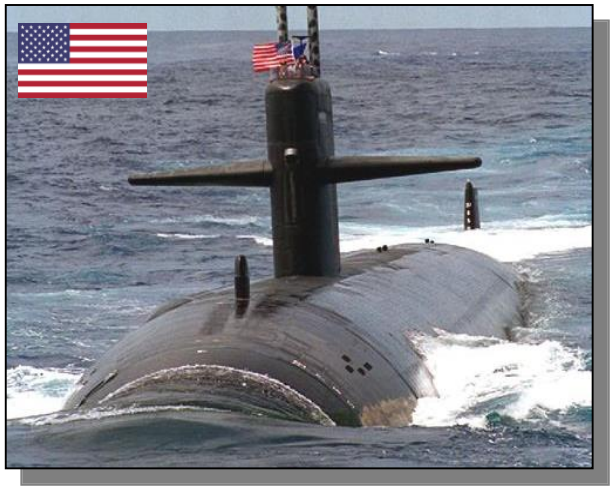


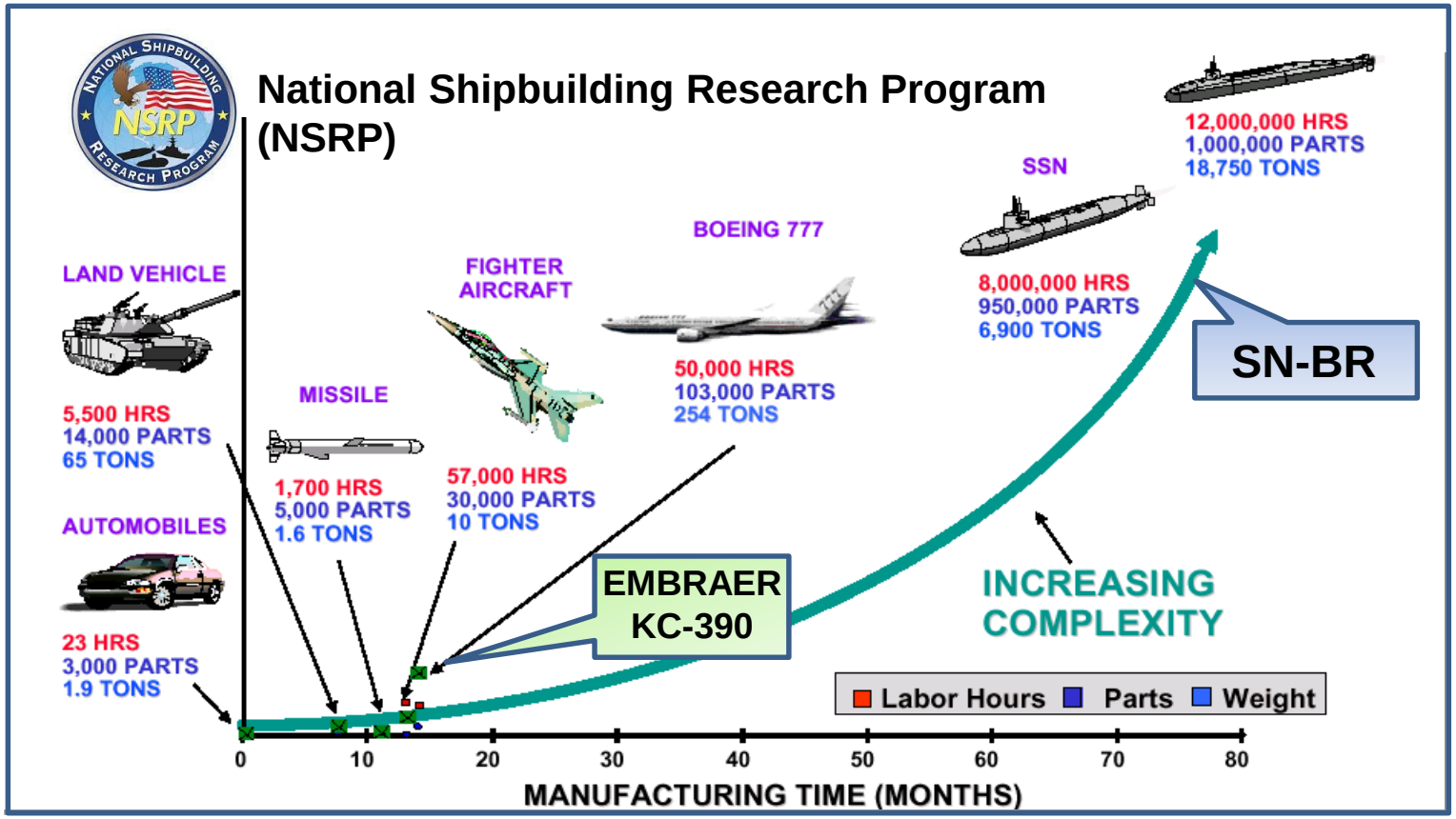
# NUCLEAR SUBMARINE OVERVIEW

There are six nations operating nuclear (powered) submarines.
By 2030, Brazil will be the seventh one



# NUCLEAR SUBMARINE OVERVIEW

## Nuclear submarines are complex machines




http://blogs.ssi-corporate.com/waveform/2017/technology/hardest-problem-in-shipbuilding-sister-ships/

