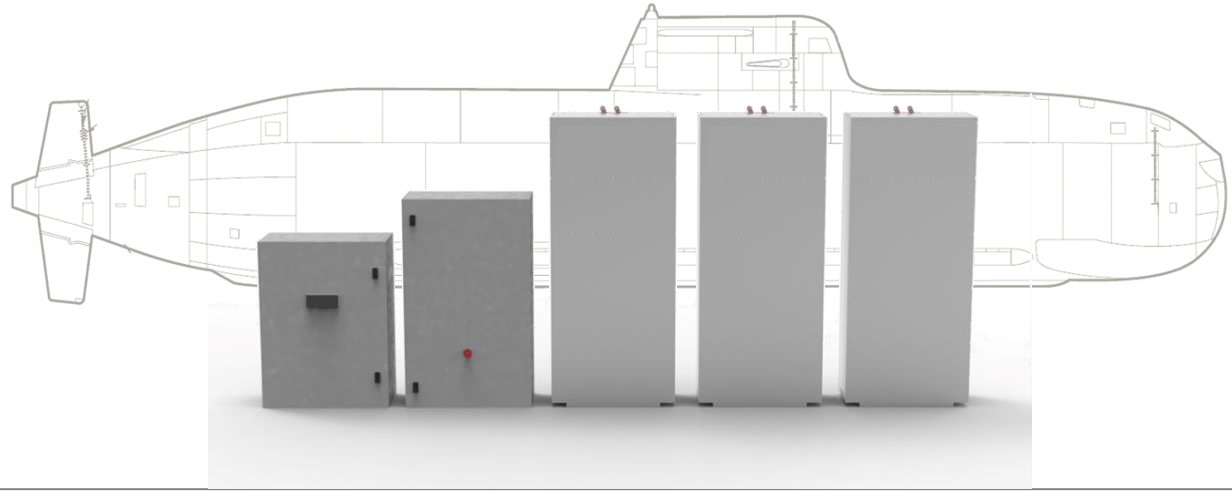
UDT
Undersea Defence Technology
13-15 May 2019
Stockholmsmässan, Sweden

LITHIUM-ION BATTERY SYSTEM FOR U212NFS



ITALIAN DIRECTORATE OF THE NAVAL ARMAMENTS
SUBMARINES SUPPORT DIVISION

AGENDA

- U212 NFS PROGRAM
- R&D BACKGROUND
- PROJECT DEVELOPMENT
- LITHIUM-ION BATTERIES COMPLEMENTARY USE

U212 NFS PROGRAM

- Unmatched superiority of U212A design in the underwater domain after a decade of operational activities WW

U212 NFS PROGRAM

FINCANTIERI
FINCANTIERI S.p.A.
DIVISIONE NAVI MILITARI

thyssenkrupp

ITN 1st batch

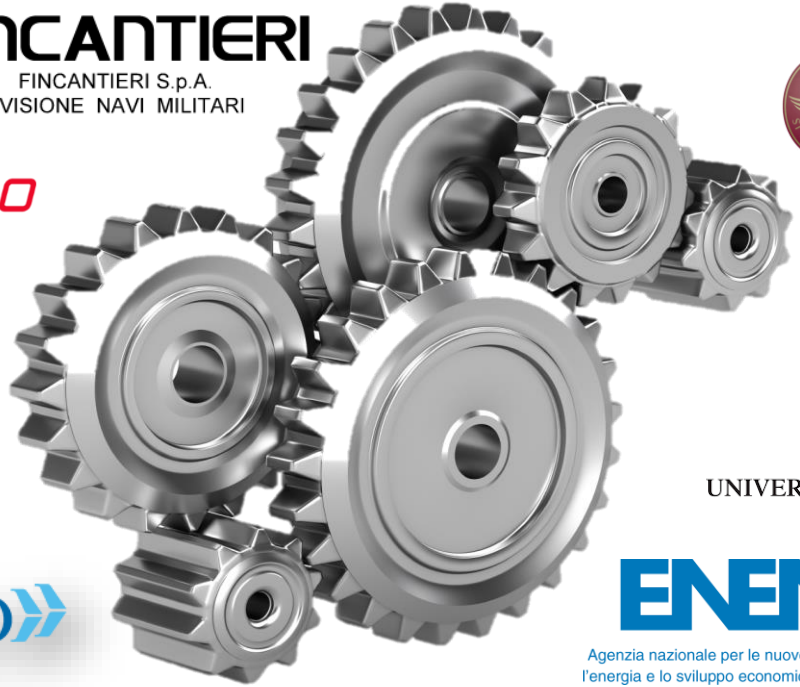
- Salvatore Todaro (06.2005)
- Sciré (02.2007)

