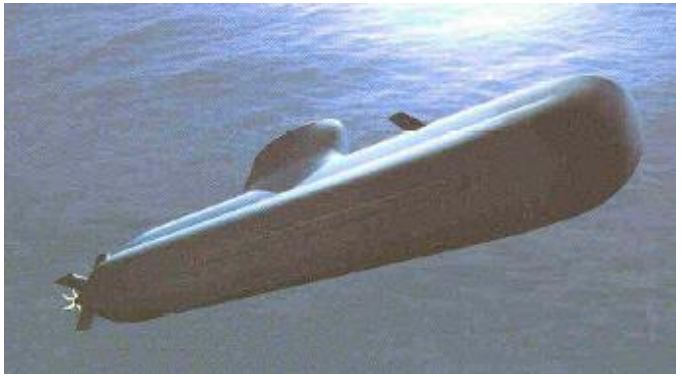
IN-FICCI SEMINAR



AIP Technologies/Stored Energy Devices

M PATRI

Naval Materials Research Laboratory
Ambernath-421506

N M R L

Air independent propulsion (AIP) for Diesel-electric class of Submarines

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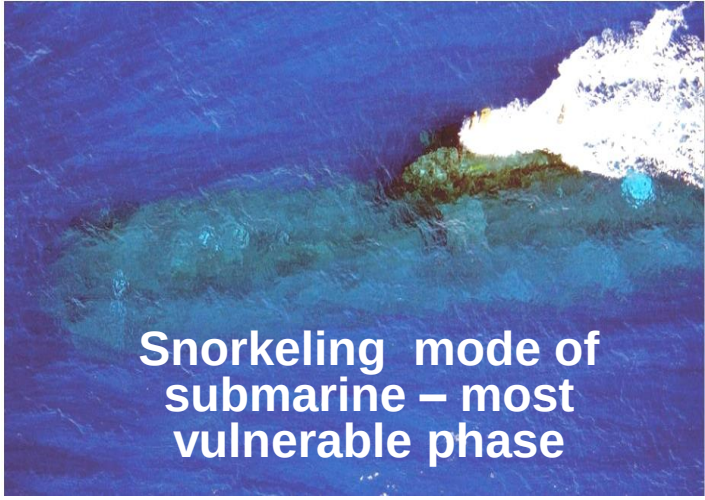