SN-BR – Brazilian Nuclear Powered Submarine

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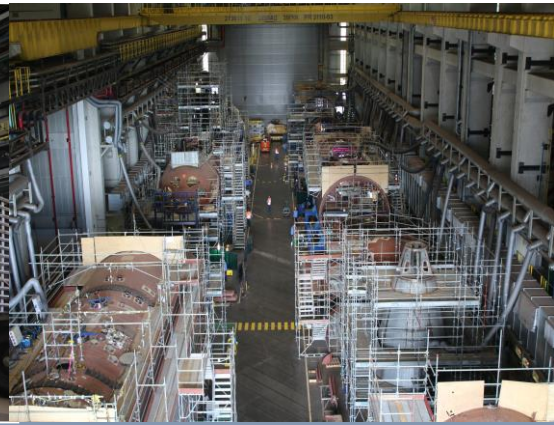

# NUCLEAR SUBMARINE DECOMMISSIONING CONSIDERATIONS

## Nuclear Installation Decommissioning

Formal process to be carried out at the **end of a nuclear installation life** in order to have it released from regulatory control, when the installation **is no longer a radiological risk**, and the place where it was built (**site**) **can be released for other uses** (adapted from CNEN-NN 9.01).

## Nuclear Submarine Decommissioning

Formal process to be carried out at the **end of the nuclear submarine's operational life** to ensure that **its constituent materials** pose no risk to the public and **can be released from regulatory control**.

# NUCLEAR SUBMARINE DECOMMISSIONING CONSIDERATIONS

## Total number of nuclear submarines

| Country | Built (Until 2014) | Operational (on 2014) | Deactivated (Until 2014) | Decommis-sioning (Until 2014) | To be Decommis-sioned by 2020 |
|---|---|---|---|---|---|
| Russia | 258 | 33 | 204 | 184 | 22 |
| USA | 203 | 72 | 127 | 108 | 23 |
| UK | 30 | 11 | 19 | 0 | 21 |
| France | 16 | 10 | 6 | 6 | 3 |
| China | 16 | 12 | 3 | 1 | 2 |
| India | 1 | 1 | 0 | 0 | 0 |
| TOTAL | 524 | 139 | 359 | 299 | 71 |

Conflicting information in different references

Jane´s Fighting Ships 2012-2013 & Bellona Foundation Report nr 2:96

Nuclear submarines decommissioning is not a new business

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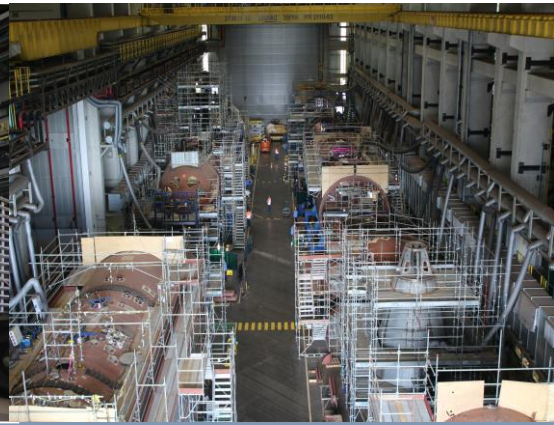


# FOREIGN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS

- Foreign Navies adopted similar Nuclear Submarine Decommissioning process - Safe Enclosure (SAFSTOR) option;
- Differences between decommissioning process reflect the different national regulatory basis;


http://www.iaea.org/OurWork/ST/NE/NEFW/CEG/documents/ws032003 _kalistratov-e.pdf

# FOREIGN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS

**1 – SSN Temporary storage (floating)**

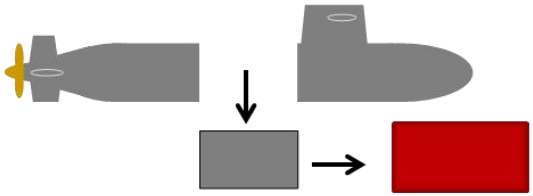
**2 – Defueling (SNF removal and storage)**

**3 – Activated components removal and storage**



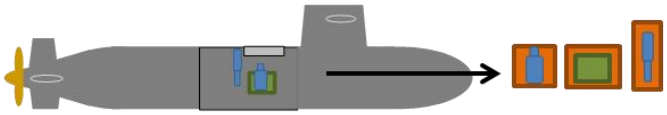
2

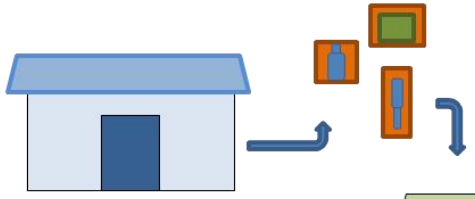
A - Reactor section removal and hull dismantling



or

B - Primary Circuit removal without cutting the hull

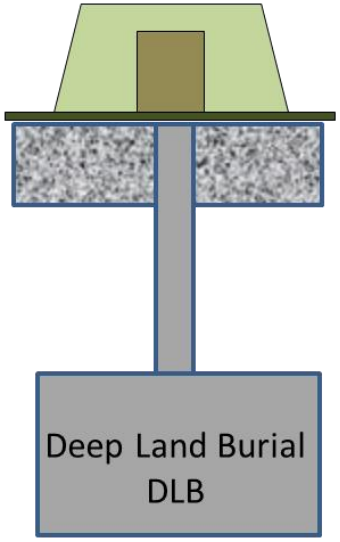





Volumetric reduction

**5 – Dismantling Facility**

**4 - Provisory Storage**



Deep Land Burial DLB

**Geological Storage**

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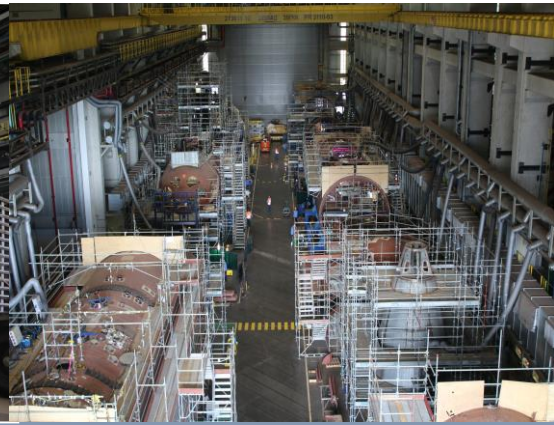


# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

- SN-BR decommissioning process is similar to the ones adopted by foreign navies (safety proven)
- SN-BR planned operational life is 30 years;
- SN-BR decommissioning process will start after 2060;
- BN is conducting the required studies to ensure a safe decommissioning process in Itaguaí Naval Base (INB);
- BN is preparing SN-BR Preliminary Decommissioning Plan to be presented to Nuclear Regulatory Authority;
- **The Decommissioning Process in the following slides represents the BN on going studies.**

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## Safe Enclosure (SAFSTOR) option

## Phased decommissioning process

**SN-BR decommissioning Phases**

1. Preparatory;
2. Fuel and Wastes Removal;
3. Fuel and Wastes Management;
4. Activated Material Management;
5. Hull dismantlement.

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 1 - Preparatory Phase

**Purpose:**

Reduce environmental contamination risk (removal of non radiological contaminants) and prepare the SN-BR for defueling.

**Submarine condition:**

SN-BR “waiting” at Deactivation Berth in INB; Reactor in cold shut down; heat removal by onboard nuclear systems (fully operational).

**Comments:**

Removal of weapons, spare parts and reusable non nuclear equipment;

Time between deactivation and defueling is longer than 1 year

(1 to 3 years).

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## Itaguaí Naval Base (EBN – Estaleiro e base Naval)








MARINHA DO BRASIL. **PROSUB - Programa de Desenvolvimento de Submarinos**. Folder do PROSUB. Centro de Comunicação Social da Marinha-RIO. Rio de janeiro, 2011.

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 2 - Fuel and Wastes Removal Phase

**Purpose:**

Reduce nuclear contamination risk (removal of SNF and radioactive waste).

**Submarine condition:**

SN-BR in Dry Dock; all nuclear safety functions provided by Radiological Complex; Defueling via Reactor Access House (RAH).

**Comments:**

Defueling, draining of all Primary Circuit fluids and removal of radioactive waste in the Reactor Section removes nearly 99% of the radioactivity associated with the Reactor;

After defueling, SN-BR is prepared for the Reactor Section cut and removal, Estimated time 1 year.

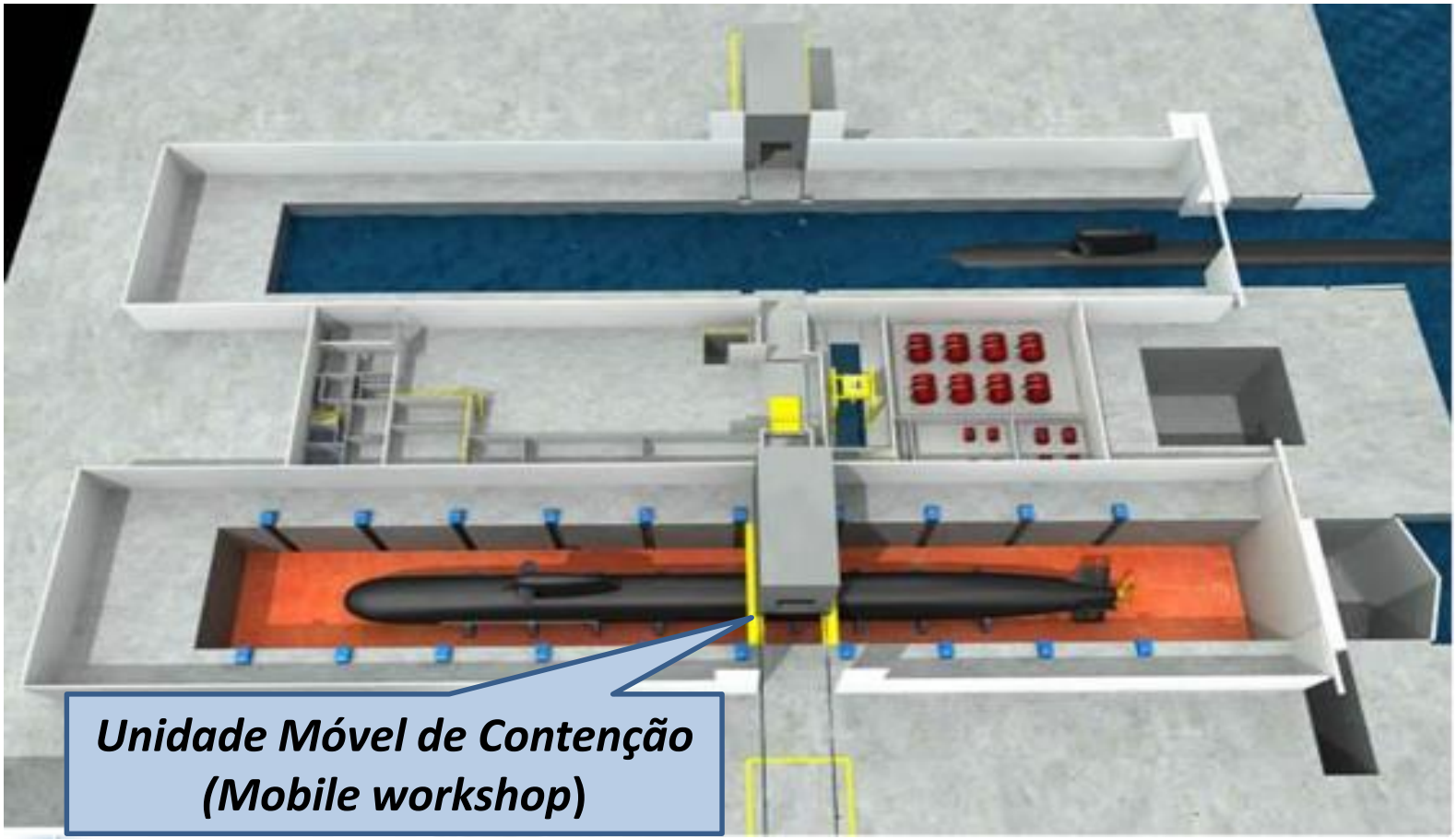
# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## Nuclear Submarine at dry docks