ITN 2nd batch:

- Pietro Venuti (07.2016)
- Romeo Romei (05.2017)




U212 NFS PROGRAM



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LEONARDO

L3 CALZONI

FAAM

Avio Aero
A GE Aviation Business

SAPIENZA
UNIVERSITÀ DI ROMA

Consiglio Nazionale
delle Ricerche

UNIVERSITÀ DEGLI STUDI
DI GENOVA

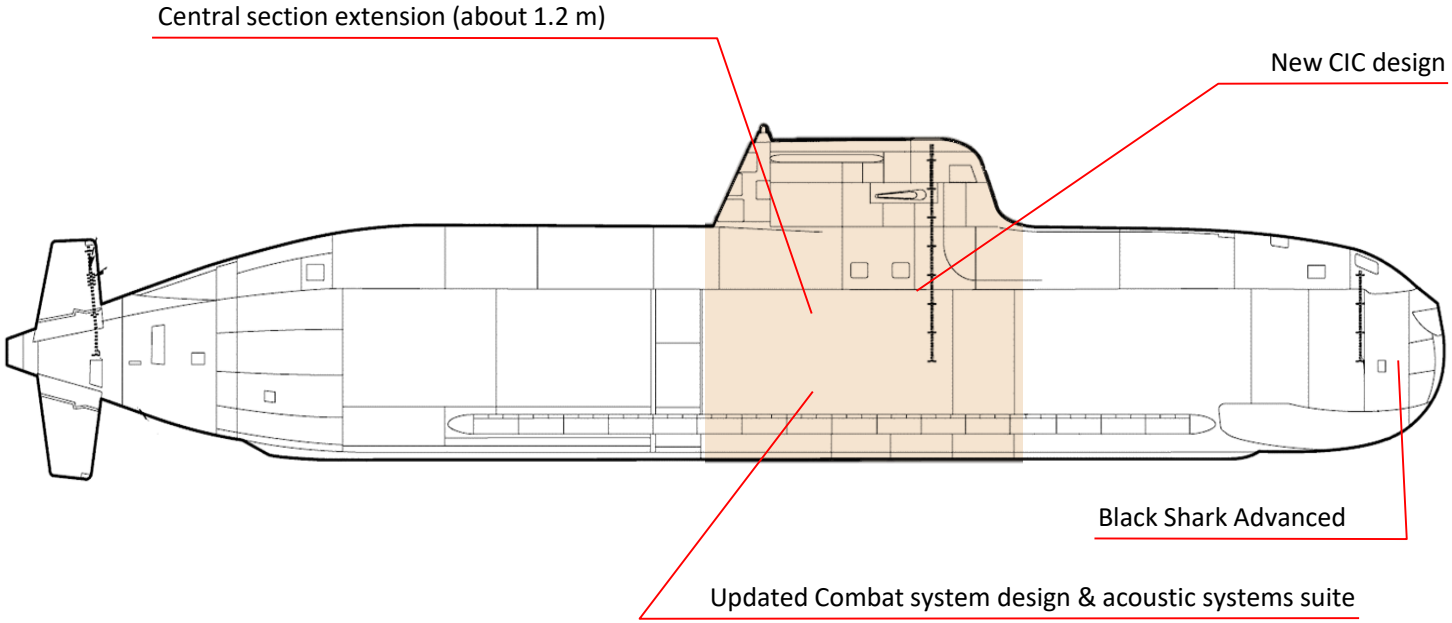
ENEA
Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