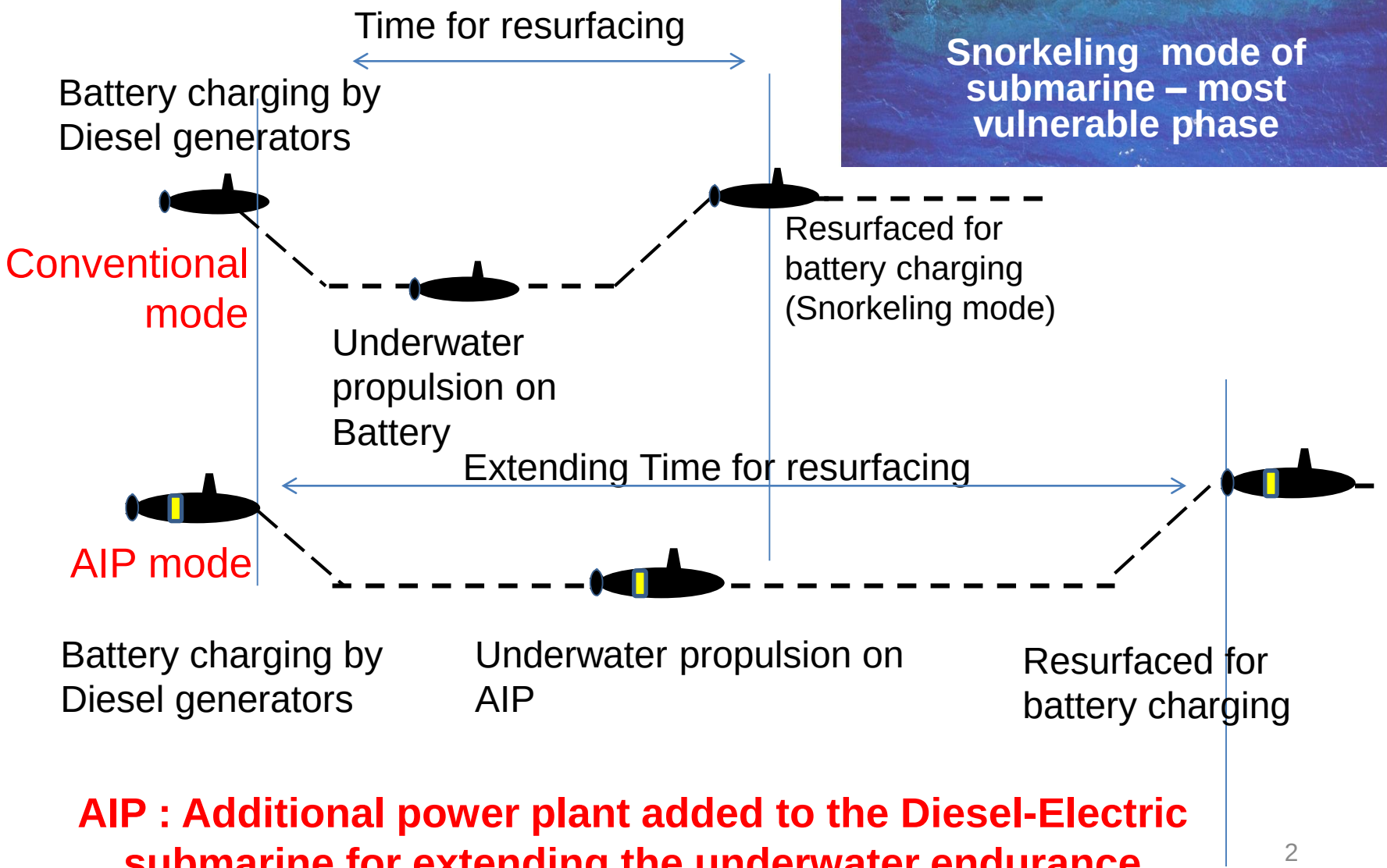

AIP : Additional power plant added to the Diesel-Electric submarine for extending the underwater endurance

The AIP ……..

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- It is an non-nuclear alternative
- Longer endurance under submerged condition by supplementing the lead acid batteries
- Provides higher stealth (acoustic silence) characteristics underwater
- Reduces the risk of exposure by avoiding frequent surfacing

How AIP works……..

