FICCI Conference, New Delhi

Technology Development - New Technologies

April 18./19.2016 | Andreas Grunicke
thyssenkrupp Marine Systems – Operating Unit Submarines

engineering.tomorrow.together.

thyssenkrupp

Content

1. Introduction
2. Li Ion Batteries
3. Fuel Cell Methanol Reformer System
4. IDAS
5. Hydrodynamics, propeller development
6. Acoustic Coating
7. UUV integration concepts
8. Summary

thyssenkrupp – Organizational overview

thyssenkrupp Business Areas

Components Technology

Sales (€ mill)	6,753
EBIT[2)] (€ mill)	313
Employees	29,627

Elevator Technology

Sales (€ mill)	7,208
EBIT[2)] (€ mill)	794
Employees	51,335

Industrial Solutions

Sales (€ mill)	6,256
EBIT[2)] (€ mill)	424
Employees	19,388

Materials Services

Sales (€ mill)	14,254
EBIT[2)] (€ mill)	206
Employees	20,.226

Steel Americas

Sales (€ mill)	1,773
EBIT[2)] (€ mill)	(138)
Employees	3,725

Steel Europe

Sales (€ mill)	8,697
EBIT[2)] (€ mill)	492
Employees	27,601

Key indicators – fiscal year 2014/2015[1)]

1) Continuing operations (after reclassification of Steel Americas) before consolidation. 2) Adjusted before consolidation, after definition changes

thyssenkrupp Marine Systems – Operating Units

Business Unit thyssenkrupp Marine Systems

Operating Units

Submarines	Surface Vessels	Services
		
Kiel	Hamburg/Emden	Kiel/Hamburg/Emden

Atlas Elektronik

Generic Tasks of Research and Development

Mid- and Long-Term Enhancement of Competitiveness

Technology Leadership

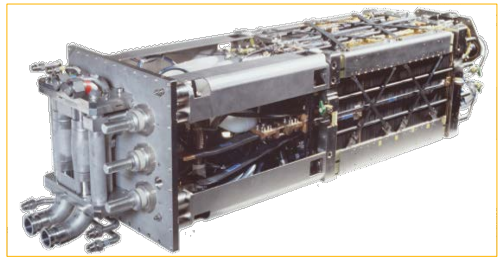
Cost Leadership

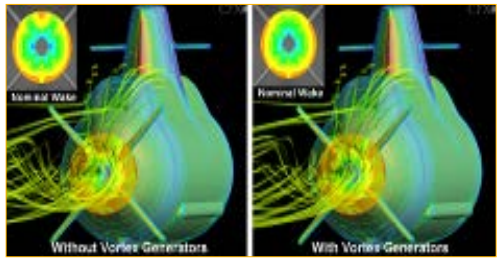
- Enhancement of Customer Value
- Cost Reduction
- Risk Reduction

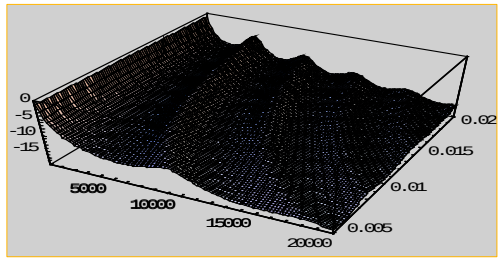
Scope of Research and Development Activities

R&D - Activi-ties

- Products
- Components and Systems
- Processes and Tools

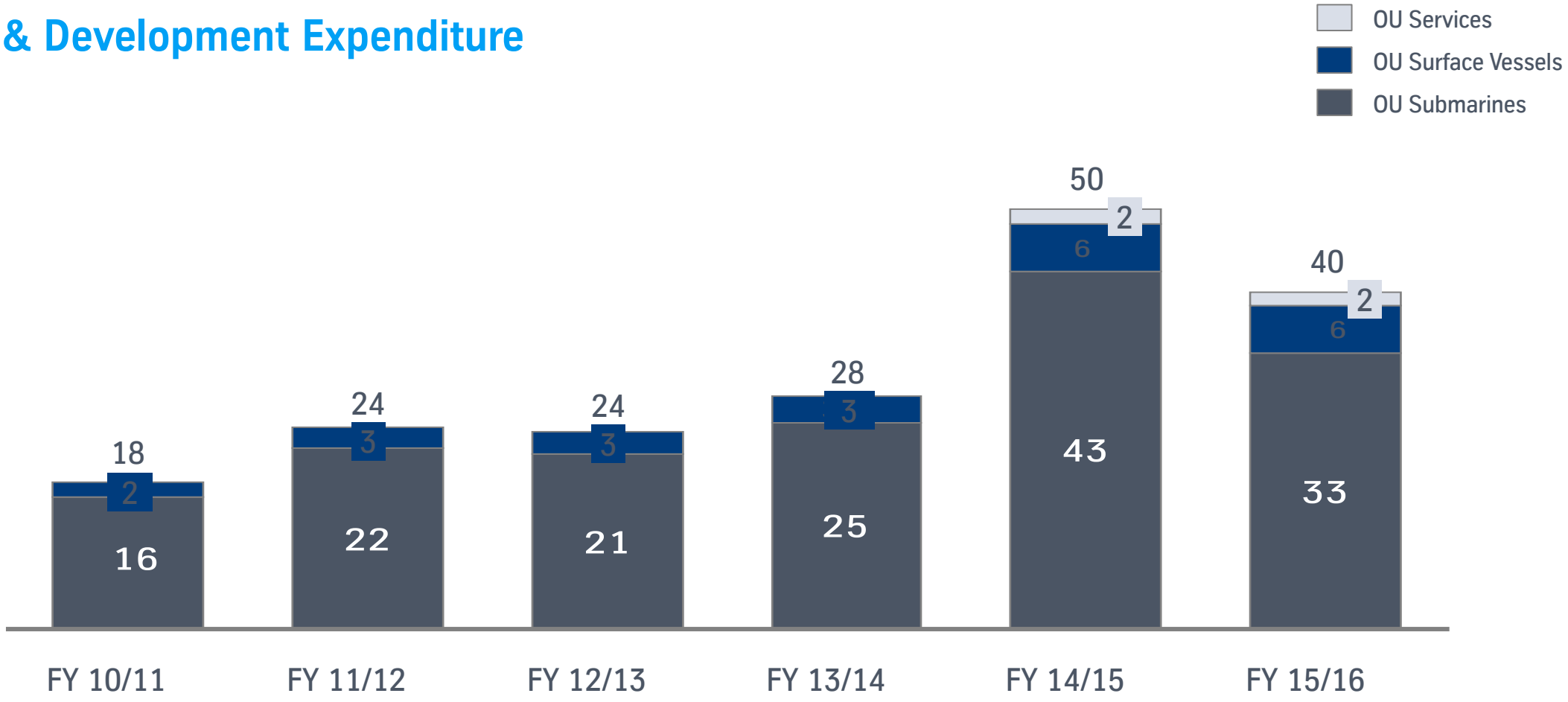






Research& Development Expenditure

Mio. EUR

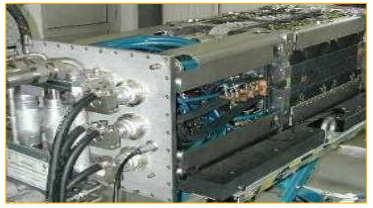
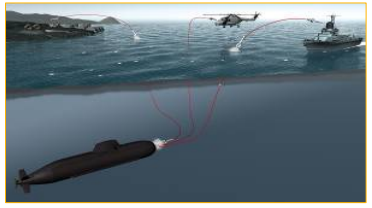


More than 160 R+D projects running at present time

Long Lasting Developments[1]

Weapon Section	*1988 - 1994*
Torpedo Counter Measures	*1999 - 2005*
ISUS 90 Family	*1990 - 2005*
PERMASYN® Motor	*1985 - 2005*
Fuel Cell System	*1980 - 2005*
IDAS	*1996 -*
Lithium Battery System	*2003 -*
Class 212	*1987 - 2005*
Class 214	*1996 - 2007*



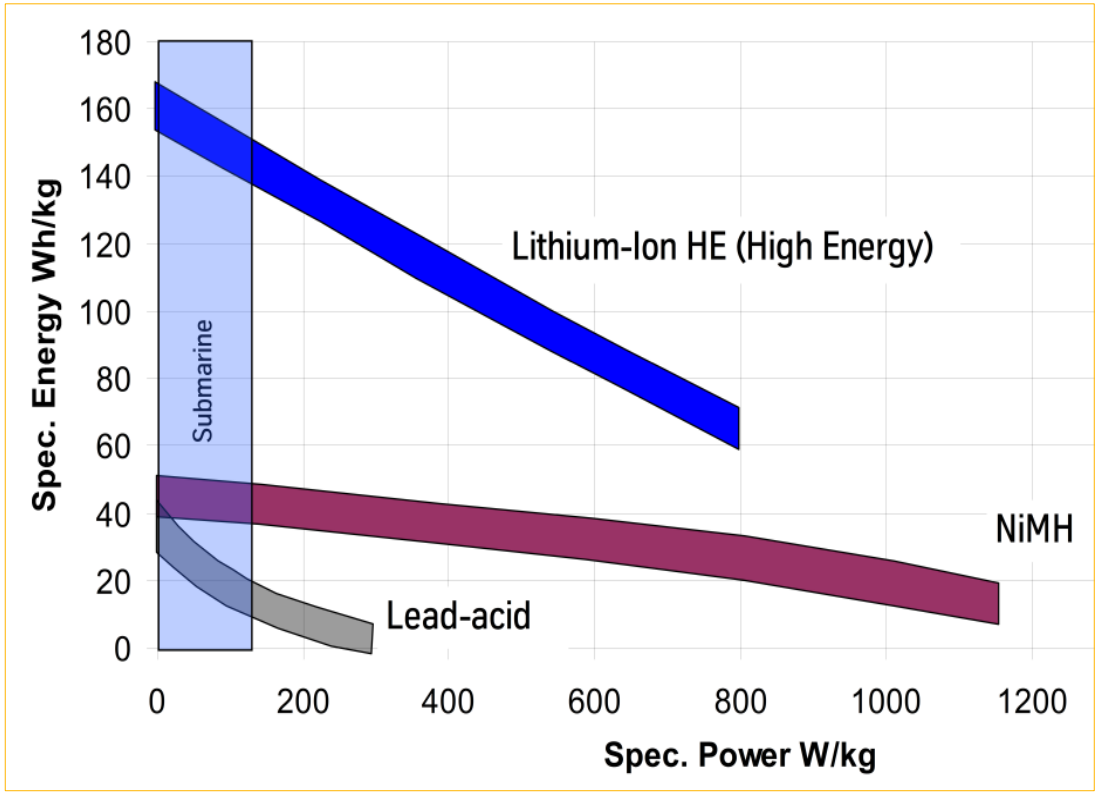





1 From start of development to delivery of first submarine with this technology

Lithium Ion Batteries - Introduction and Motivation

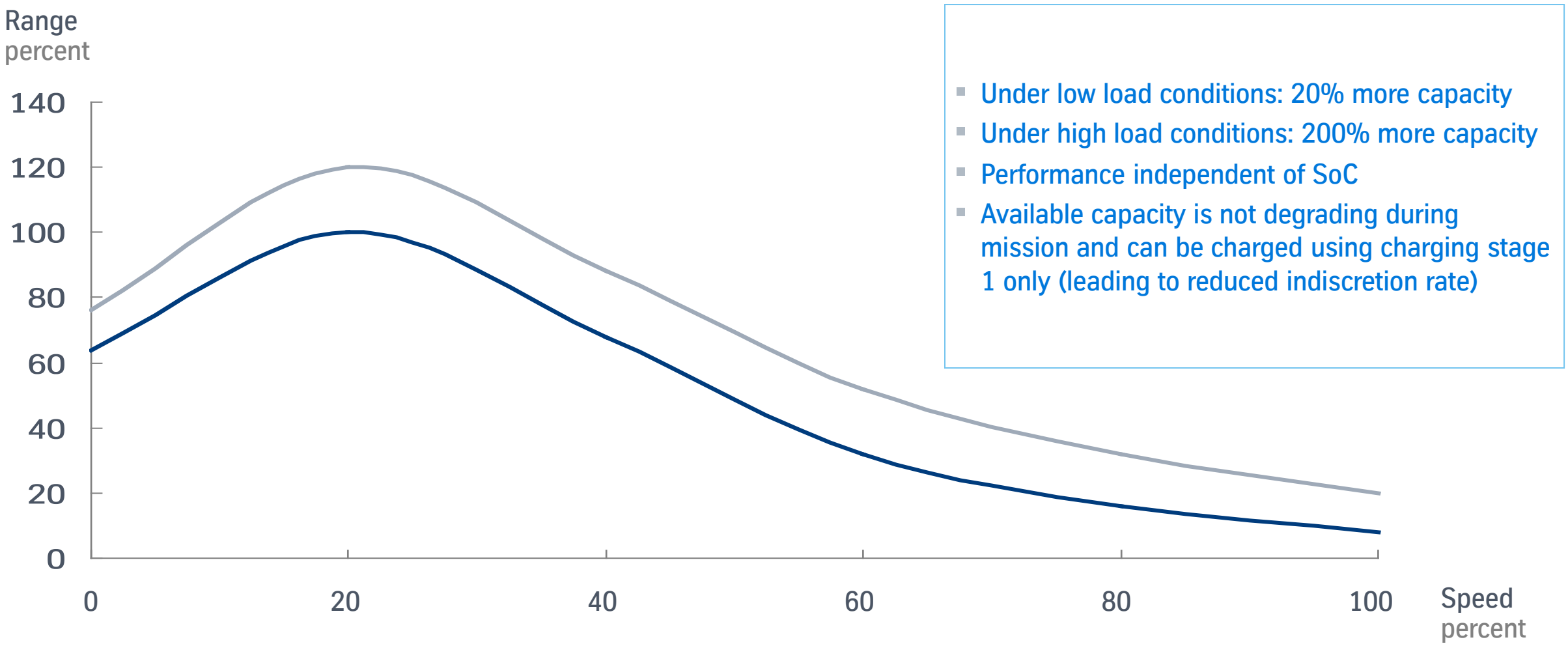
To Improve Operational Value of the Submarine

- Extend time submerged
- Increase speed spectrum while submerged
  - Complement to the AIP-System designed to fulfill low power requirements
- Decrease indiscretion rate
  - Improved charging and discharging characteristics
- Increase availability
  - Decrease maintenance requirements
- Decouple submarine performance from battery characteristics (as much as possible)
  - High speed independent from State of Charge (SoC)
- Extend life time.