Arrosage de la Coque on SNA PERLE, Toulon, 2008
http://www.meretmarine.com/ fr/content/derniere-iper-pour-le-sous-marin-rubis.

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## SN-BR at dry docks for defueling




MARINHA DO BRASIL. **PROSUB - Programa de Desenvolvimento de Submarinos**. Folder do PROSUB. Centro de Comunicação Social da Marinha-RIO. Rio de janeiro, 2011.

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

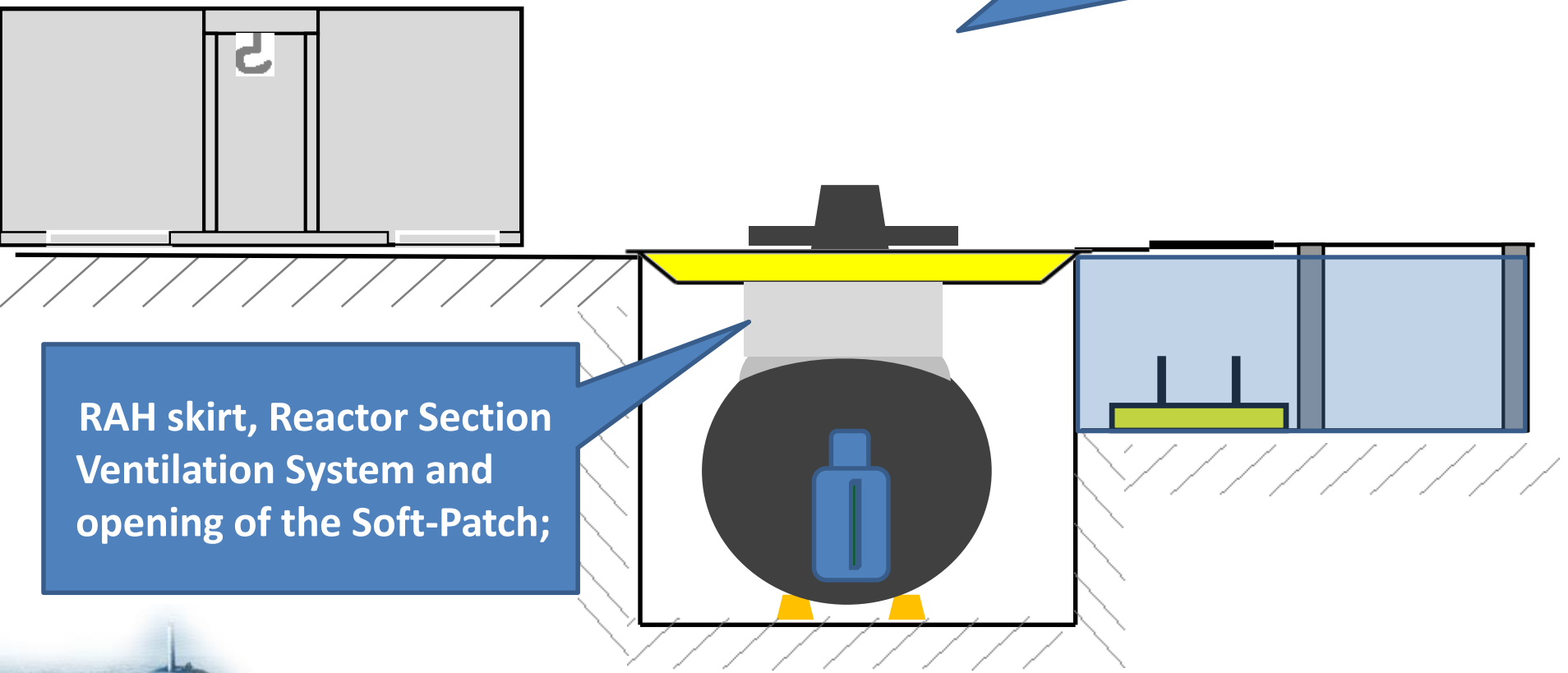
## Reactor Access House at HMNB Devonport, Plymouth - England


MINISTRY OF DEFENCE. **Submarine Dismantling Project (SDP), our approach to decision making,** Defence Equipment & Support. Abbey Wood, Issue 2.0, 2011. Disponível em: < ttps://www.gov.uk/government/publications/submarine-dismantlingproject-our-approach-to-decision-making>.