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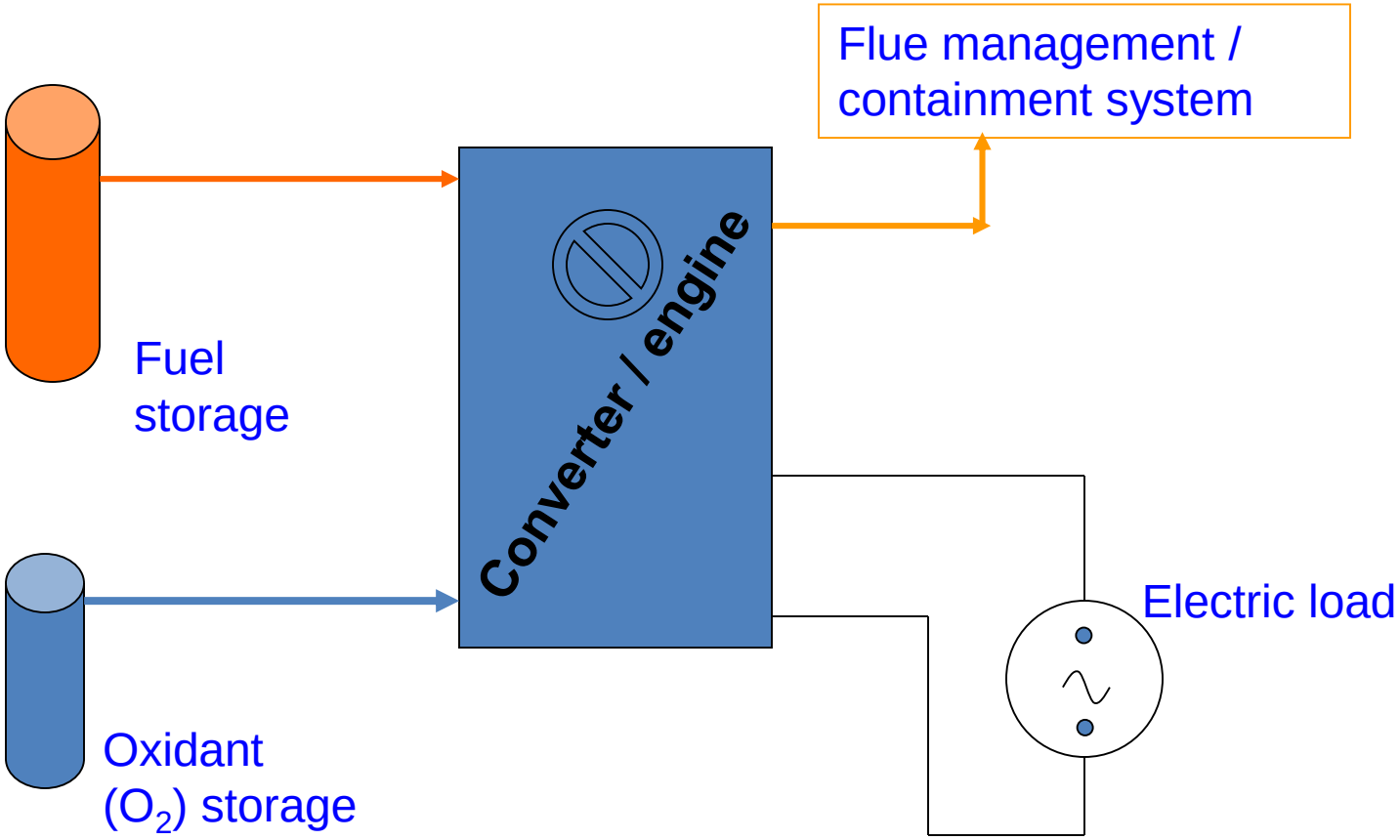


Objective :- to preserve battery power while underwater

Comparison of global AIP technologies

- Closed cycle Diesel (CCD) – Russia – (*****)
  - Noisy, discarded by the modern Navy
- Steam alternator MESMA – France (*****)
  - Noisy, exported to Pakistan Navy
- Sterling engine – Sweden {*****}
  - Adopted in Kockum class and technology exported to China
- Fuel cell system {*****}
  - Metal hydride / PEMFC – Germany (used by many countries)
  - Diesel reformer/ AFC – Russia – prototype level
  - Diesel reformer / PEMFC – France|Spain – prototype level
  - Borohydride / PAFC – DRDO India – prototype level(advanced)

(***** Ratings based on AIP efficiency, low signature and safety)

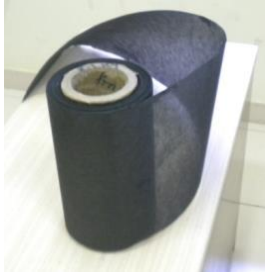
Selection of Hydrogen-Oxygen Fuel Cells…a trade off

Fuel Cell Types	Efficiency	Life	Size	Reactant quality required
Alkaline Fuel Cells (AFC)	High ✓	Poor ✗ < 2000 hrs	medium ✓	Ultra high purity ✗
Polymer Electrolyte Fuel cells (PEMFC)	Medium ✓	Medium < 5000 hrs ✗	small ✓	High purity ✗
Phosphoric Acid Fuel Cells (PAFC)	Medium ✓	High > 45000 hrs ✓	big ✗	Low purity ✓
Solid oxide fuel cells (SOFC)	Technology under development			
Molten Carbonate fuel Cells (MCFC)	Technology under development			