Technical Concept

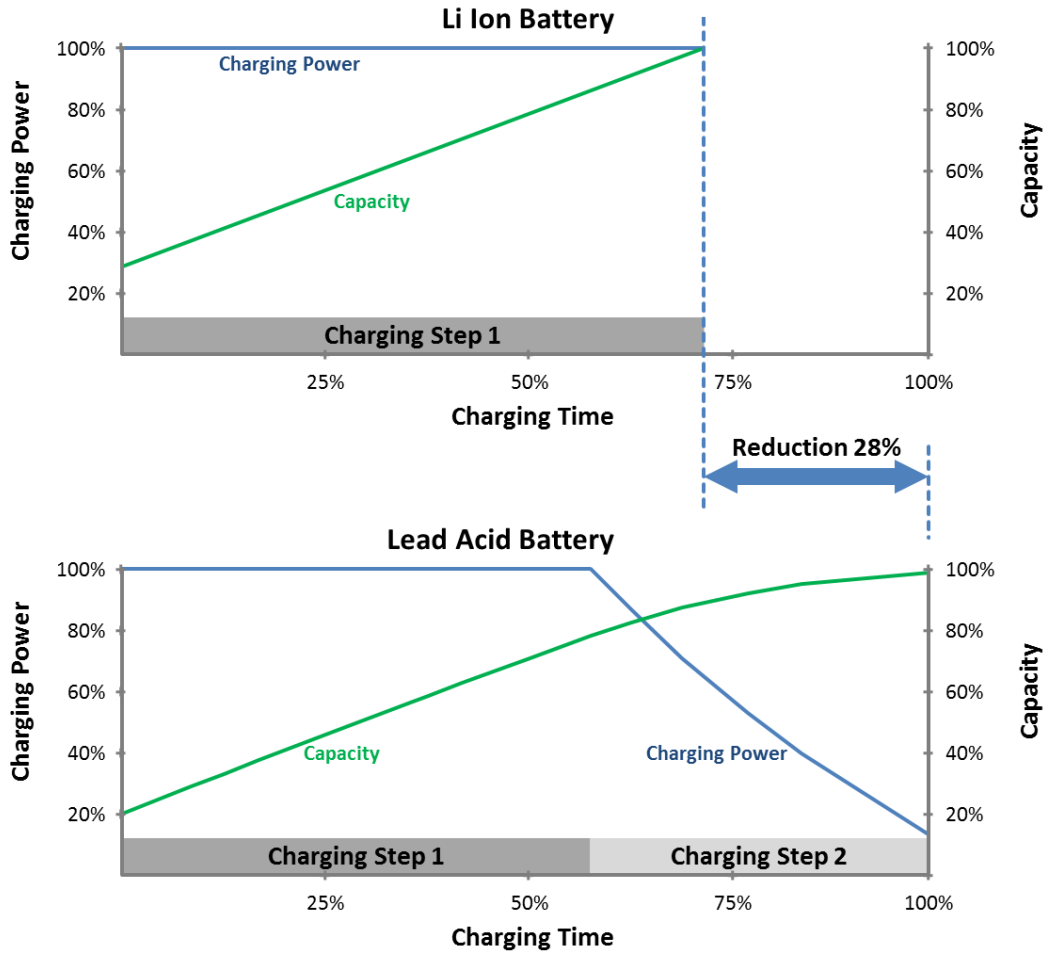
How about Performance?



- Under low load conditions: 20% more capacity
- Under high load conditions: 200% more capacity
- Performance independent of SoC
- Available capacity is not degrading during mission and can be charged using charging stage 1 only (leading to reduced indiscretion rate)

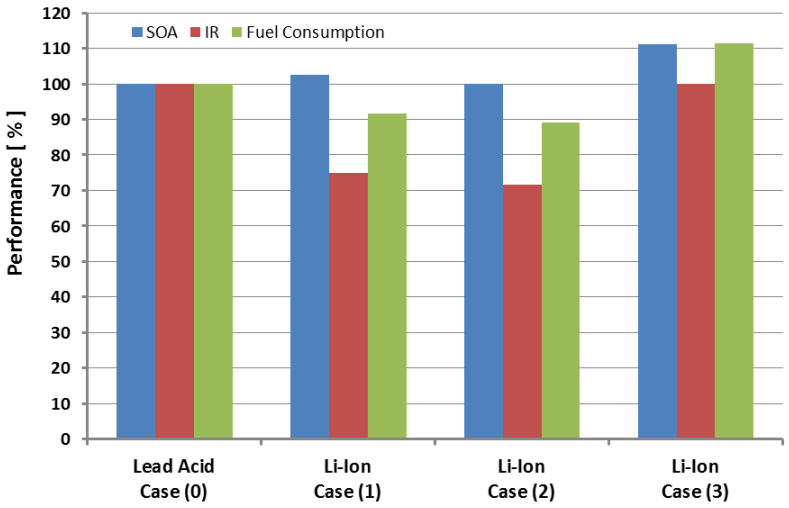
Comparison of Charging Times

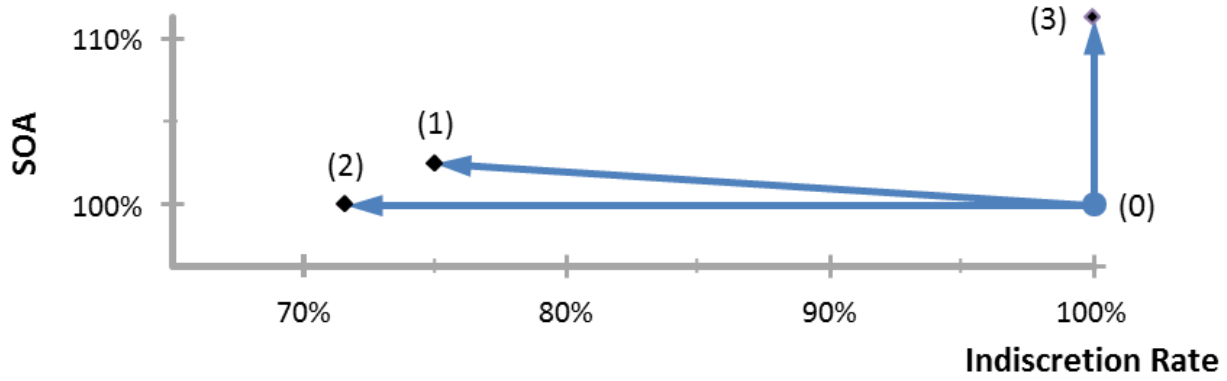
- Boundary Conditions
  - Both batteries are discharged with the same charging power
  - Both batteries are discharged the same time (same discharged energy)
  - Both batteries are charged with the same max. charging power
    - Lead Acid Battery: Charging Step 1 with max. power, charging step 2 with max Voltage and reduced current (= reduced charging power)
    - Li Ion Battery: Only charged in charging step 1
  - The charging time of the Li Ion battery is approx. 28% less than the charging time of the lead acid battery. This means improved Indiscretion Rate

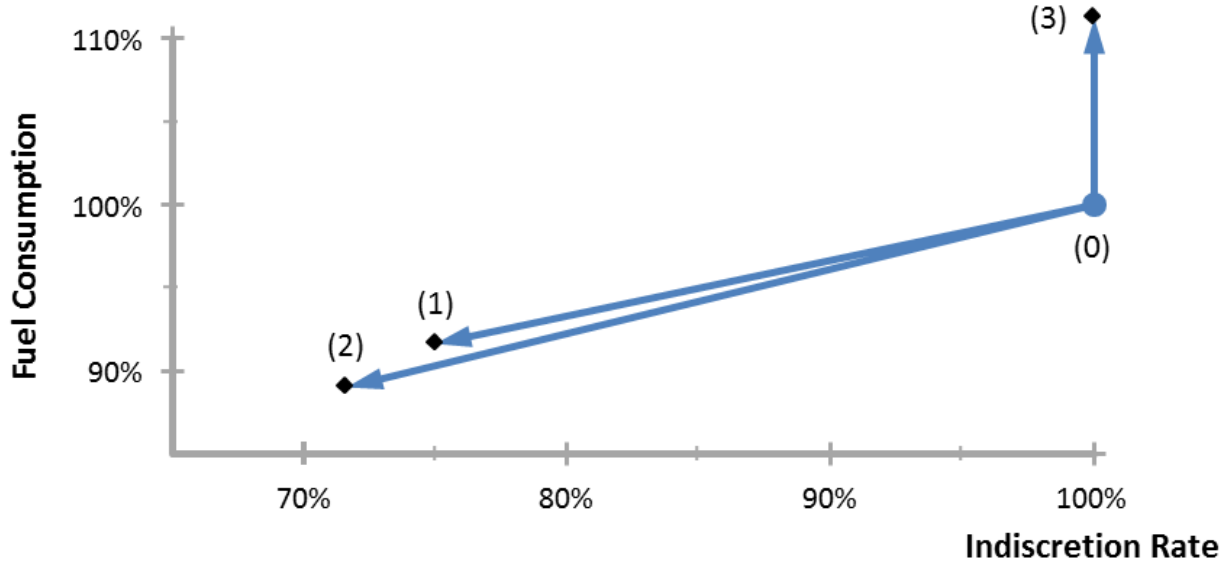


Optimization of Transit SOA

- Lead Acid Battery
  - Case (0): Optimized transit SOA for Indiscretion Rate
- Li-Ion Battery
  - Case (1): Same speed combination as in case (0)
  - Case (2): Same SOA as in case (0)
  - Case (3): Same IR as in case (0)







Major Integration Aspects

System Safety is Critical!

Risk

- Thermal Runaway and the chain reaction within the battery compartment
- High Energy Chemistries bear the risk of open fire in the battery compartment
  - NCA – Nickel-Cobalt-Aluminum
  - NMC – Nickel-Manganese-Cobalt
  - NCO – Nickel-Cobalt-Oxide

Trigger

Overcharge Overload	*To be handled by control electronics*
Overheat Mechanical Damage	*To be handled by mechanical integration*
Internal Short	*A manufacturer's quality assurance issue with a remaining risk*

- There are intrinsically safe chemistries
  - LFP – Lithium-Iron-Phosphate.

A damage and risk assessment lead to high safety integrity level (>= SIL4) requirement for the control electronics when NCA/NMC/NCO is used.

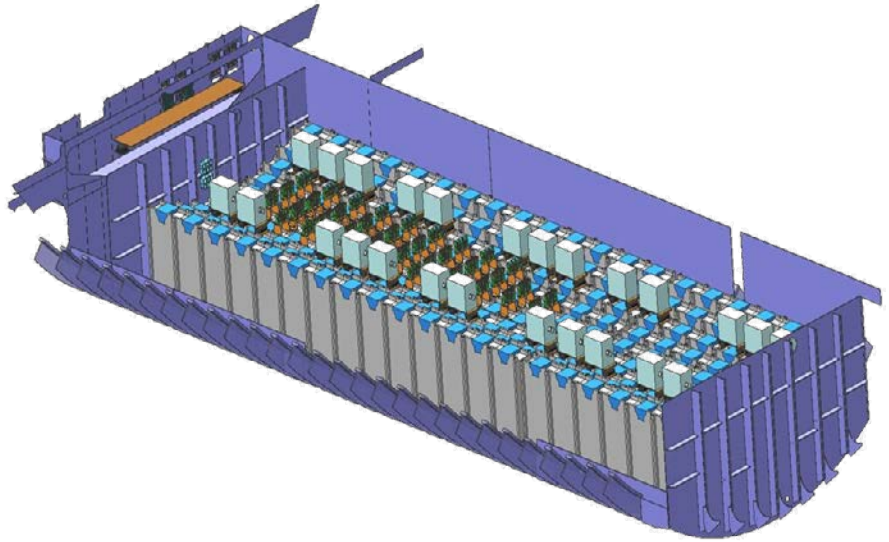
Battery Development at thyssenkrupp Marine Systems

Decision

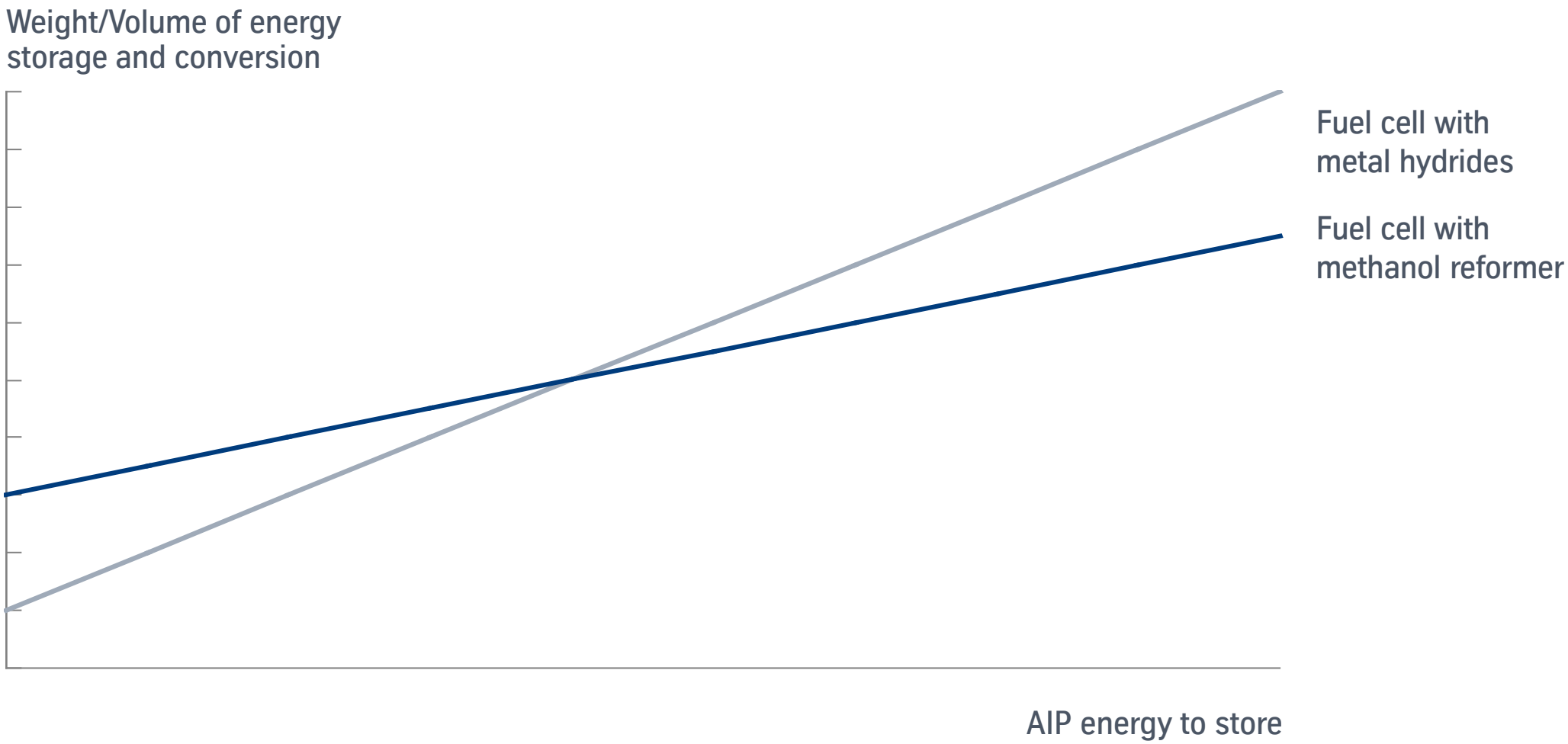
- Selection of well established cell manufacturer with system development competency
- Standard cell as core element
- Selection of LFP (blend) as the cell chemistry
- Focus on system integration as thyssenkrupp Marine Systems expertise.