Si14

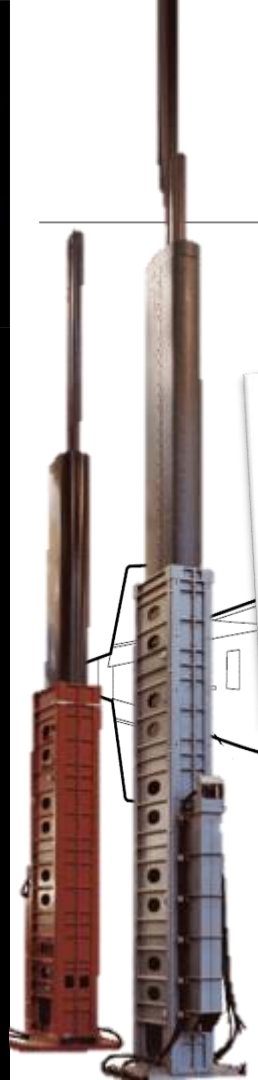
U212 NFS PROGRAM

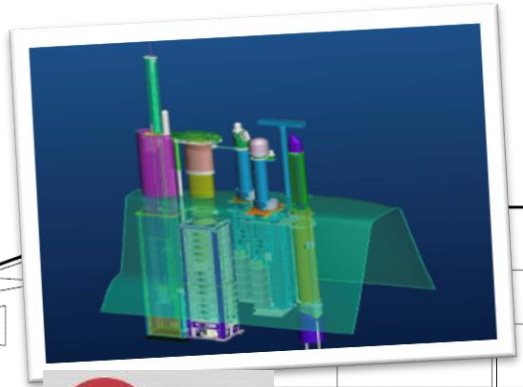
- 4 U212 NFS Submarines delivery in little more than a decade
- First 2 boats contract forwarded by July 2019
- Surgical improvements of latest technological findings on a U212A based design

U212 NFS PROGRAM



U212 NFS PROGRAM



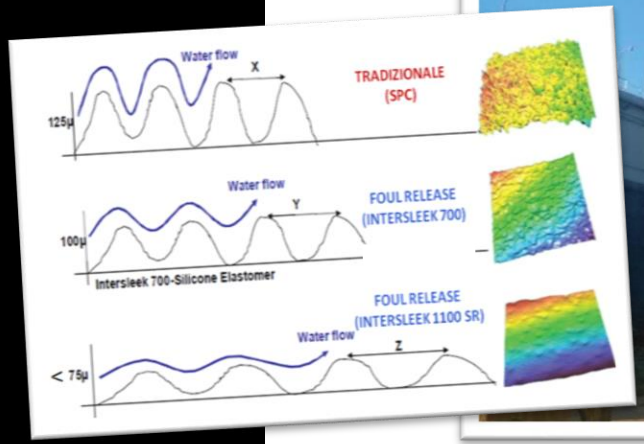


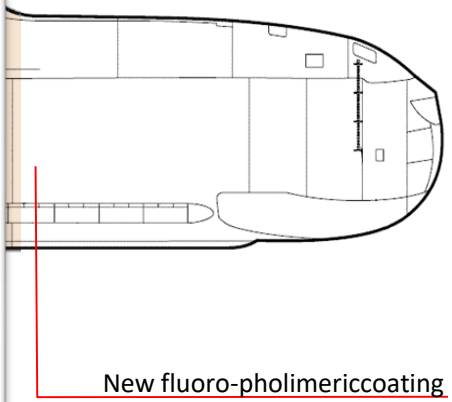
Electric masts

HEBD
(Hybrid Emergency Blowing Device)