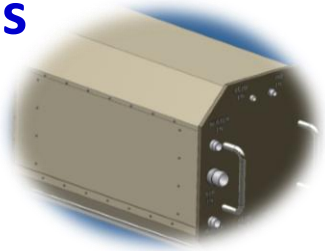
Onboard Hydrogen storage/generation .. Primary driver

Technology	Additional LOX complimen t	Gaseous effluent (cause noise)	Life	Hydrogen qty
Metal hydride	Nil ✓	Nil ✓	Low ✗	Low ✗
Diesel Reforming	High ✗	High ✗	Uncertain ✗	Medium ✓
Methanol reforming	Low ✓	Low ✓	High ✓	high ✓
Borohydride hydrolysis	nil ✓	nil ✓	high ✓	high ✓

NMRL competence in fuel cells technology



- **Materials for Phosphoric acid fuel cells (PAFC)**
  - **Complete material solutions for PAFC 1996-1998**
    - **Catalyst, moulded graphite bipolar plate, carbon paper, sealants, acid holder matrix etc. (innovations patented)**
  - **Indian Industry partner developed for all materials**

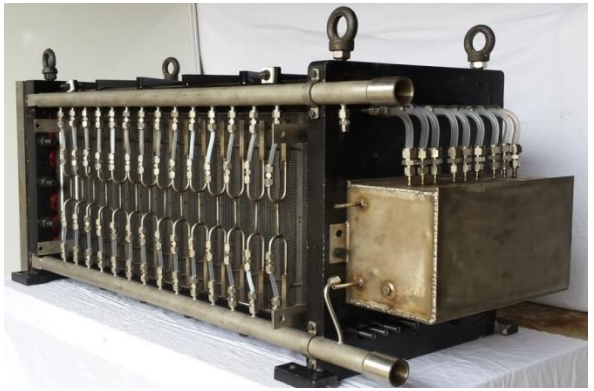


- **Fuel cell Stack 1998-2003**
  - **PAFC stacks 1-3kw**
  - **PAFC technology for production transferred to industry**
- **Fuel cell power plant 2003-2009**
  - **Compact packaged methanol reformer for fuel cell Field use (any fuel cell) with filters if required upto 15kw power plant**

Upgradation of Fuel cell Stacks for Marine grade ruggedization & Compaction

• 6kw, N6
(2011)

• 9kw, N9
• Shock/vibration –ok
(2013)



• 11.5 kw, N11
• Rugged cocoon
• Shock /vibration –ok
(2015)