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## SN-BR at dry docks for defueling

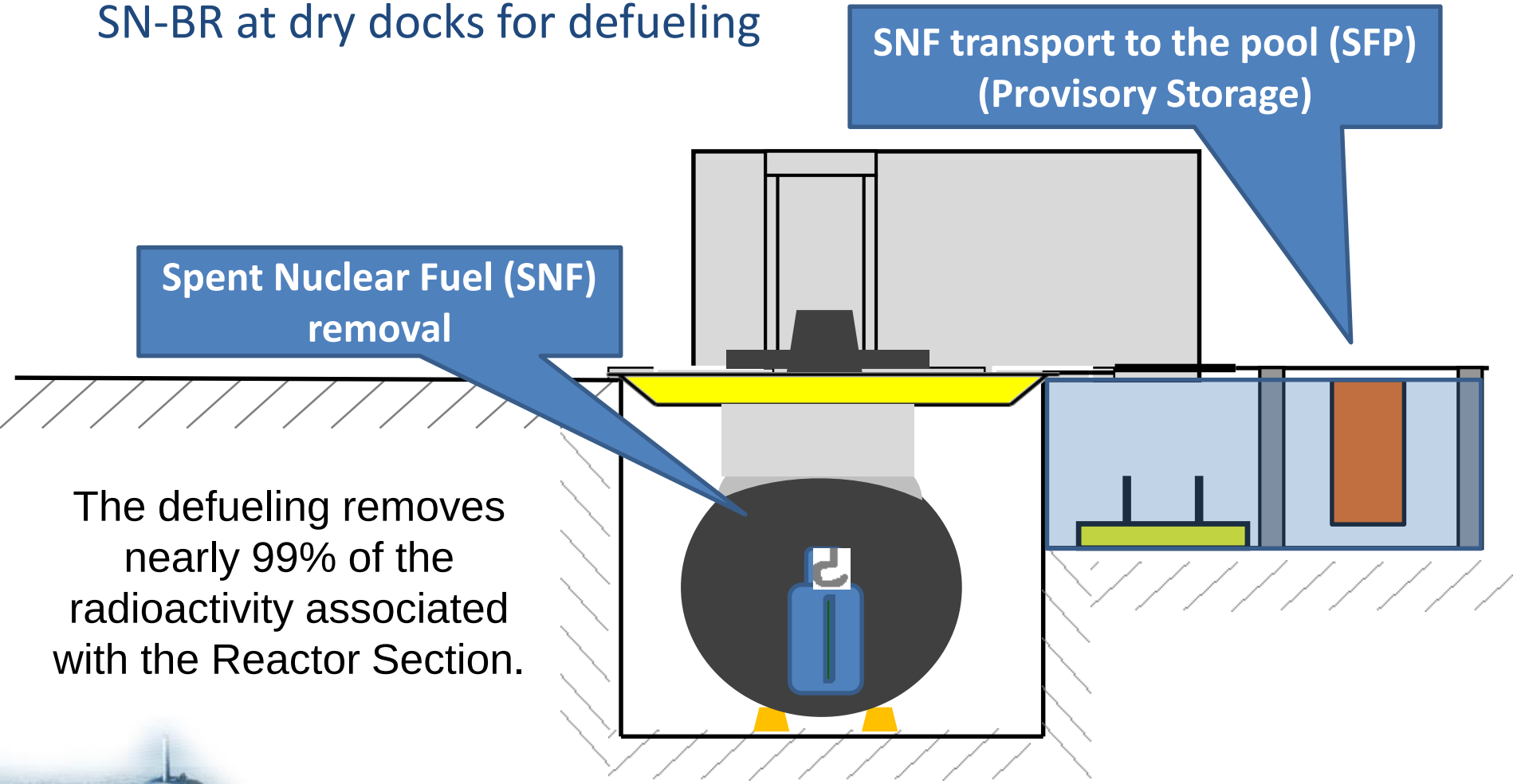
Reactor Access House (Mobile Workshop) positioned over the SN-BR for defueling



RAH skirt, Reactor Section Ventilation System and opening of the Soft-Patch;

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## SN-BR at dry docks for defueling




The defueling removes nearly 99% of the radioactivity associated with the Reactor Section.

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 3 - Fuel and Wastes Management Phase

**Purpose:**

Ensure the safe transport and storage of the Nuclear Fuel and radioactive waste.

**Comments:**

Radiologic Complex will manage SNF storage and radioactive waste processing

The transportation, processing and storage of SNF and radioactive waste are considered standard operational procedures and will not be discussed in this presentation

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 4 - Activated Material Management Phase (Reactor Section removal)

**Purpose:**

Reduce the risk of radiological contamination by activated materials from the Reactor Section.

**Submarine condition:**

After the defueling, the radioactivity in the Reactor Section comes from activated materials (nearly 1% of the previous radioactivity in the Reactor)