Lithium-Ion Battery Integration into the Submarine

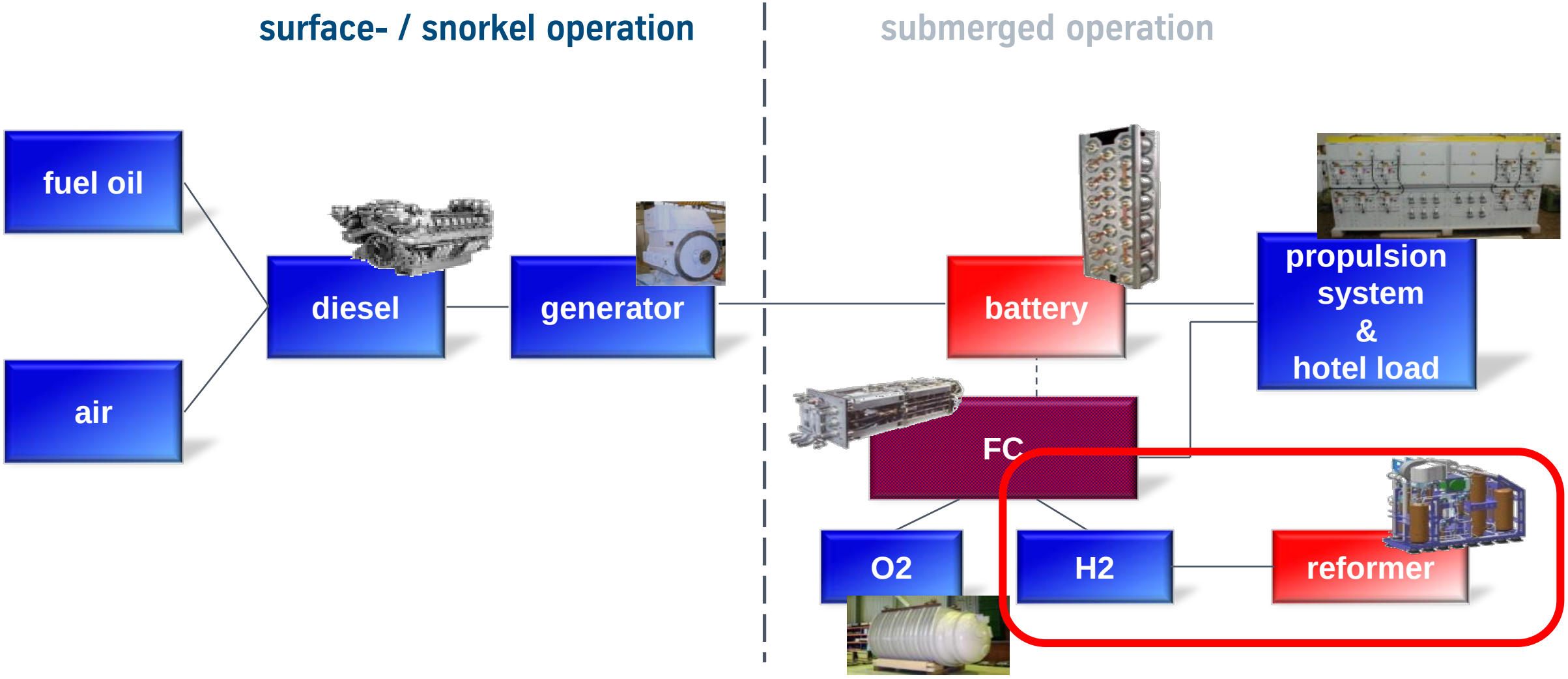
	Cl. 214
Number of modules transversal	12
Number of modules longitudinal	2 x 16
Module voltage [V]	89 - 125
Energy per module [kWh]	38
Total number of modules	384
Number of modules per string	6
String voltage range [V]	535 - 752
Engine voltage range [V]	520 - 830
Number of strings	64
Total number of cells	101376
Energy [MWh]	14,5



Methanol Reformer – Why start the Development



Power Supply



Source: Siemens, Gaia, MTU, Piller

Hydrogen Generation by Methanol Steam Reforming

- Simple alcohol CH_3OH
- Lowest reforming temperatures of 250° - 300°C
- Cheap and easily available worldwide (like LOX)
- Methanol steam reforming is a proven technology in the process industry

$$CH_3OH + H_2O \Rightarrow 3H_2 + CO_2$$

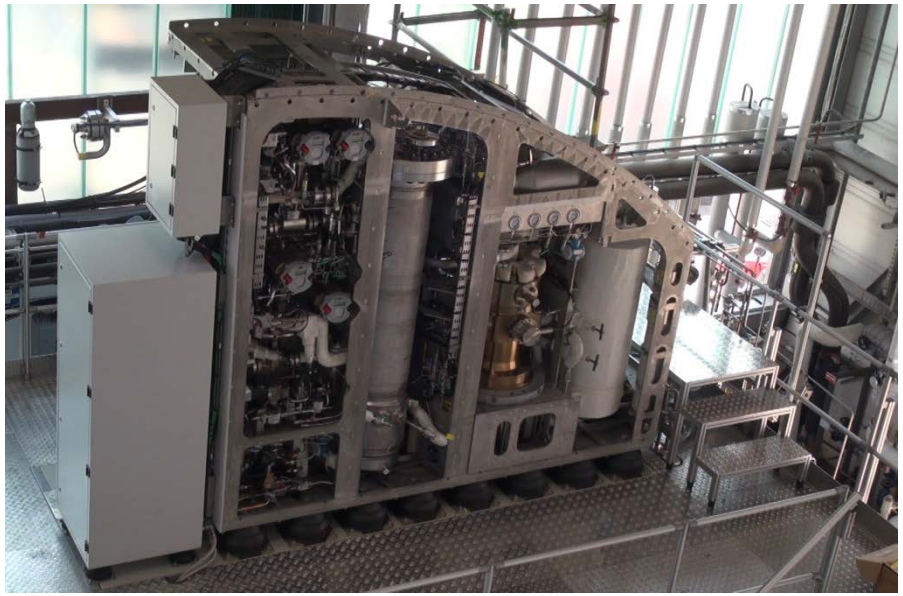
Best choice for hydrogen generation on submarines

Fuel Cell Methanol Reformer System

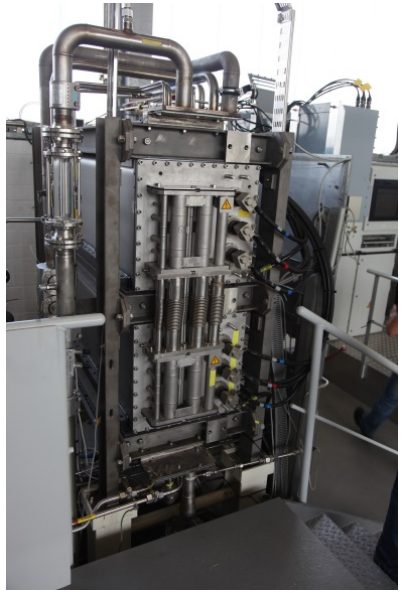
The Fuel Cell Methanol Reformer System (FCMRS) combines the advantage of the existing, proven Fuel Cell System with the advantage to utilize a liquid fuel with high energy density. A first demonstrator has been operated since the year 2000

The reformer prototype system has been set into operation in the test field at thyssenkrupp Marine Systems premises in Kiel in summer 2015.

The system has already successfully produced ultra-pure hydrogen. Furthermore the Fuel Cell Modules have been operated on hydrogen produced by the reformer system.



Methanol Reformer



Fuel Cell Modules

IDAS at a Glance

- IDAS – Changing the paradigms of anti submarine warfare!
  - Active self defence against airborne ASW for submerged submarines
  - High precision through Human in the Loop Concept
  - Coastal and small surface targets attack capability

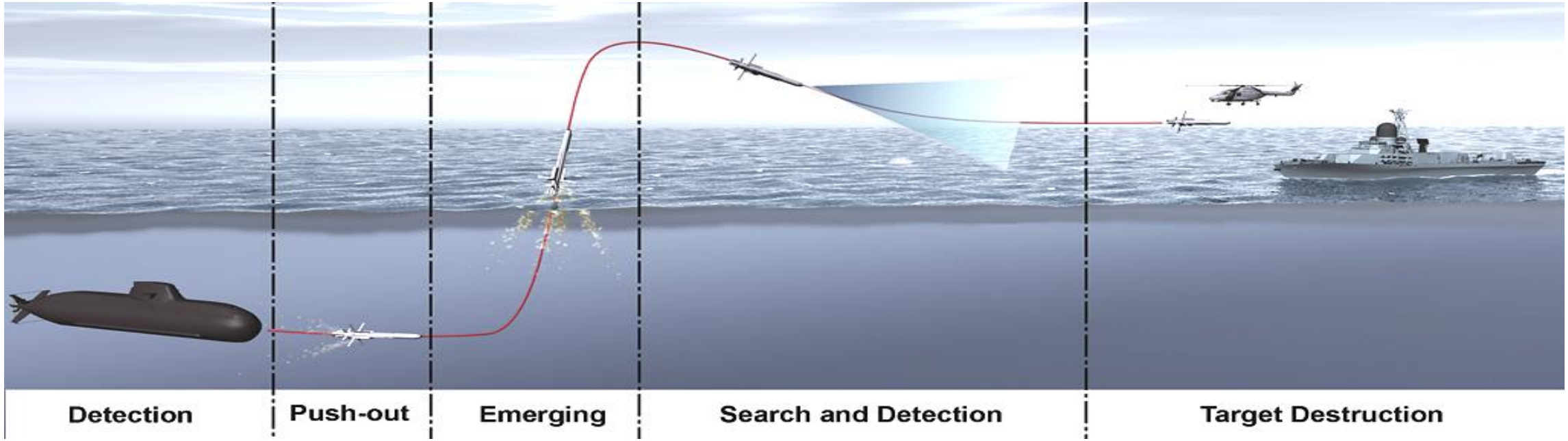
IDAS Consortium

DIEHL BGT Defence

thyssenkrupp

Nammo

roketsan



Operational Concept

The IDAS Target Spectrum

Defensive Role

Offensive Role

Weapon of choice for targets which are too fast or not accessible for a heavy weight torpedo, or for which a torpedo is over dimensioned

Technical Concept

- IDAS Submarine Integration

Very easy integration, handling with existing equipment for standard heavy weight torpedoes

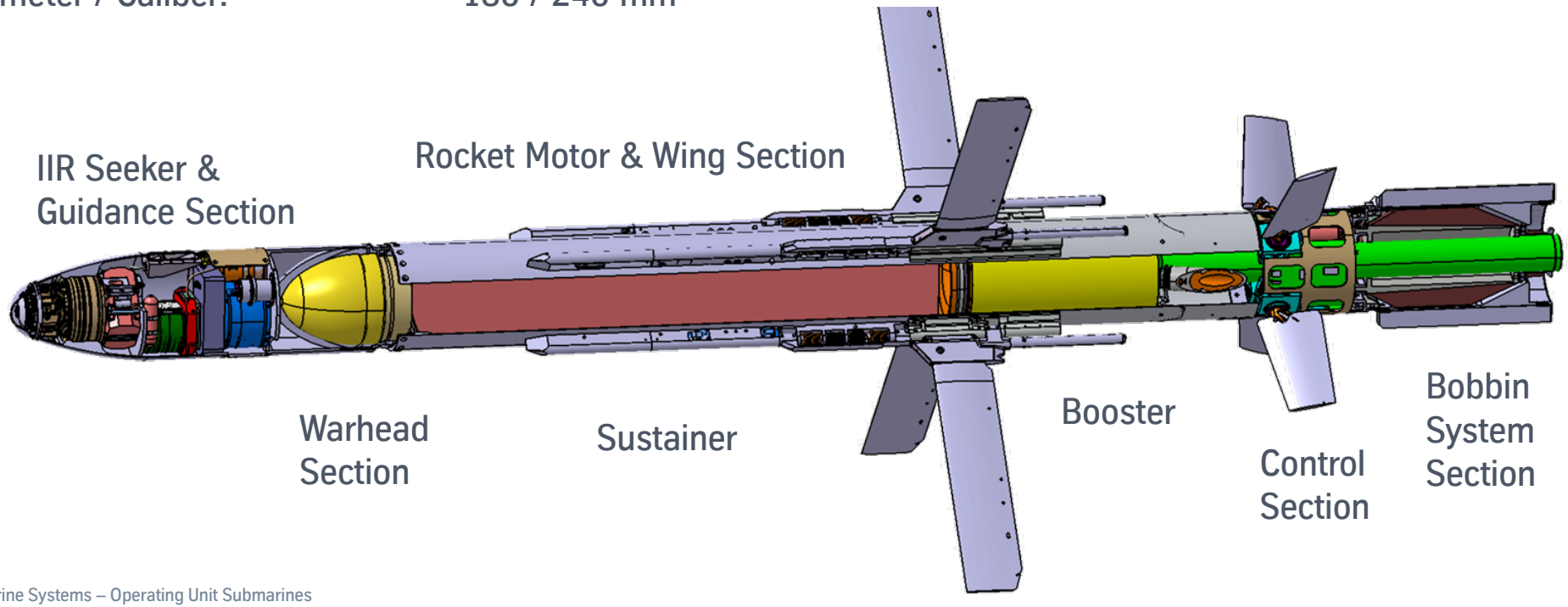
Operator controlled during the whole mission

Technical Concept

- IDAS Launching Container System
  - Four (4) missiles per launching container
  - All launching subsystems in container (autonomy)
  - Weight/ dimensions comparable to heavy weight torpedo, easy retrofit to all standard torpedo tubes

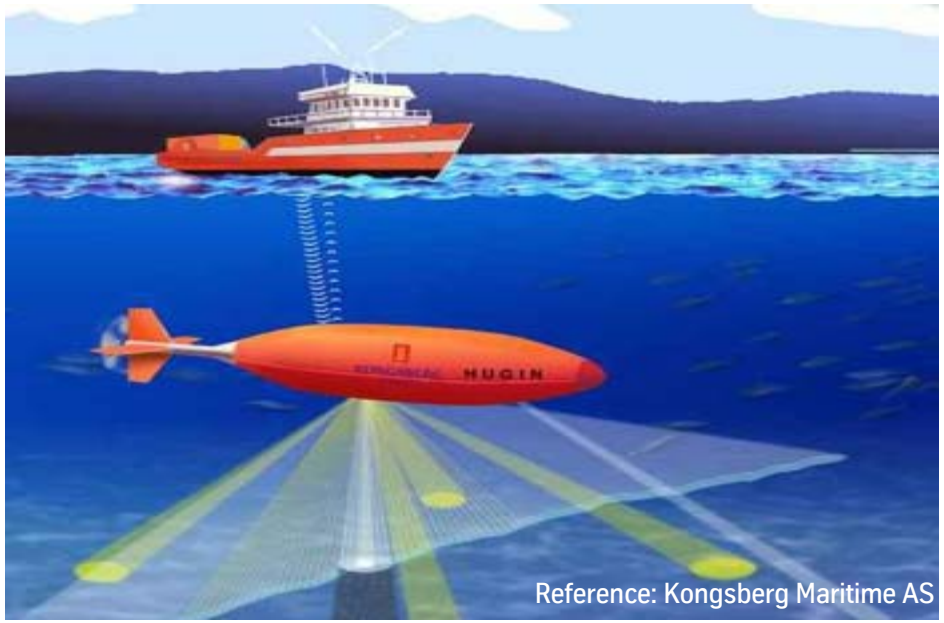
The IDAS Missile

- Main Technical Data
  - Launching Mass: 138 kg
  - Length: 2800 mm
  - Diameter / Caliber: 180 / 240 mm
  - Mass of Warhead: 15-20 kg
  - Range: approx. 20 km
  - Cruising Speed: approx. 230 m/s



Unmanned Underwater Vehicles on Submarine

- What is the original purpose of unmanned underwater vehicles?
- Normally
  - AUVs bring sensors from the surface
    - down in the ocean
    - close to the targets
    - away from disturbing noise and vibrations
- Submarines
  - AUVs bring sensors from down into the ocean
    - away from the submarine
    - to areas of very shallow waters
    - to the surface
    - to areas with a high risk for Manned Underwater Vehicles.