Knowhow transferred to Industry partner & is completely industrialized

Possible to use upto 500kw power generation by series /parallel connection

Air Independent Propulsion (AIP) Technology Conceptualized & Developed in NMRL

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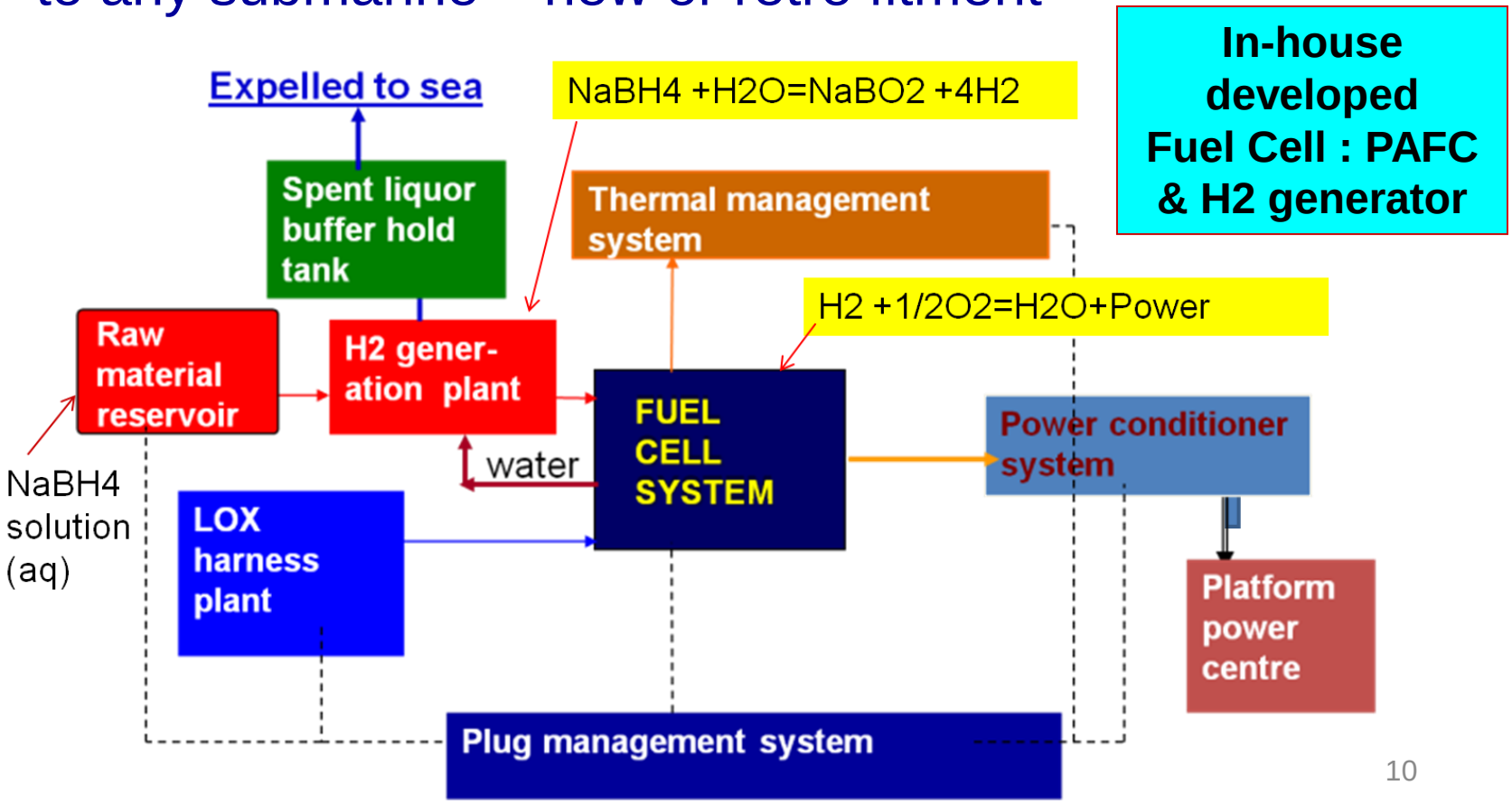
- Present system configuration is customized for P-75 Submarines;
- Flexible modular design approach allows adaptation to any submarine – new or retro fitment