U212 NFS PROGRAM

U212 NFS PROGRAM





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U212 NFS PROGRAM

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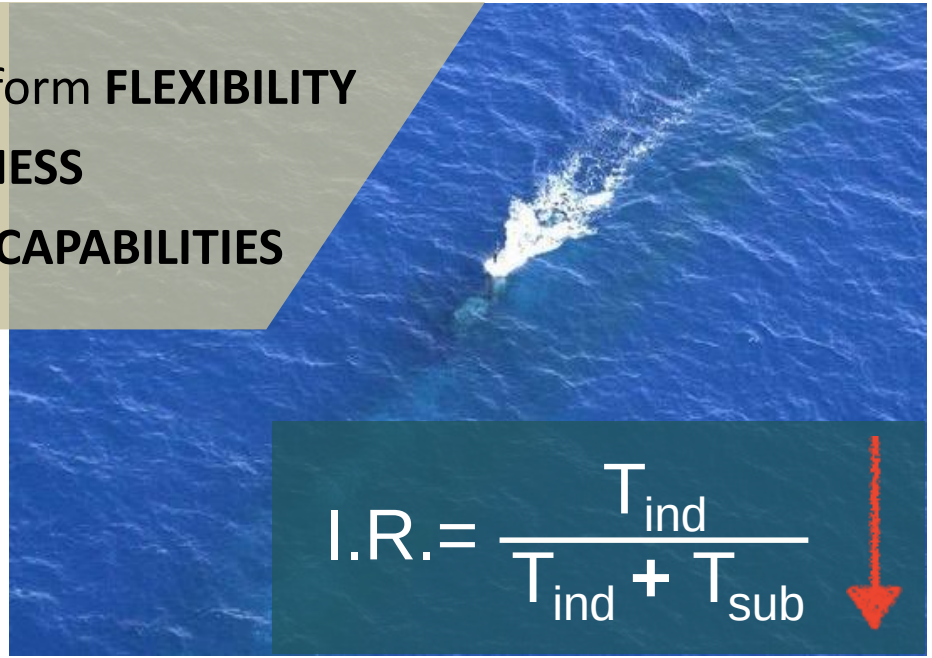
U212 NFS PROGRAM

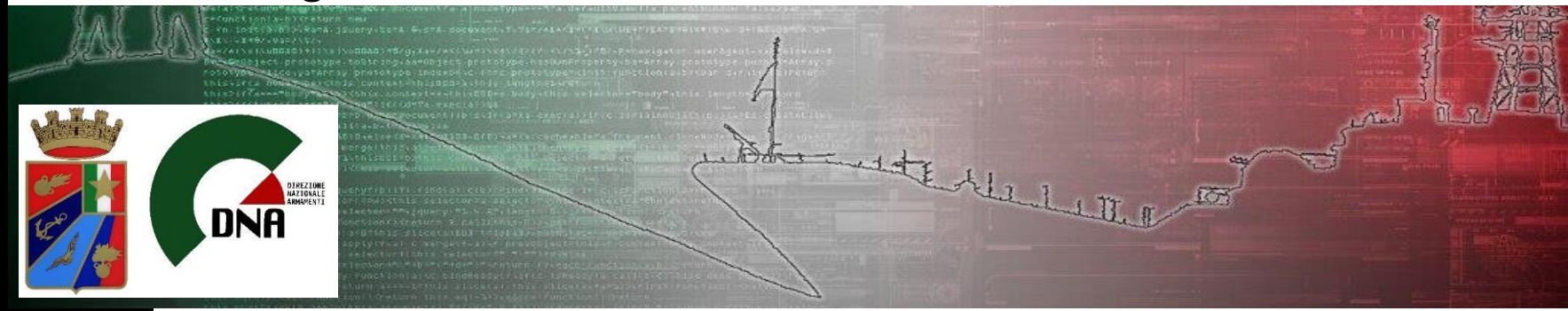
- Higher **ENDURANCE**/platform **FLEXIBILITY**
- State of the art **STEALTHNESS**
- Improved **OPERATIONAL CAPABILITIES**