Reference: Kongsberg Maritime AS

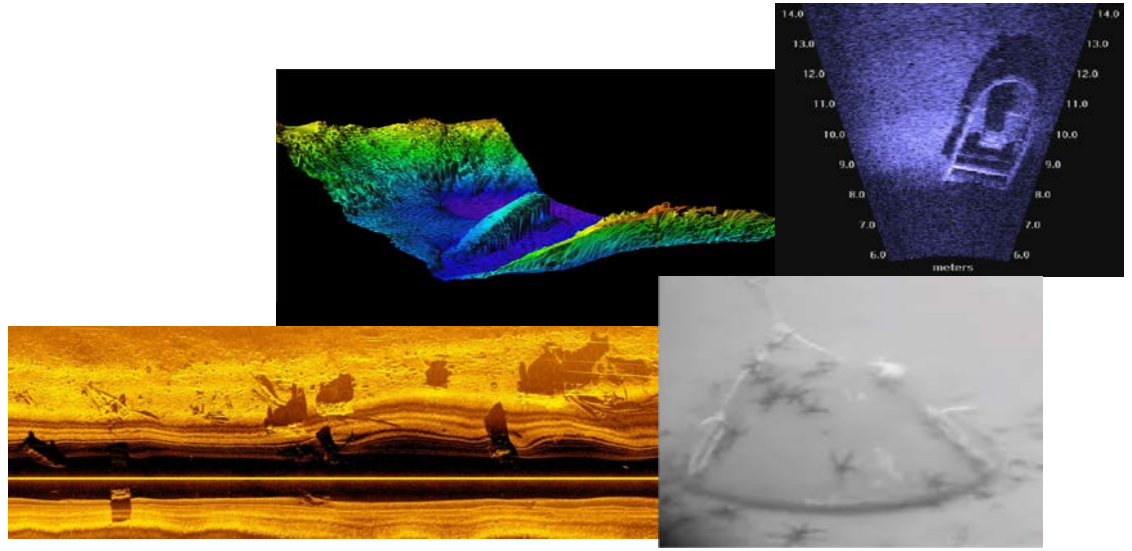
Tasks of UUVs Deployed by Submarines

- Rapid environmental assessment (REA)
  - sonar images and conditions
  - bathymetric data
  - water current information
  - mine reconnaissance
  - pictures of underwater objects
- Preparation and assistance of landing activities
  - actual situation assessment
  - guidance of the combat diver teams
  - visual escorting of landing forces on/offshore
  - communication relay

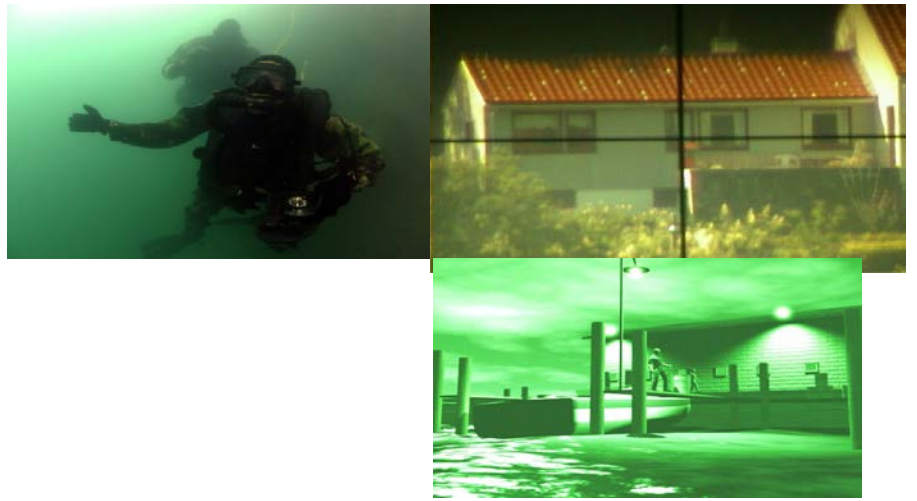
Meanwhile the submarine could stay covert

Observing areas which were inaccessible for conventional submarines

In parallel while the submarine fulfils other tasks.



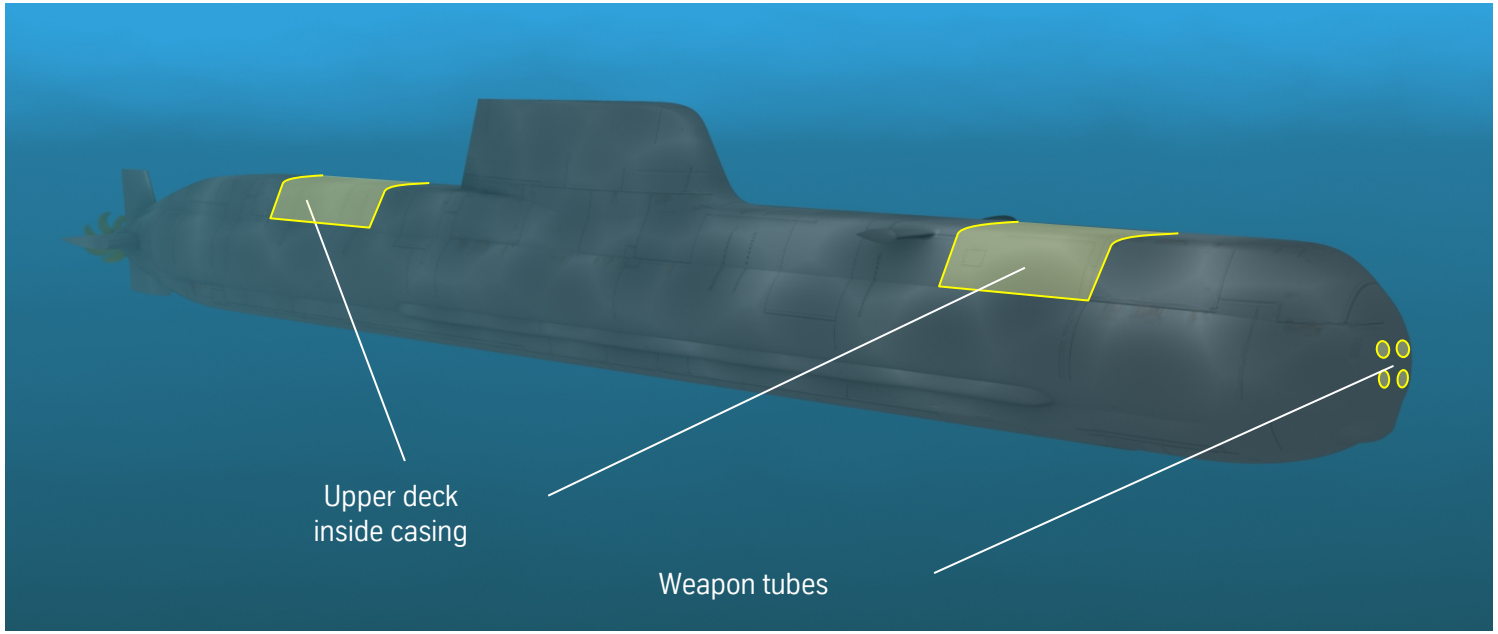
⇨ online data link to the submarine



Concept Idea – UUV Launch & Recovery System for Submarines

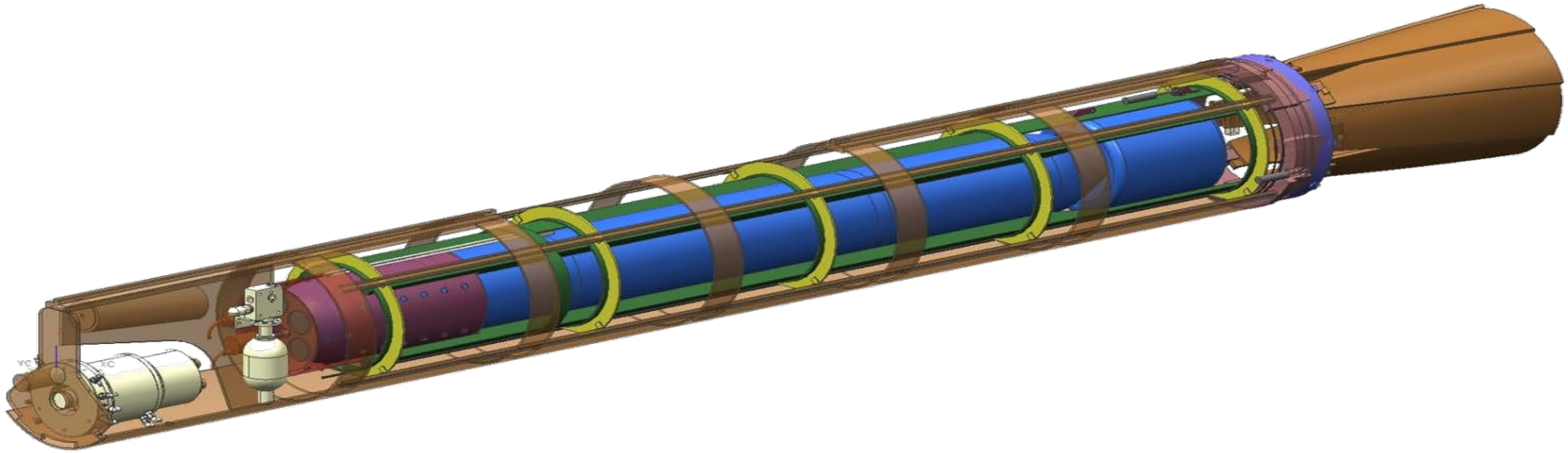
- Capable for retrofitting on existing HDW Class Submarines
  - less conversion effort
  - easy to handle and simple interfaces
  - also for new submarine projects
- Minimized negative influence on the present submarine performance
  - no additional signatures
    - not visible if the submarine is surfaced
    - no disturbing flow noise around stowage devices
  - no further appendages
    - no increased drag or manoeuvring limitations for the submarine
  - no/minimal increased weight

⇨ Only two options for integration UUVs on submarines.



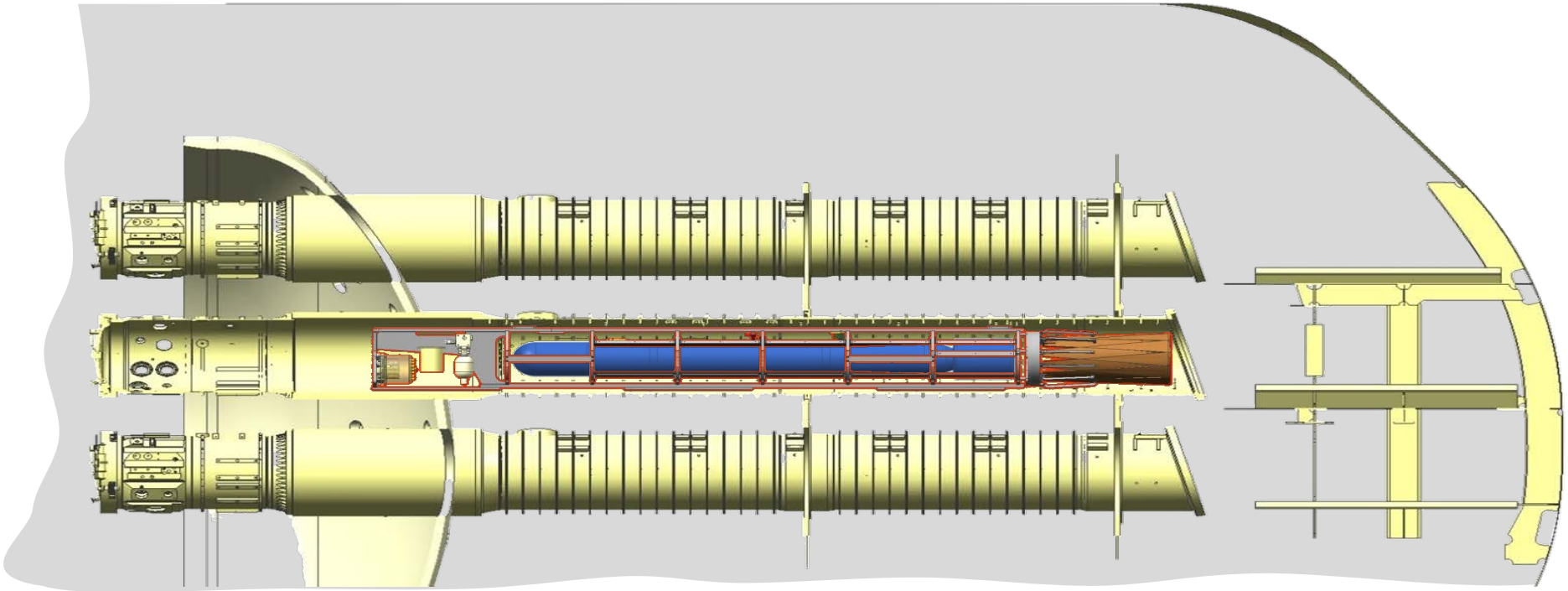
Launch & Recovery System for Weapon Tubes