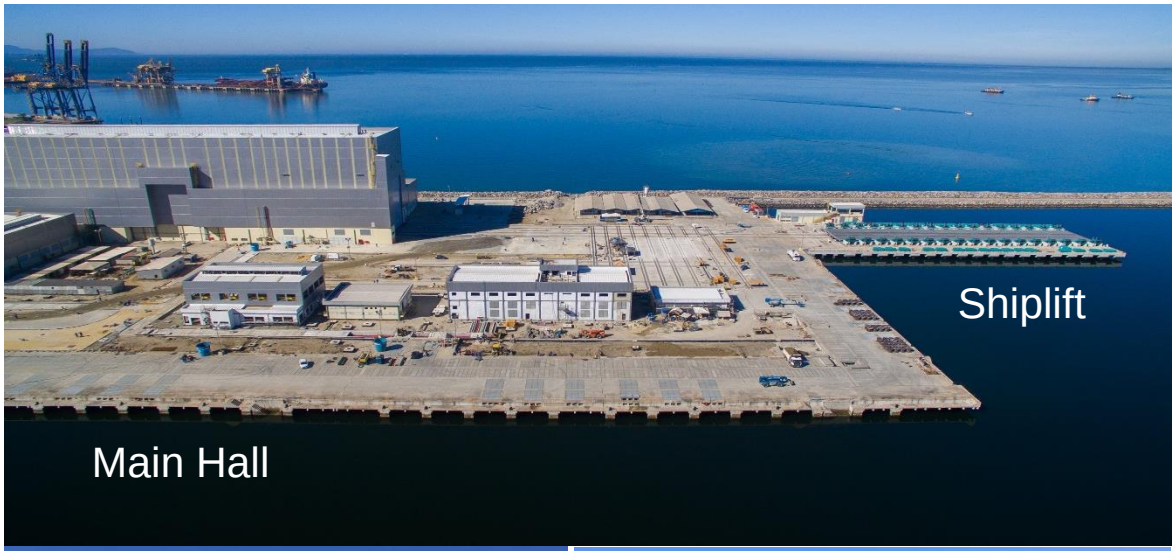
**Comments:**

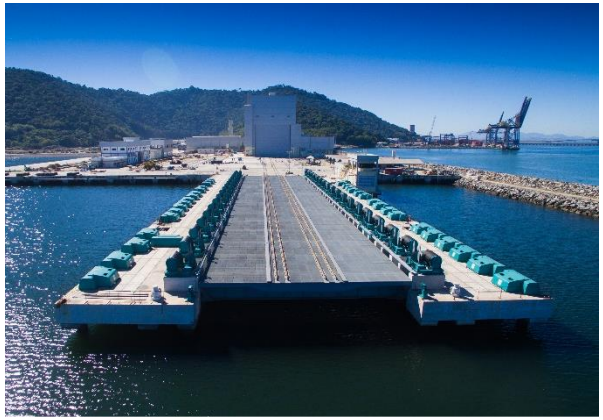
Reactor Section will be cut and separated from the rest of the submarine's hull in order to confine the activated materials (Safe Enclosure option - SAFSTOR)

Temporary storage of the Reactor Section until its dismantlement (30 – 60 years)

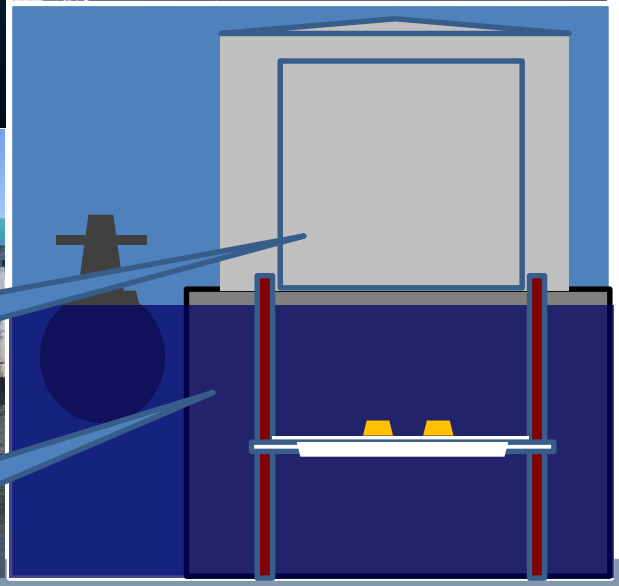
# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 4 - Activated Material Management Phase (Reactor Section removal)







# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 4 - Activated Material Management Phase (Reactor Section removal)

**SN-BR preparation for Reactor Section cutting and removal**

- Reactor Section decontamination before cutting the pipe lines and equipment connected with the rest of the SN-BR
- Submarine preparation for Reactor Section cutting takes 10 to 14 months (according to MNF)

Hull cutting

SSBN *Redoutable* Reactor Section

SSBN Reactor Section (USN)

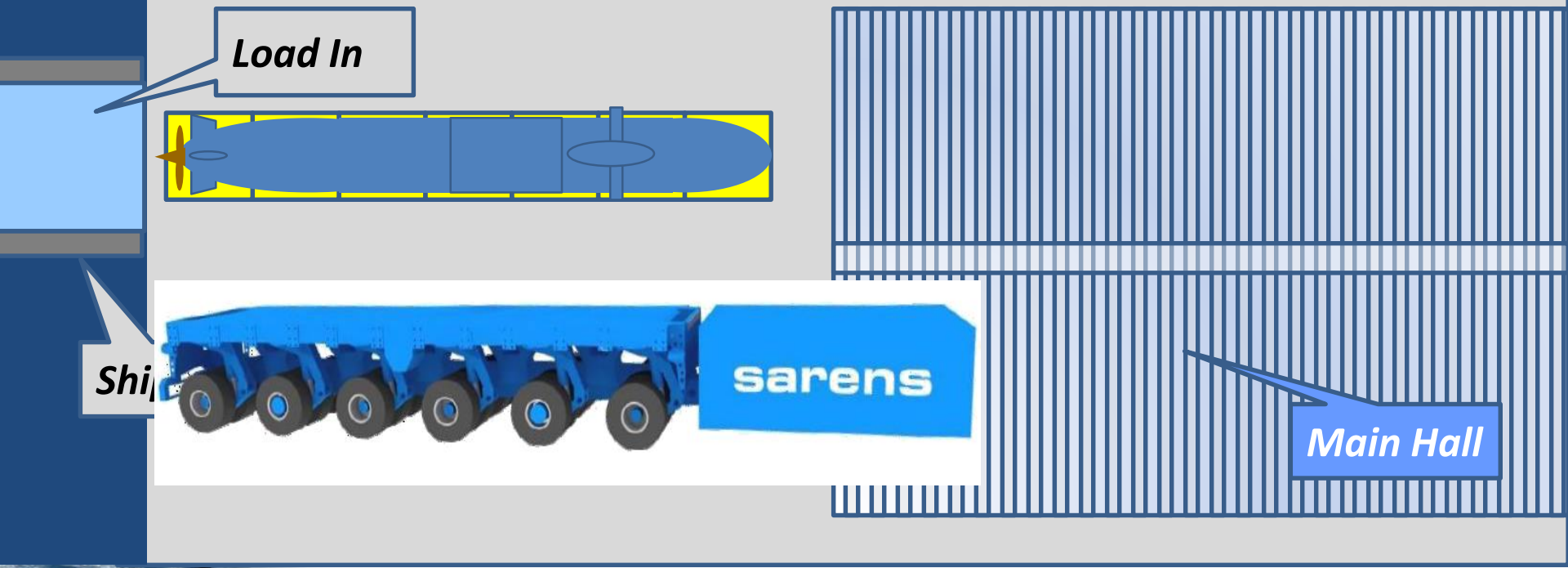
www.hctisn.fr/Presentation_DSND_démantèlement_des_sousmarins_nucléaires.pdf