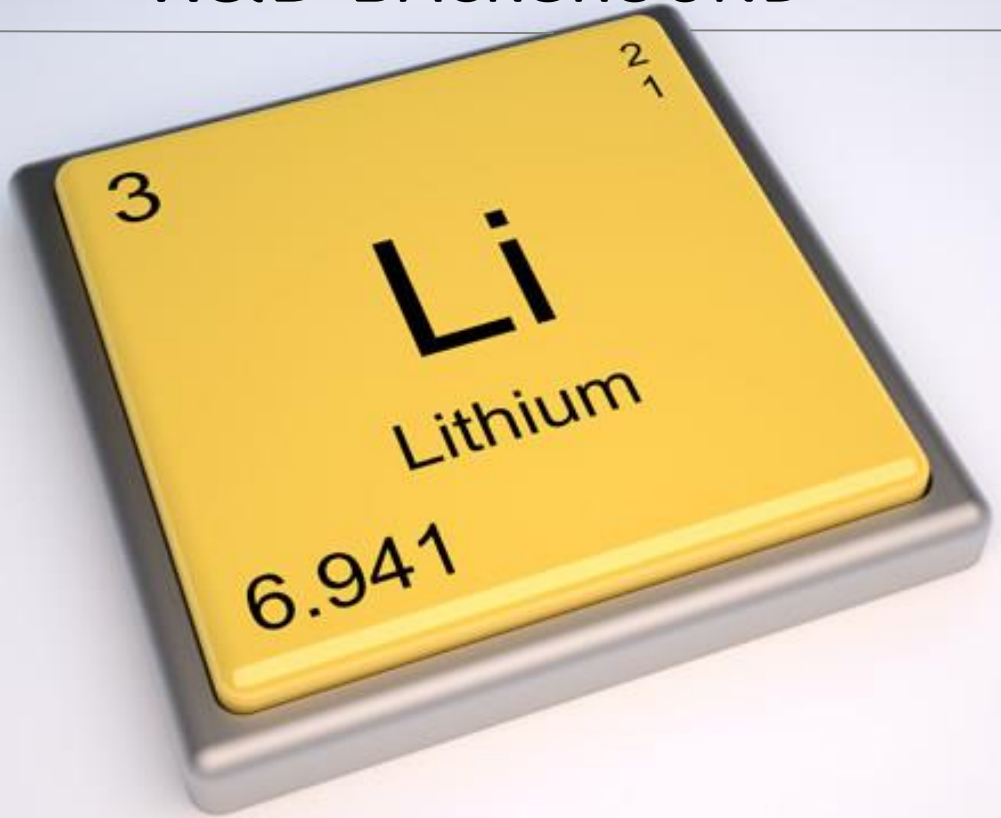
R&D BACKGROUND

PNRM 2009

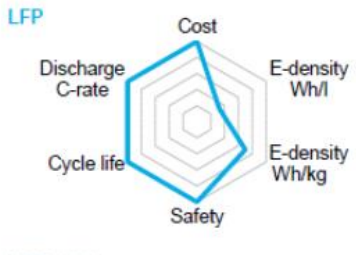
Cofunded R&D programme with the aim to investigate new technologies for increasing the endurance of AIP U212A Submarine



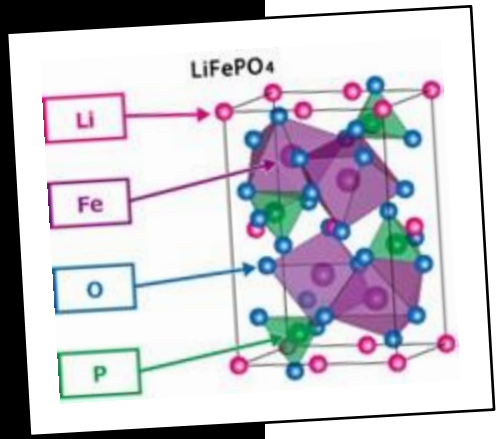
R&D Background



R&D BACKGROUND



- *low internal resistance and capacity basically independent from the load*
- *high energy density (≈ 220 Wh/l)*
- *high power density (≈ 6000 W/kg)*
- *working life reliability and maintainability*