- e.g. AUV DAVID made by Diehl BGT Defences



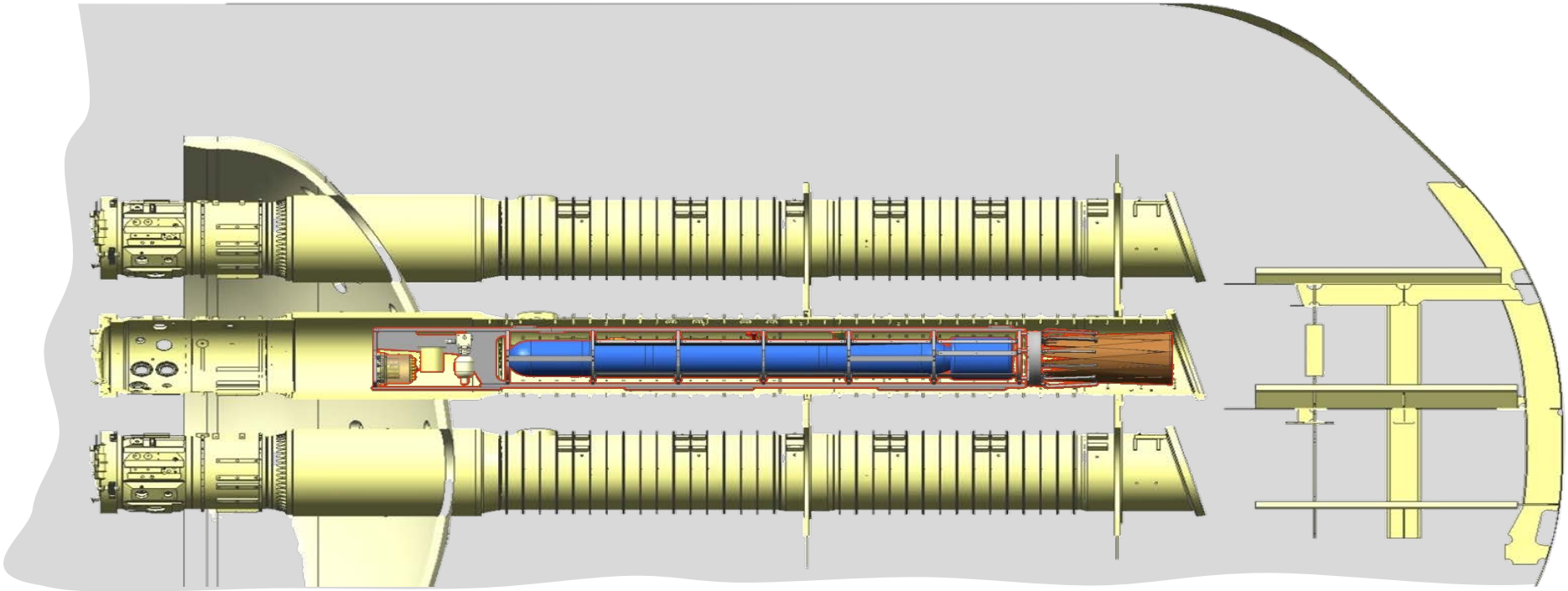
Launch & Recovery System for Weapon Tubes

- e.g. AUV DAVID made by Diehl BGT Defences



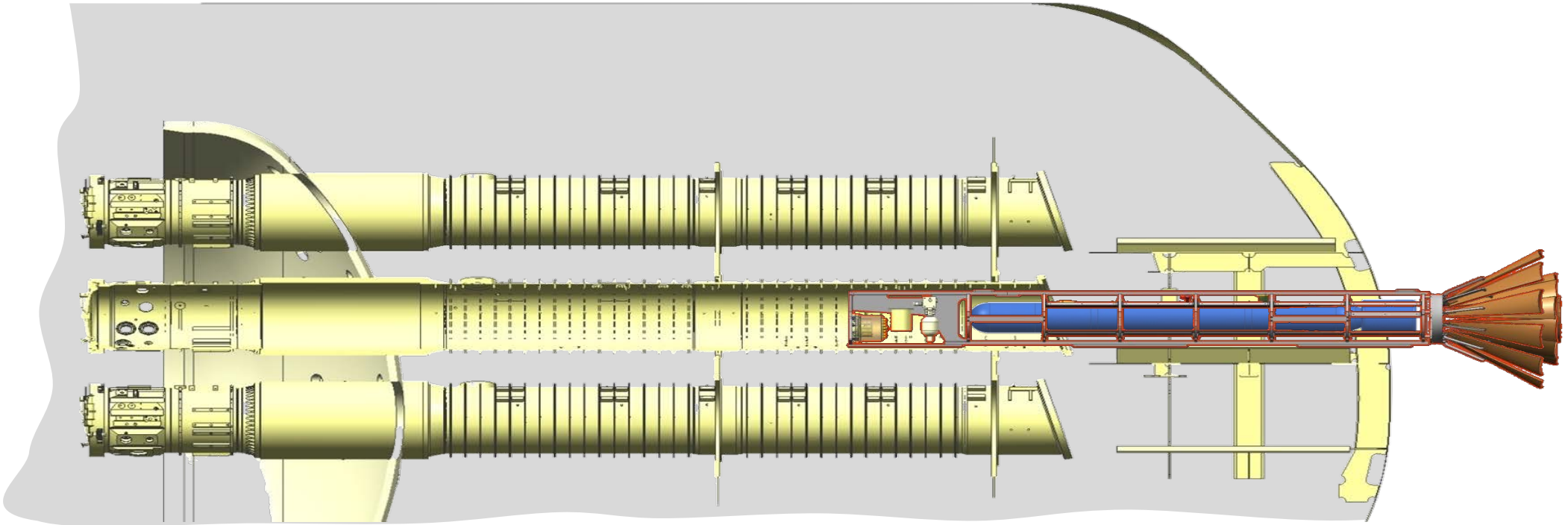
Launch & Recovery System for Weapon Tubes

- Horizontal movement in the weapon tube



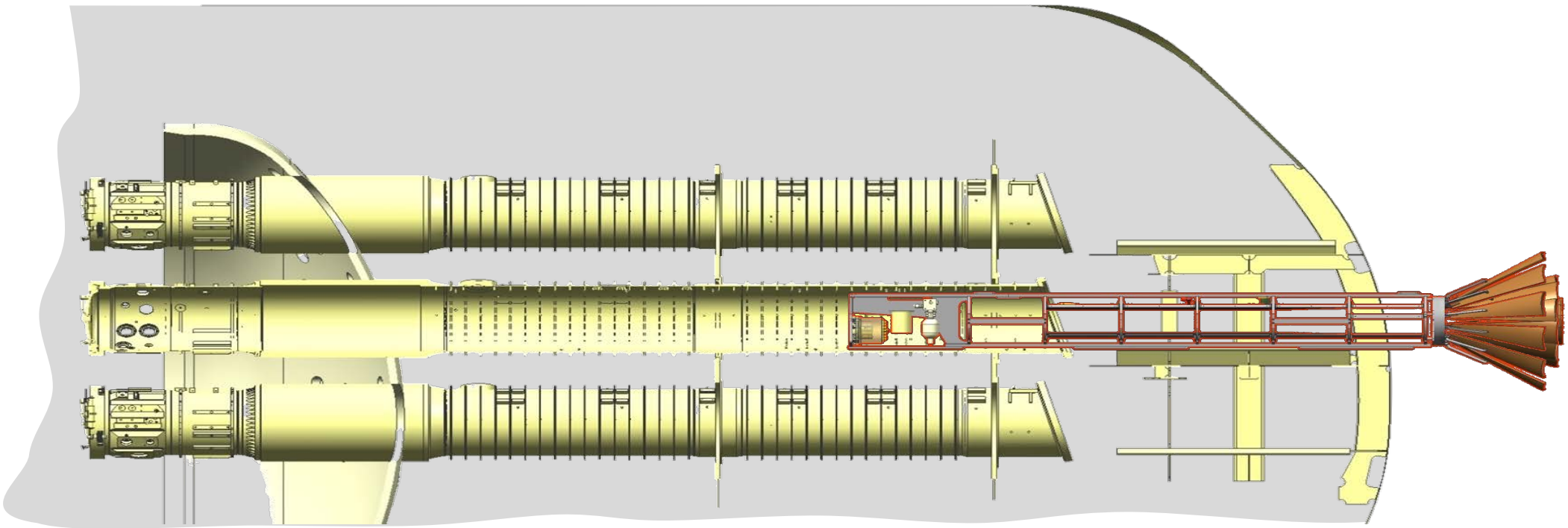
Launch & Recovery System for Weapon Tubes

- Launching of the AUV



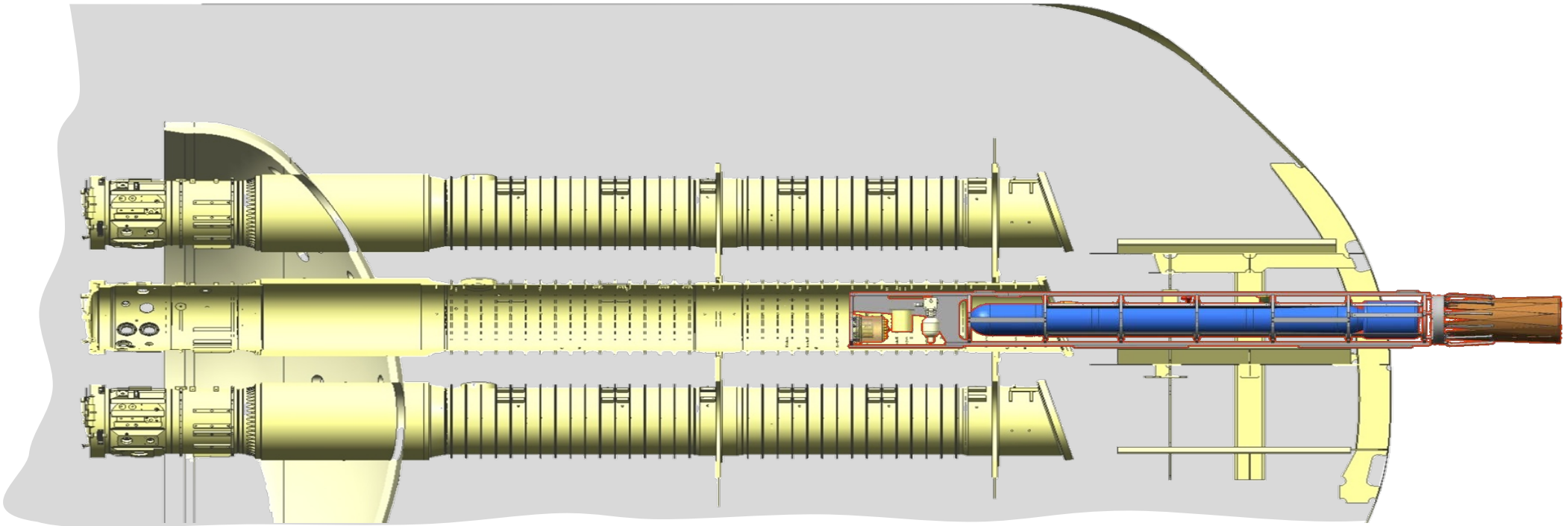
Launch & Recovery System for Weapon Tubes

- Recovery of the AUV



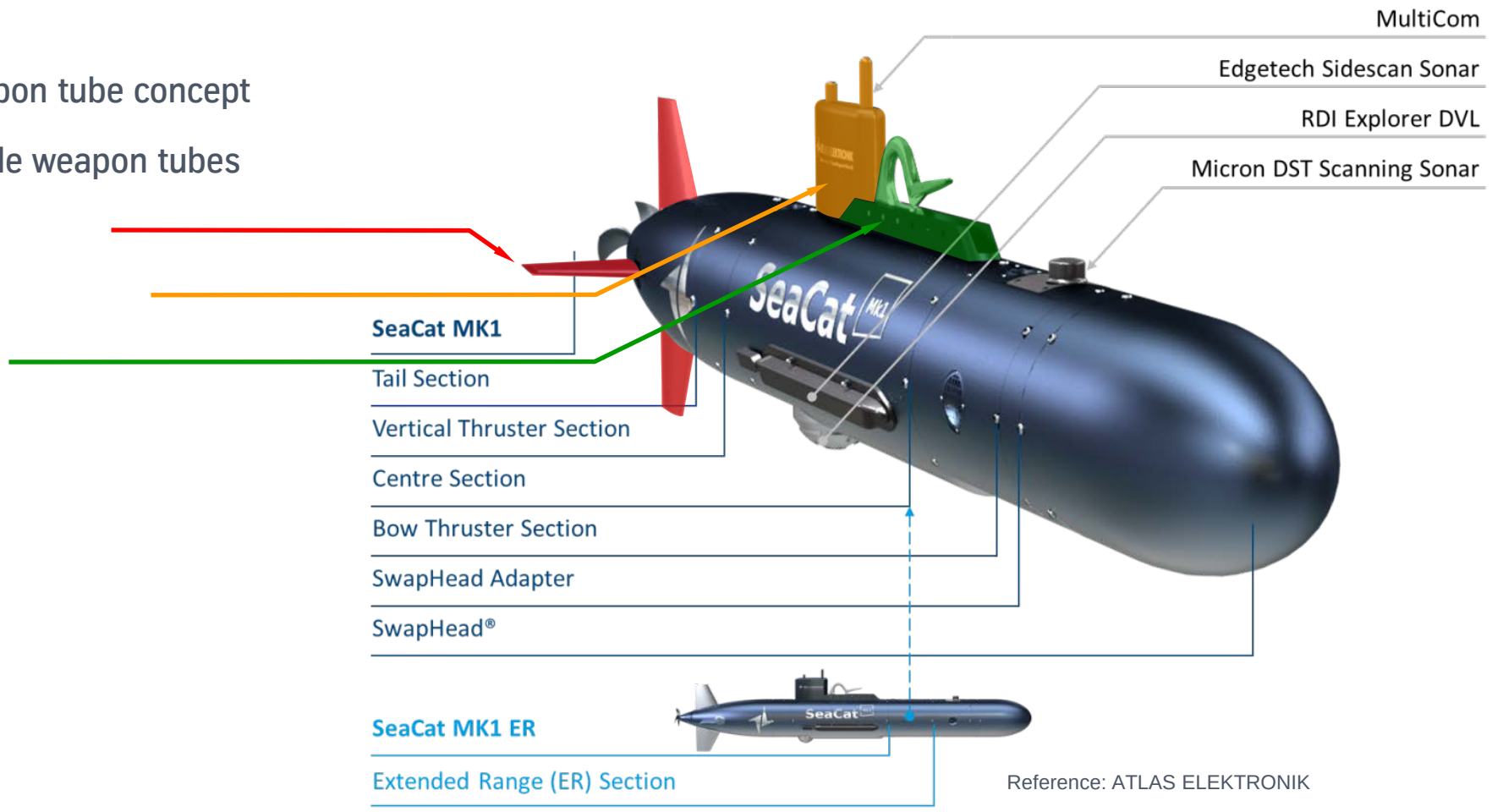
Launch & Recovery System for Weapon Tubes

– Retraction into the weapon tube.