http://www.navy.mil/navydata/cno/n87/history/chrono.html

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

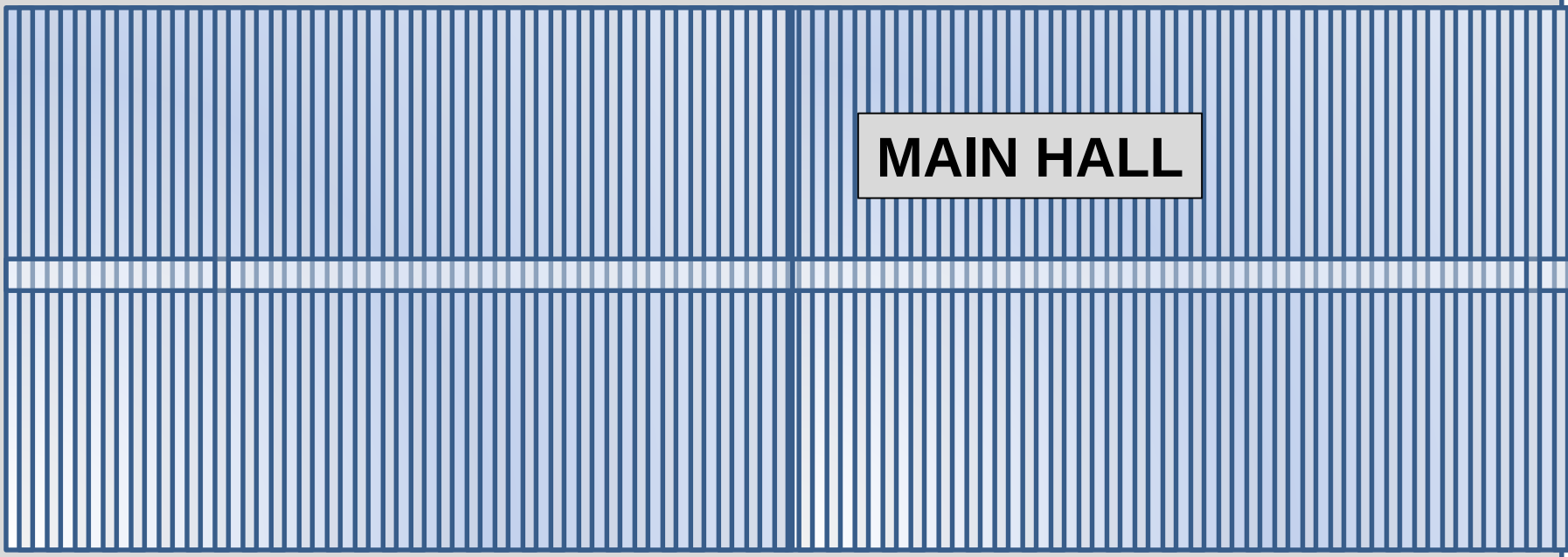

**SN-BR on the way back to Shipyard's Main Hall**

Reactor Section after defueling is
Low level radiologic waist



# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

**Container transport to the Provisory Storage at the MSY and, later, to the Final Storage (CNEN).**



# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 4 - Activated Material Management Phase (Reactor Section transport)

Reactor Section transportation from Cherbourg (PMC) to Homet – France

MINISTERE DE LA DEFENSE, **Le démantèlement des sous-marins nucléaires**, Direction Générale de l'Armement. In: Apresentação ao MD em 2013. Disponível em: www.hctisn.fr/Presentation_DSND_démantèlement_des_sousmarins_nucléaires.pdf>