- *working life reliability and maintainability*
- *excellent cycle stability*
- *design an efficient thermal management to maintain an overall temperature in the required temperature range*
- *develop a safety system allowing cell balancing, low charge time and full capacity all along the missions*
- *low material price*

R&D Background

Type		Voltage	Energy density	Energy density	Power density	Efficiency	Cycles	Life
		(V)	(Wh/kg)	(Wh/L)	(W/kg)	(%)	(N)	
Lead-acid		2.0	30-40	60-75	180	70%-85%	600-1500	5-12
Ni-cadmium		1.2	40-60	50-150	150	70%-90%	1500	5
NiMH		1.2	30-80	140-300	250-1000	66%	1000	5
Li-ion	LCO	3.6	160	270	1800	99 %	1200	5
	NCA	3,6	240	600	1000	98%	3000	15
	LMO	4,0	140	250	2000	98%	2000	10
	NMC	3.7	140-160	300	3000	98 %	5000	10
	LFP	3.25	100-140	220	6000	98 %	3000	10
	LTO	2.3	90	160	10000	95%	10000	20
V redox		1.41	25-35			65-75%	15000-300	15
Ni-NaCl		2,6						
NaS		2,7						

R&D Background

Type cell	Cylindrical – LiFePo4
Nominal Capacity	65 Ah
Nominal Voltage	3.2 V
Material of Shell	Aluminum
Weight	1510 ÷ 1520 g
Energy Density	139 Wh/Kg
Range Charge and Discharge	2.5 ÷ 3.65V
Voltage End Charge	3.65 V
Nominal Charge Current	33 A
Max Continuos Charge Current	66 A
Nominal Discharge Current	33 A
Max Continuos Discharge Current	132 A
Peak Discharge Current	198 A
Operative Temperature Charge	0 ÷ 45 °C
Operative Temperature Discharge	-20 ÷ 60 °C

Ø 63 x 225 [mm]

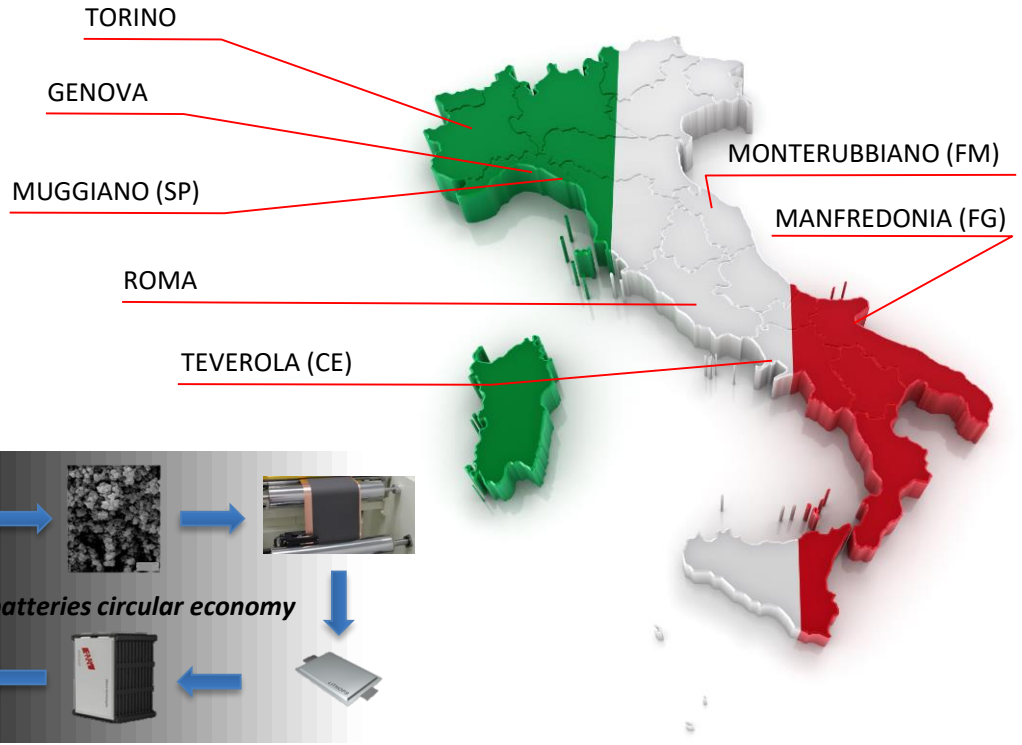
Electrodes conceived and designed by FAAM