SeaCat MKI (ATLAS ELEKTRONIK)

- Main dimension fit for weapon tube concept
  - Modification for use inside weapon tubes
    - Ruder dimensions
    - Sail and com antenna
    - Recovery hook



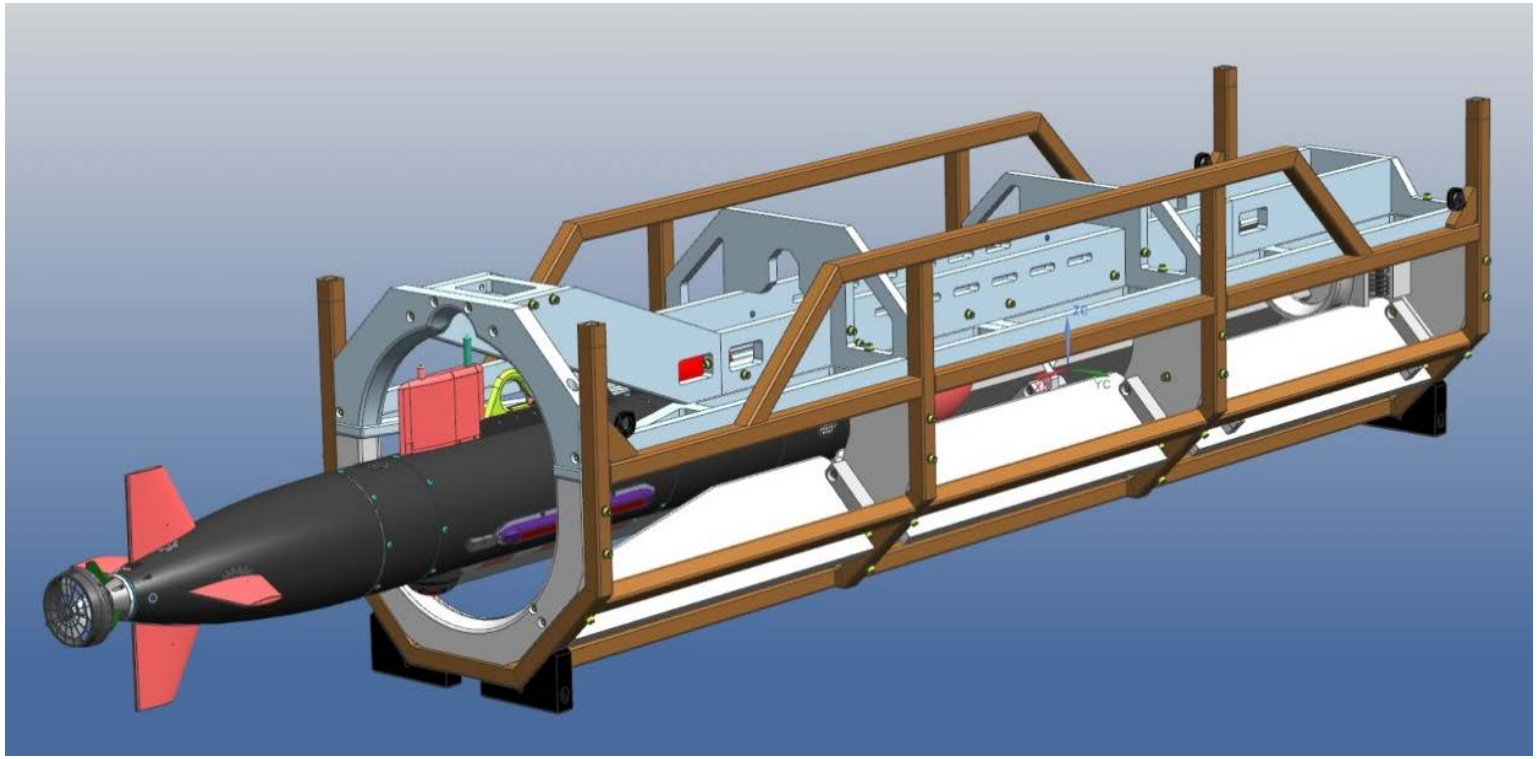
Reference: ATLAS ELEKTRONIK

Continuation with SeaCat MKI

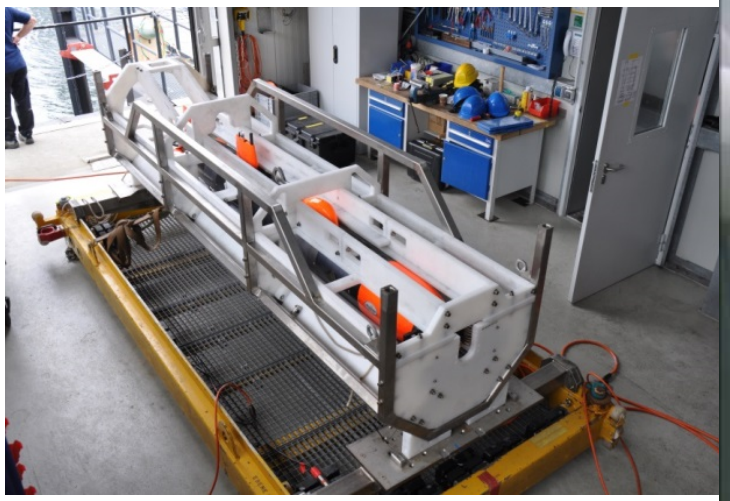
- Experience with launch & recovery procedure

- Next practical trials focusing
  - autonomous location
  - reacting on movements of submarine
  - data communication

- Interim launch & recovery device for SeaCat MKI



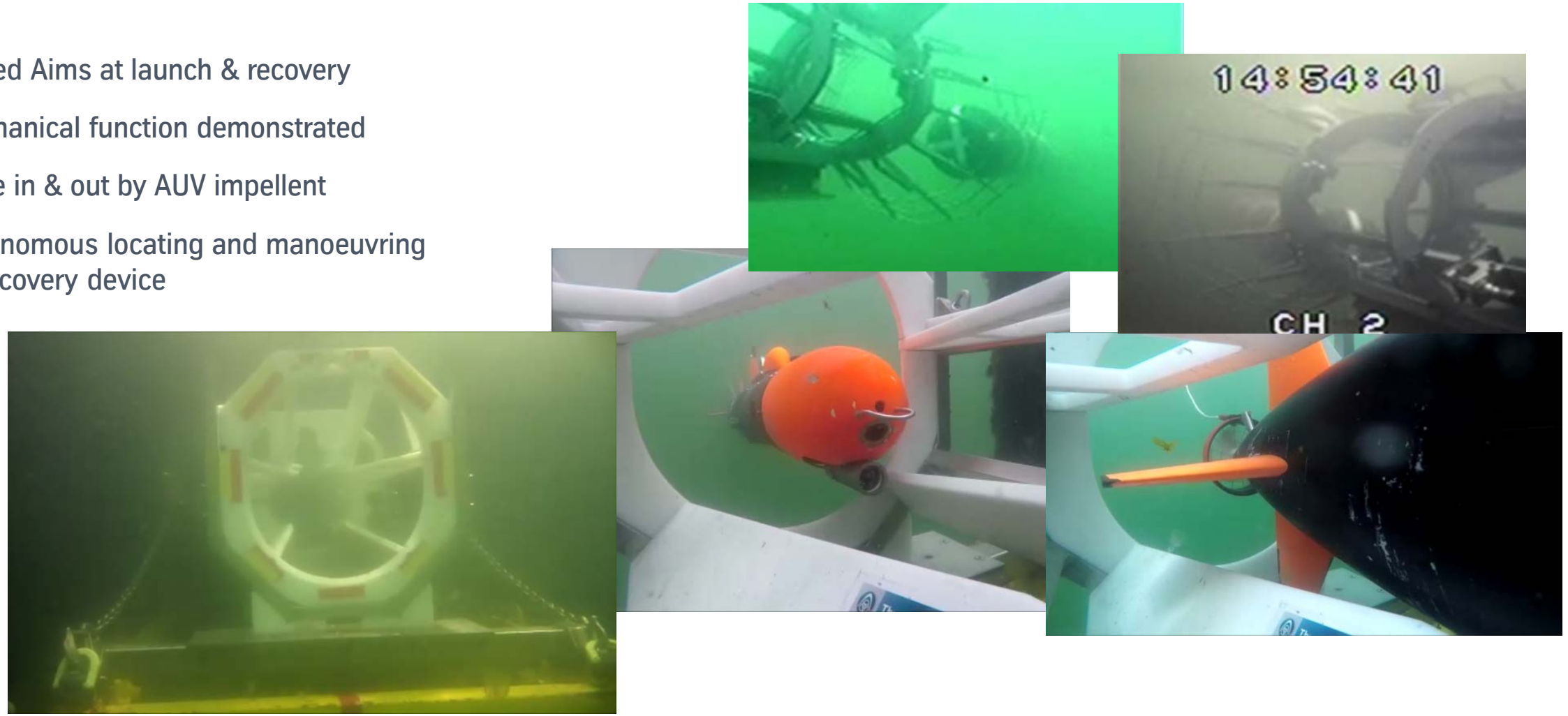
Latest Harbour Trials Summer 2015



- Autonomous locating…
- and docking of SeaCat MKI into interim launch & recovery device
- …and launching

Conclusion

- Reached Aims at launch & recovery
  - Mechanical function demonstrated
  - Drive in & out by AUV impellent
  - Autonomous locating and manoeuvring to recovery device

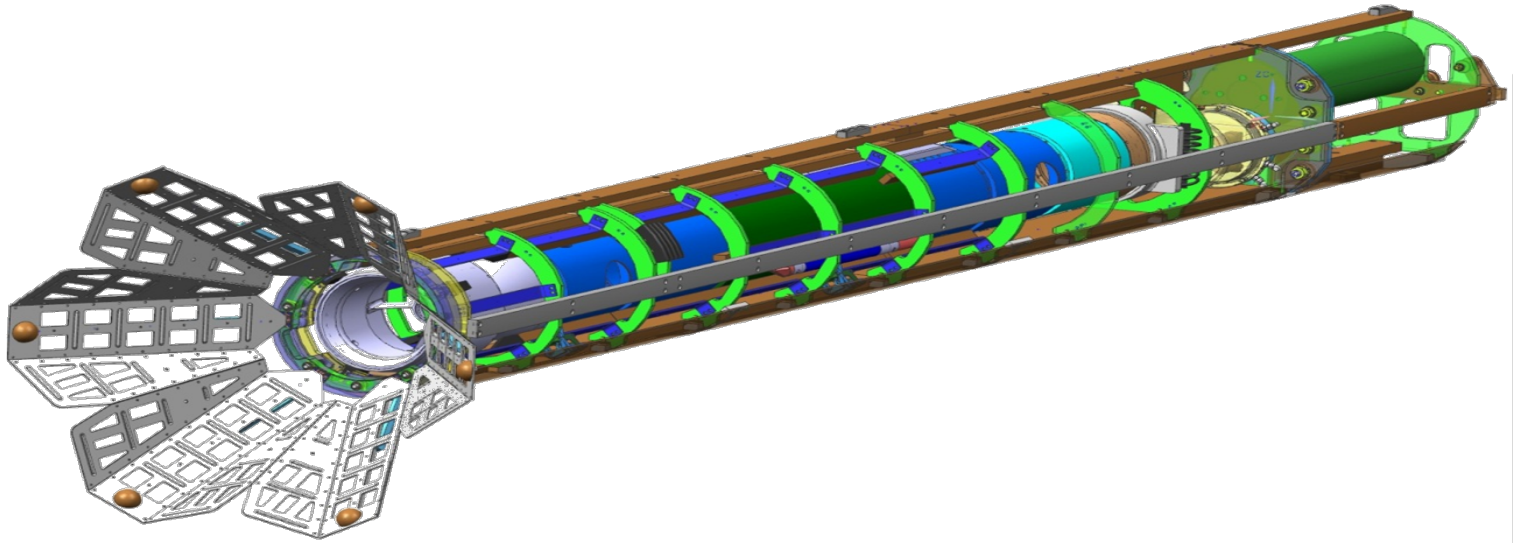


Results and Next Steps

- Functionality of the weapon tube L&R device was demonstrated at harbour trails

- Modification on our launch & recovery system for trials inside a weapon tube

- Changeover to the SeaCat System from ATLAS ELEKTRONIK .