NMRL developed Fuel Cell AIP for integration to ongoing P-75 Submarine

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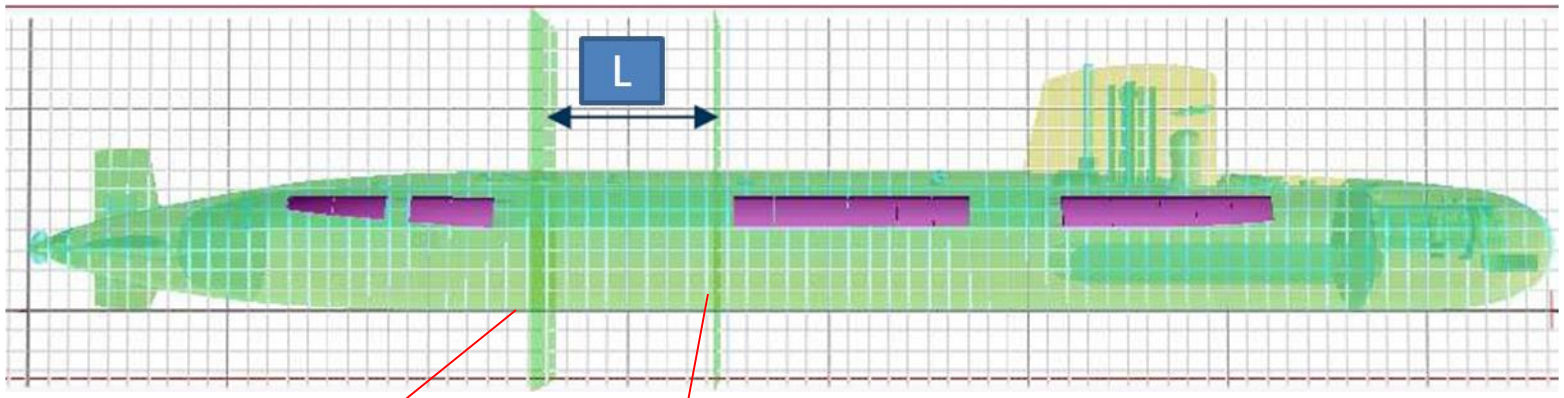

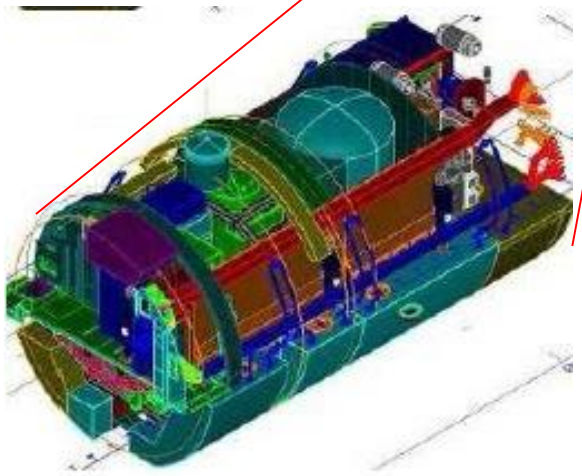

- Fuel Cell based AIP is integrated in a additional section (AIP plug) and inserted to the Submarine
- Open architecture plant proven
- Prototype conforming to Submarine stds. Under advanced phase of development

Novel H2 Provision for futuristic FC based AIP

- Ammonia electrolysis

  - Advantages

    - Small fraction of power required for splitting ammonia
    - Quick startup and simple system
    - Highly suitable for very long endurance

  -Challenges

    - Safety solution for carrying pressurised fuel
    - Noise reduction due to Nitrogen (by-product) bubbling out

- Al / Gallium liquid metal alloy based generator

  -Advantages

    - Quick startup and pumpable liquid alloy (>40°C)
    - All solid by products, possible to contain within submarine

  -Disadvantages

    - Safety solutions for explosive reaction with water in case of storage breach

1000 F ELECTROCHEMICAL SUPER CAPACITOR

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Polymer based **electrochemical super capacitors** with very **high capacitance** and **high power density**, **excellent cycle life**.

- **Configuration**
- ✓ **Capacitance:** 100 F-1000 F
- ✓ **Voltage:** 0-2.5 V (Vmax:2.75 V)
- ✓ **ESR:** 15 to 35 m ohm
- ✓ **Operating Temp.:** -40 to 55 °C
- **Applications**
- ✓ Fuel cells
- ✓ Sonar
- ✓ Telecommunication systems
- ✓ Portable Power Pack Systems
- ✓ Cranking of engines
- ✓ Electric vehicle
- **Status**:
- ✓ Technology available for transfer

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THANK YOU