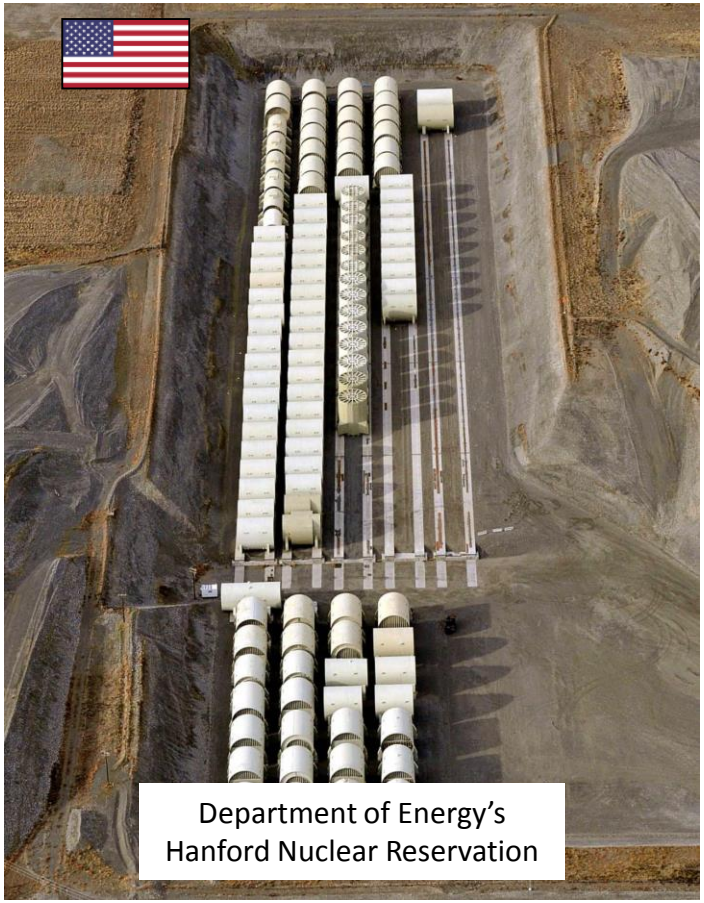
# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 4 - Activated Material Management Phase

### (Reactor Section Storage 30 – 60 years)


www.hctisn.fr/Presentation_DSND_démantèlement_des_sousmarins_nucléaires.pdf


bellona.org/news/uncategorized/2013-07-public-visit-to-sayda-bay-nuclear-wastestorage-site-in-northern-russia-shows-positive-developments




NAVAL NUCLEAR PROPULSION PROGRAM. Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and their Support Facilities. Report NT-14-1. Washington D.C., 2014.

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 5 - Hull dismantlement phase (recycling)

**Purpose:**

Reduce the risk of environmental contamination by toxic materials and the recycling of valuable materials within the rest of the submarine.

**Options:**

- Total dismantlement of the submarine or
- Conversion to MUSEUM SHIP (less expensive)

**Comments:**

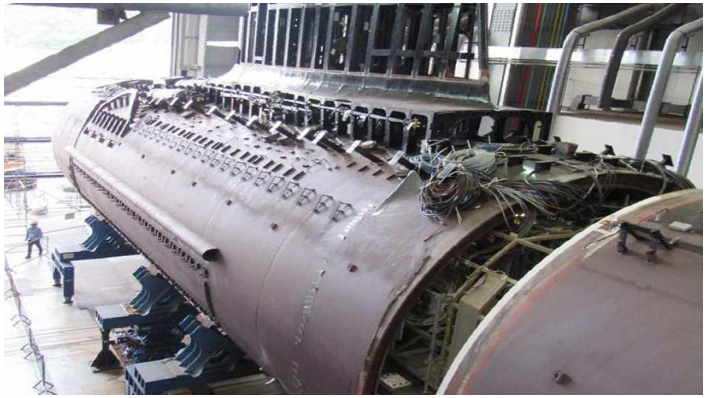
Reuse of large equipment (diesel generators, turbines, pumps);

Reuse of valuable materials (special steel; brass, copper, aluminum, etc.);

Safe disposal of toxic materials (insulants: thermic, electric and acoustic)

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## 5 - Hull dismantlement phase (recycling)

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

Estimated amount of recycled materials and waste generated in SN-BR decommissioning

| decommissioning Phases | Waste | | | | Reusable materials |
|---|---|---|---|---|---|
| | Radioactive | | Non Radioactive | | |
| | ton | $m^3$ | ton | $m^3$ | ton |
| Preparatory | - | - | - | 20 | 25 (spare parts) |
| Defueling | NA | 20 | - | - | - |
| SNF and radioactive waste management | 30 | 280 | 25 | - | - |
| Reactor Section Management | 720 | 800 | 200 | - | - |
| Hull Dismantlement | - | - | 300 | NA | 4700 |
| TOTAL | 750 (12%) | 1100 | 525 (9%) | 20 | 4725 (79%) |

- Best estimate (weight %);
- SNF & Radioactive waste processing not included

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

## Hazardous materials

| Material | Location (source in SN-BR) |
|---|---|
| **Bifenil-policlorados (PCB)** | Electrical cables, ventilation joints, transformers, thermal insulation, hydraulic fluids, oils, greases, mountings, fasteners and other rubber or expanded foam products. |
| **Asbestos** | Ventilation piping and ducts, valve gaskets and seals, electrical cable, thermal and acoustic insulation, noise dampeners and anechoic sheath. |
| **Lead** | Ballast, paints, batteries, cable, plumbing systems |
| **Acids** | Batteries and atmosphere regeneration system |
| **Mercury** | Instrument Display, Fluorescent Lamps, LCD Screens |
| **Cadmium** | Cadmium Plated Fasteners, Hydrogen Burners |
| **Etilenoglicol** | Antifreeze, frigorific, Air Conditioning and cooling systems |
| **Halogenated fluorocarbons** | Refrigeration and air conditioning systems; aerosol cans |

# BRAZILIAN NUCLEAR SUBMARINE DECOMMISSIONING PROCESS STUDIES

Deactivated nuclear submarines at HMNB Devonport, Plymouth - England

"Whatever the nuclear submarine decommissioning process selected to be implemented. The adopted solution shall be safe, environmentally responsible, cost-effective and shall inspire confidence in the public"

Ministry of Defense Policy for Decommissioning and the Disposal of Radioactive Waste and Residual Nuclear Material Arising From the Nuclear Programme, 2007.

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