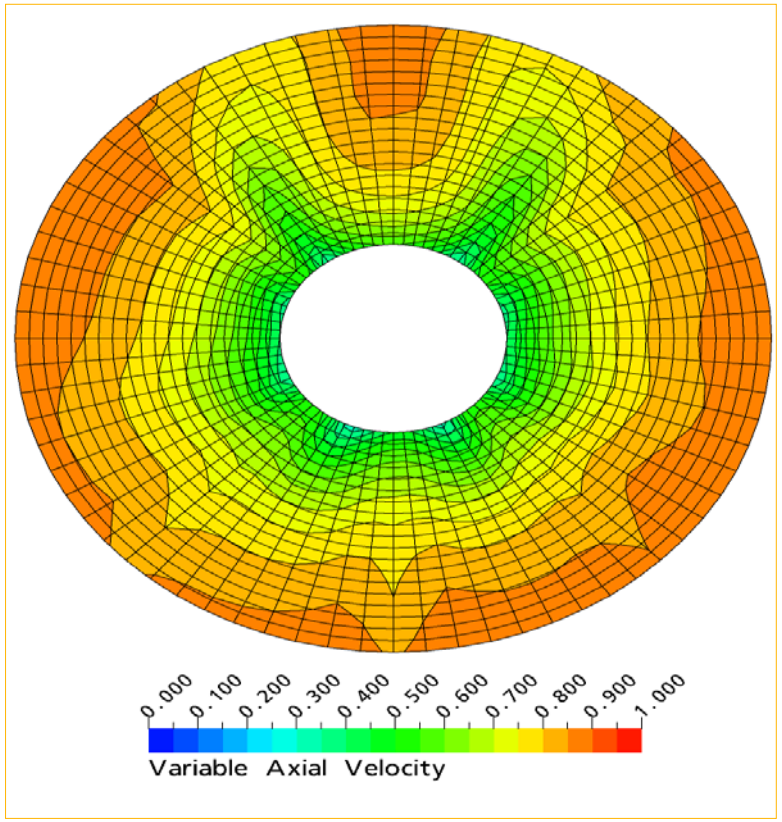


Reference: ATLAS ELEKTRONIK

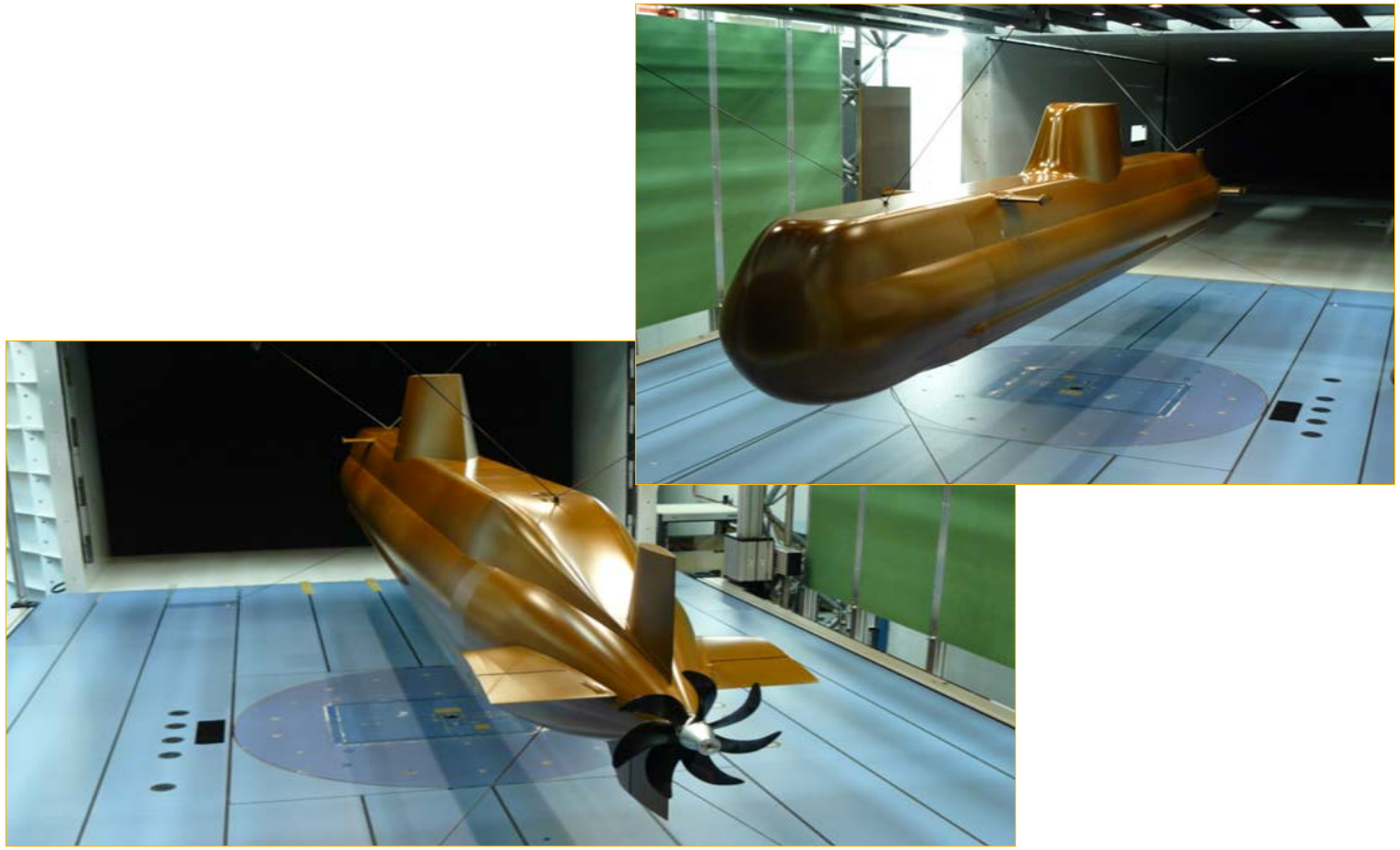
Propeller Design: Inhomogeneous Inflow to the Propeller

Simulations …

Slow
Boat speed

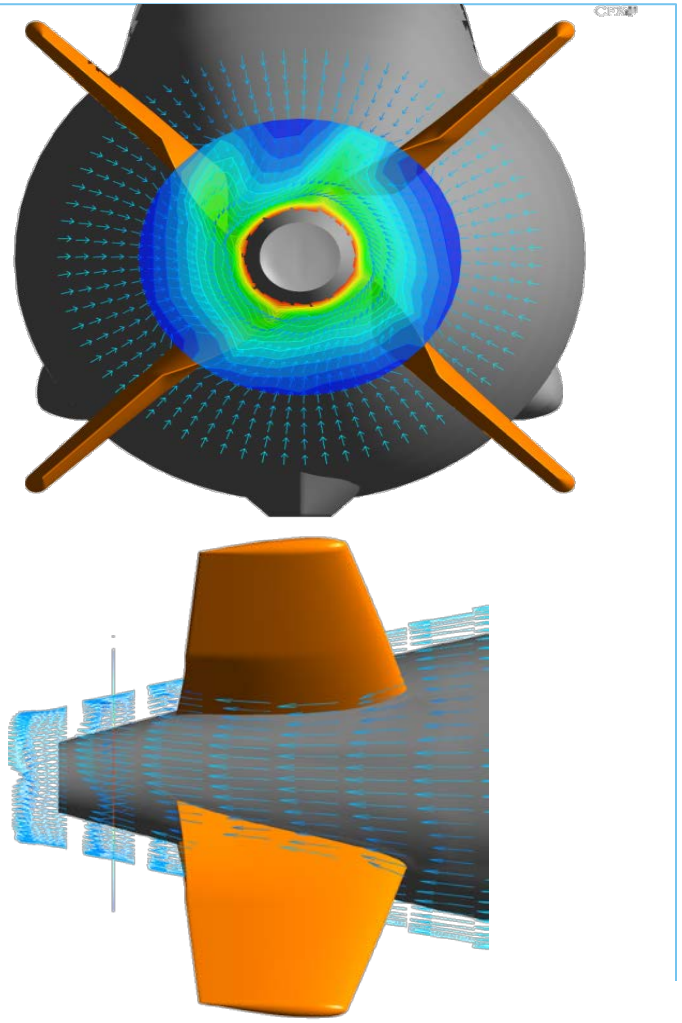


… verified by model tests

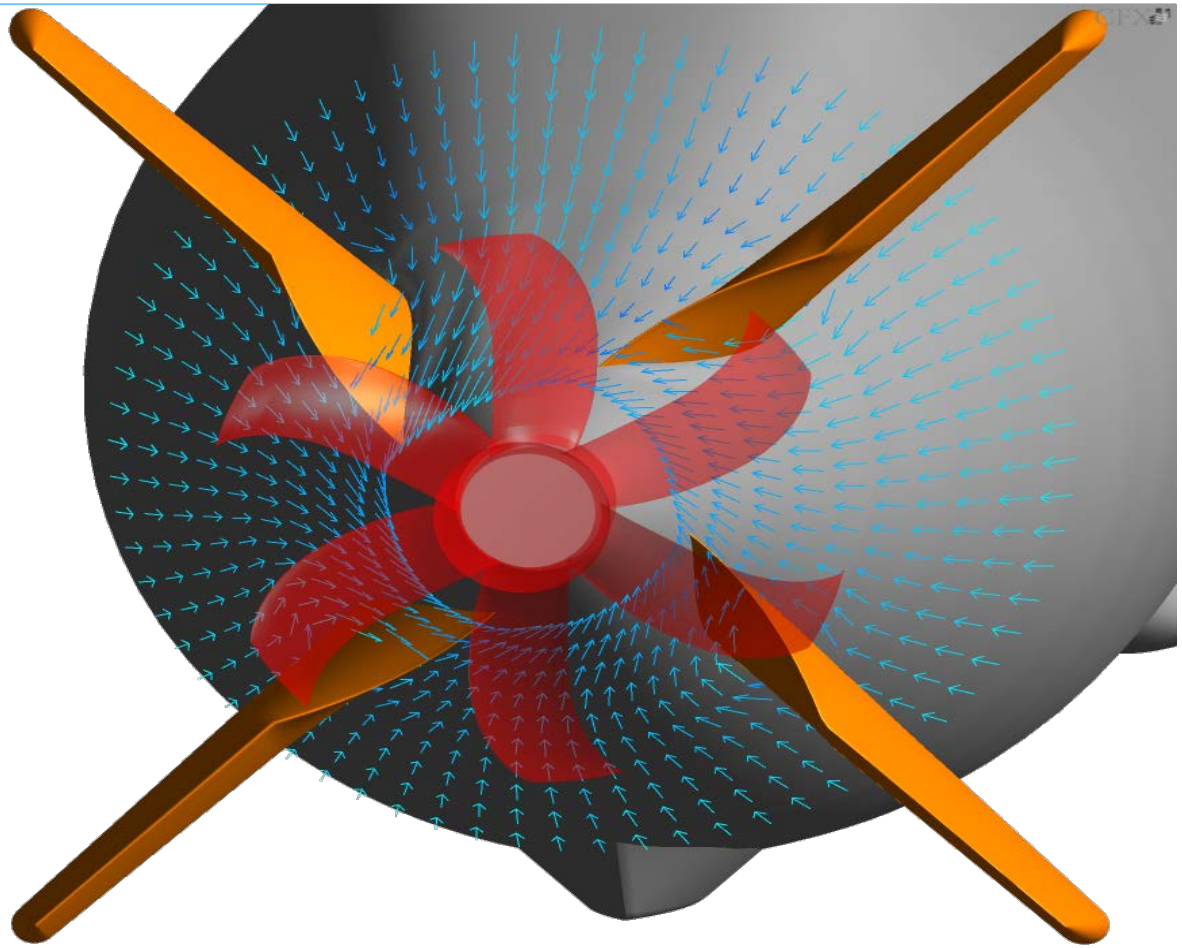


Pre-swirl Rudder

Front of the Propeller

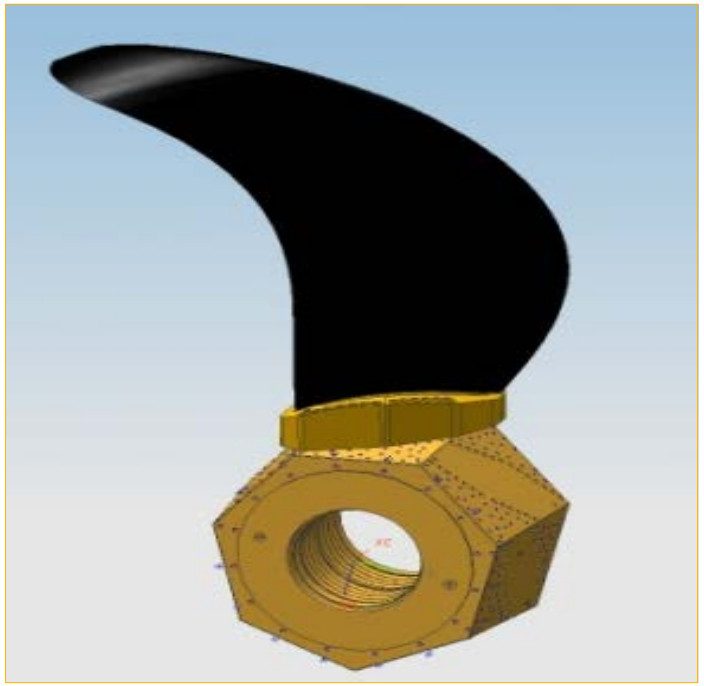


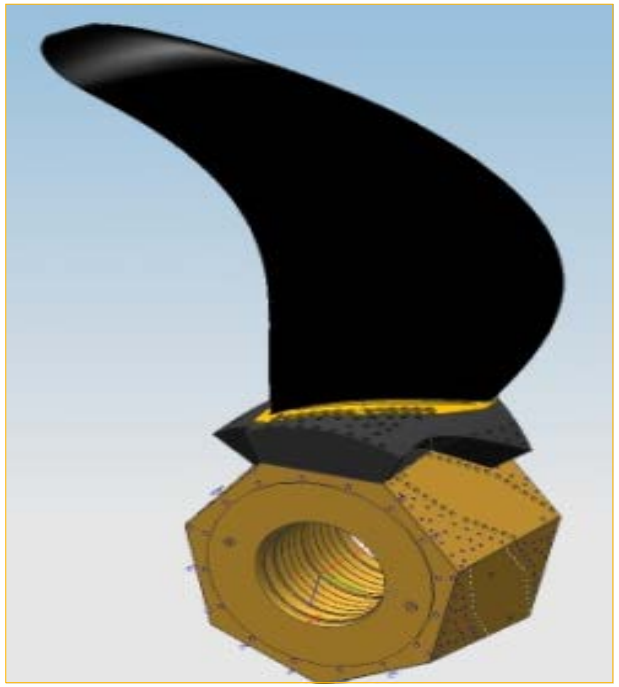
Behind the Propeller

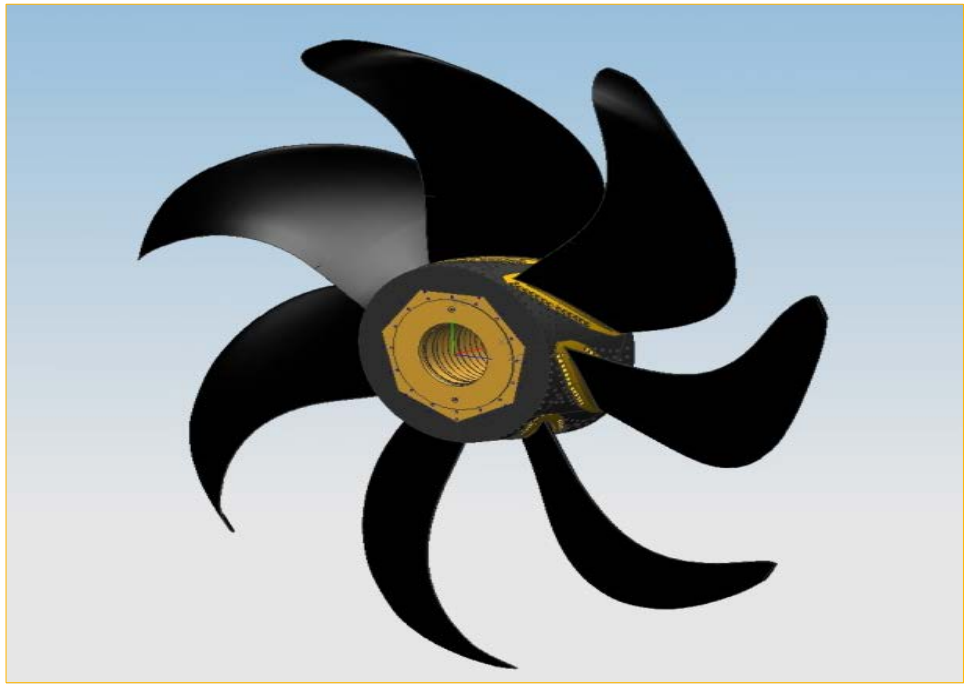


Composite Propeller - Design Principle

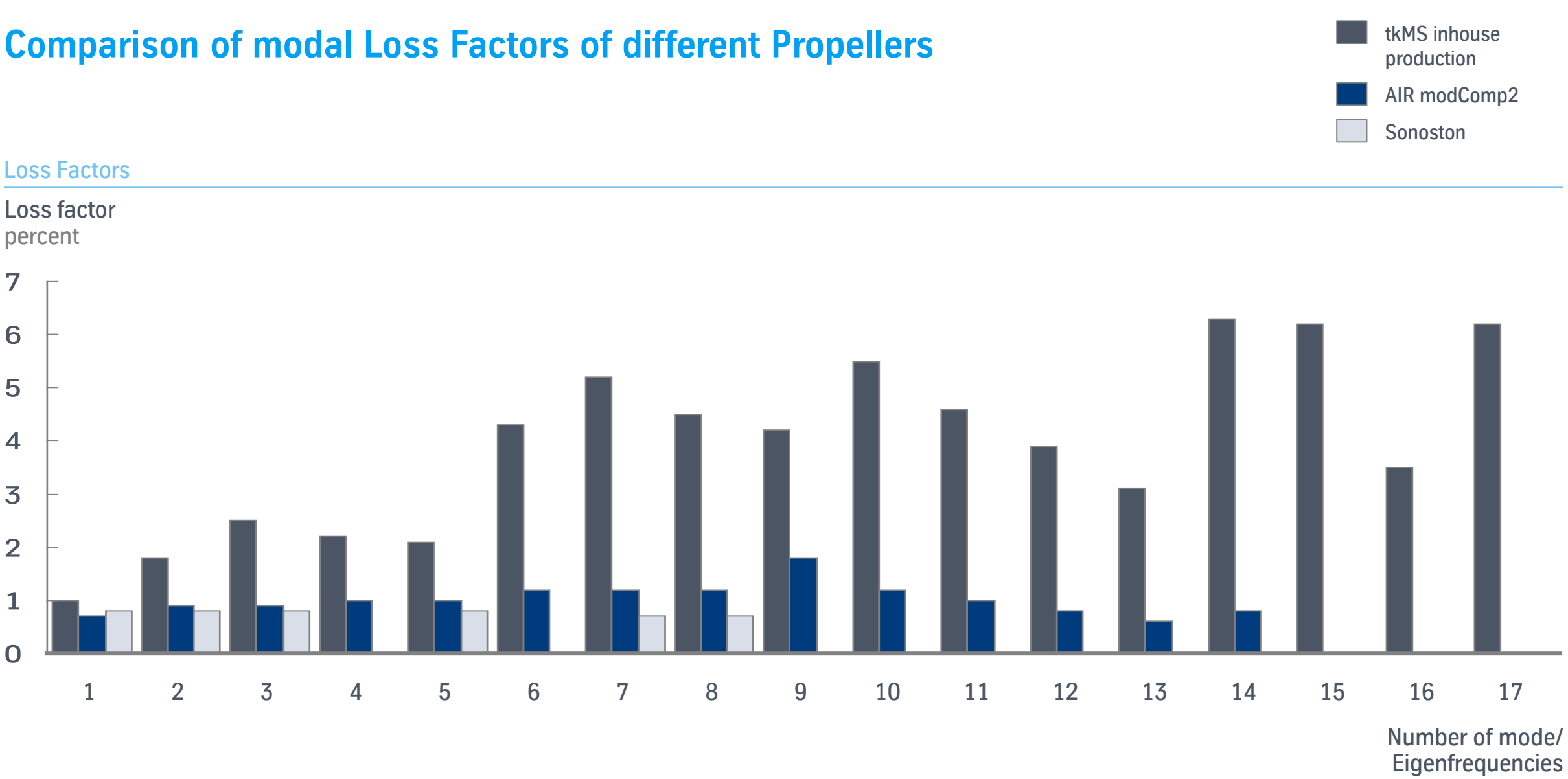
Blades individually screwed to the hub for ease of individual replacement



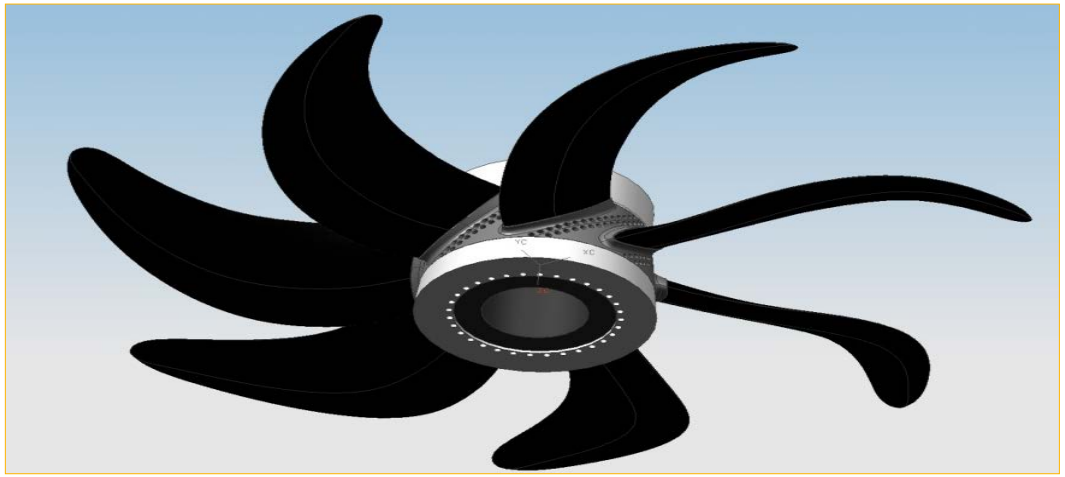




Comparison of modal Loss Factors of different Propellers



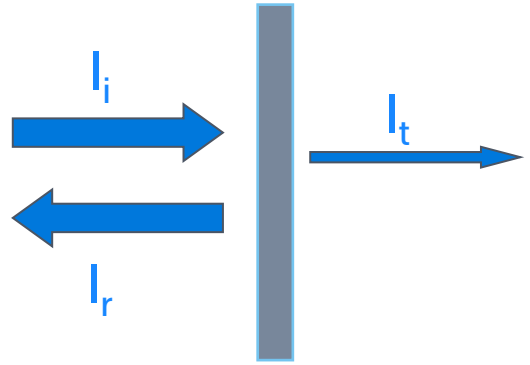
FRP Propeller



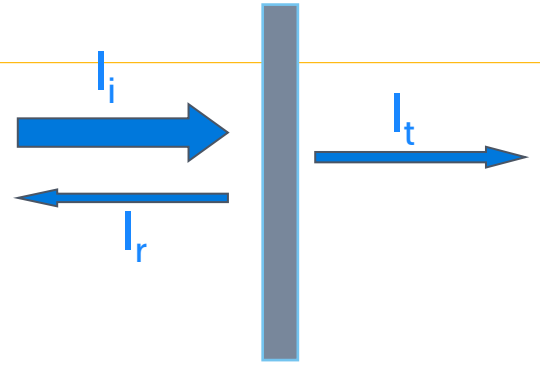
- Replaceable Blades
- Reduced Weight
- Improved Resilience
- Improved Shape and Manufacturing Precision
- Under Verification with German Navy

Acoustic Coating - Types

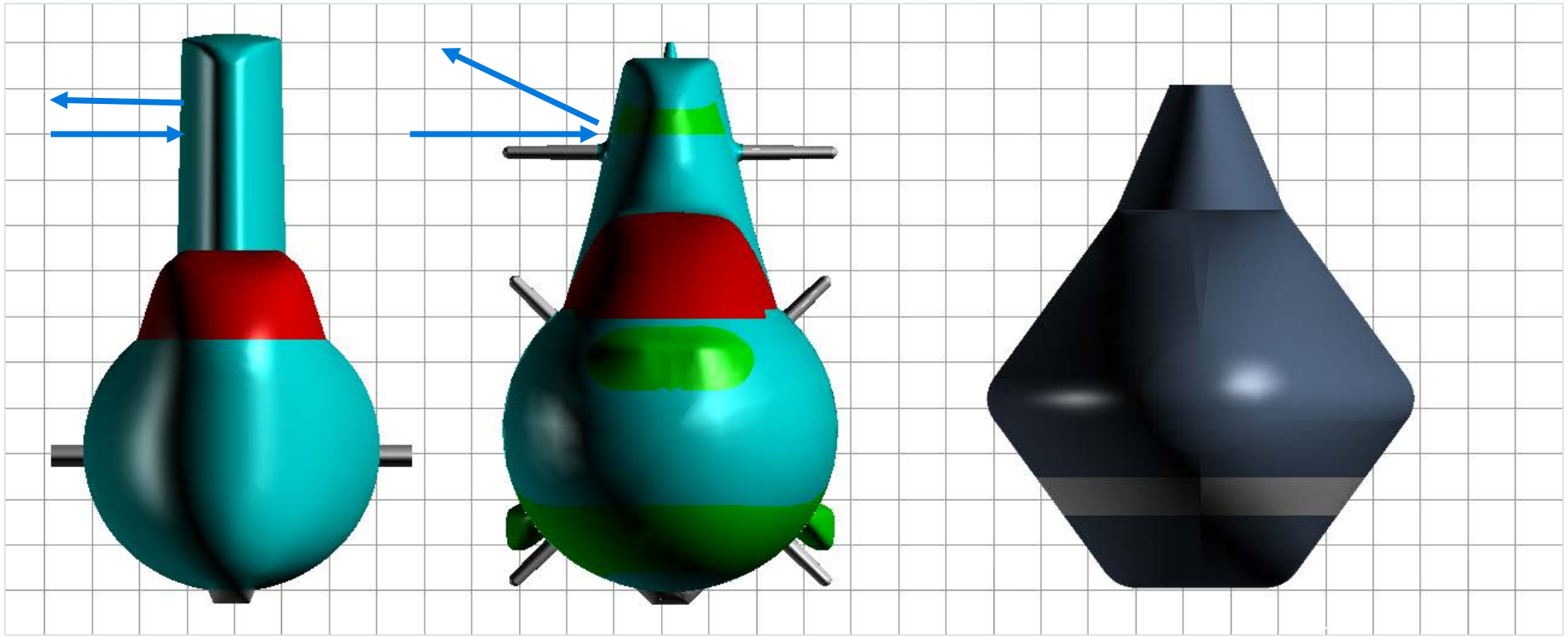
Transmission Loss Coating (TLC) (Minimized transmitted intensity):



Anechoic Coating (ANC) (Absorbing material):

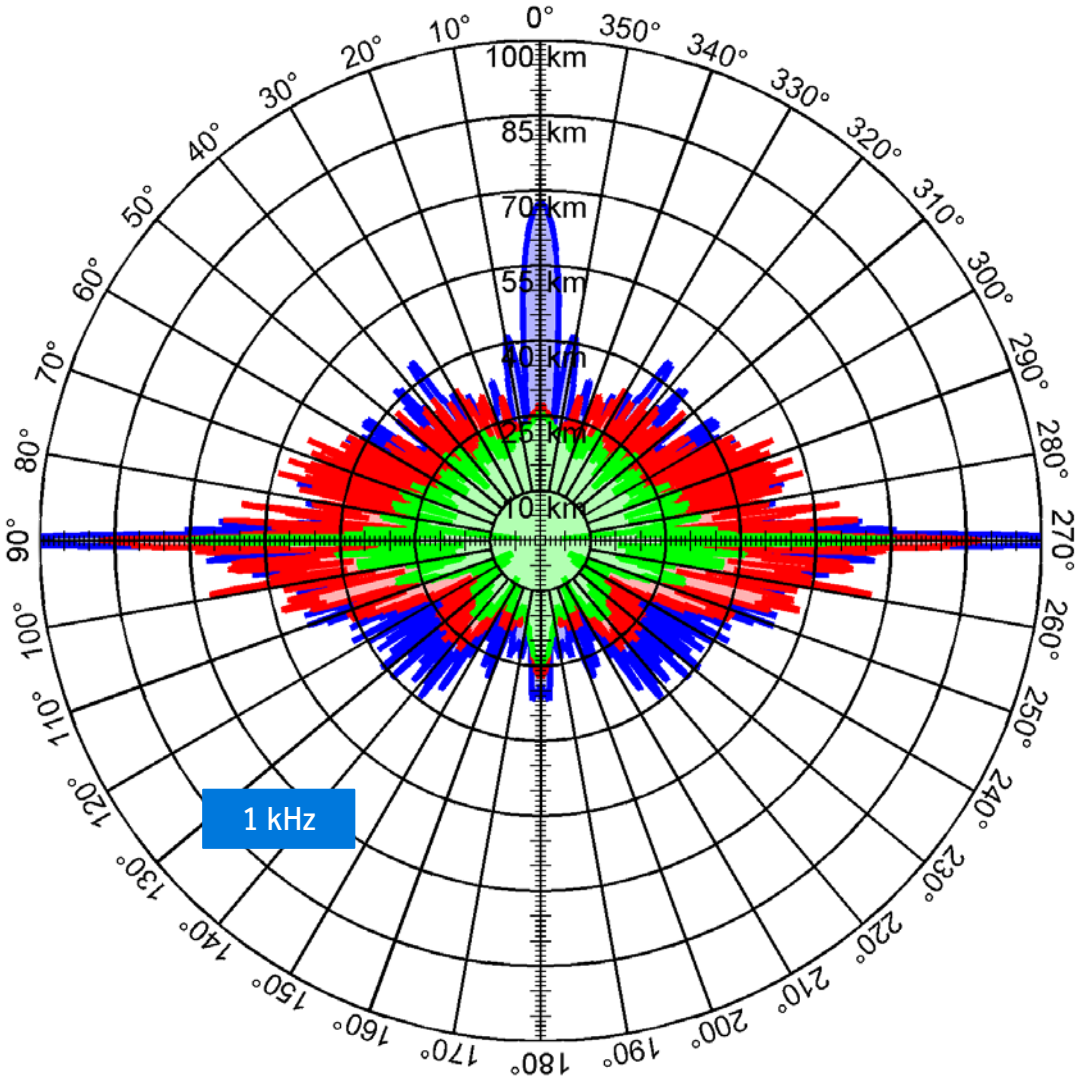


Acoustic Coating



Shaping designed to
achive low target echo strength values

Acoustic Coating - Detection Range: BeTSSi *) Comparison

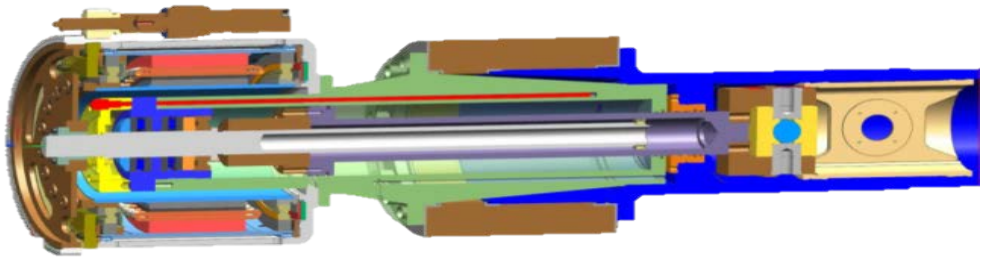


Sub	Detection Area
BeTSSi	3910 km²
BeTSSi Coated	3111 km²
BeTSSi Shaped	1472 km²

Sub	Detection Range
BeTSSi	121 km
BeTSSi Coated	88 km
BeTSSi Shaped	70 km

*) Standard submarine for TES simulations

Some more Examples



- Electrical rudder actuator
- UUV integration
- TCM Systems
- …