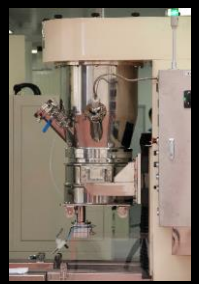
R&D BACKGROUND

FINCANTIERI
FINCANTIERI S.p.A.
DIVISIONE NAVI MILITARI

gruppo SERI
the dynamic company

FAAM





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PROJECT DEVELOPMENT

DIREZIONE DEGLI ARMAMENTI NAVALI
NAVARM

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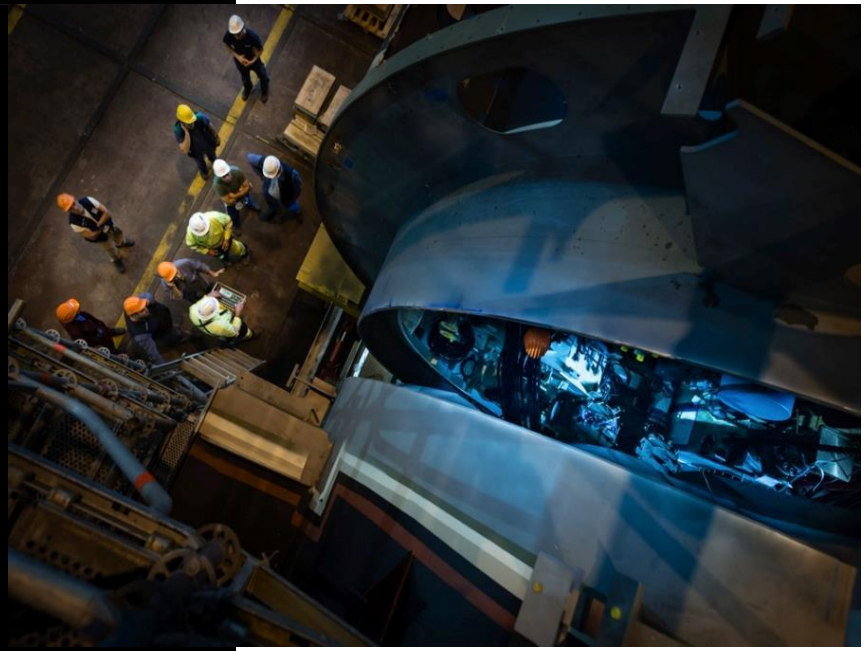
PROJECT DEVELOPMENT



Main Project Guidelines:

INCREASED ENDURANCE

but however…

- **SAFETY**
- RISK REDUCTION
- MANAGING RISKY EVENTS

and so…

- OPERATION IN CRITICAL CONDITIONS
- MAINTAINABILITY

PROJECT DEVELOPMENT

Activity	People involved (at CW 41/2018)	Firm/Classification/Body/Agency
Project management & planning	4	FINCANTIERI & FIB
	6	NAVARM & Navy General Staff
Risk assesment	3	CETENA/FINCANTIERI
• **Safety certification** • **Converter** • **Auxiliaries switchboards**	17	Sub-contractors
Electric calculation	7	FINCANTIERI & sub-contractors
Cell, String & HW/SW BMS development	10	FIB
Auxiliaries systems	8	FINCANTIERI & sub-contractors

PROJECT DEVELOPMENT

- RISK ANALYSIS
  (and system architecture detailed definition)
- BATTERY SYSTEM DYNAMIC SIMULATION
  (based on measurements on prototype cells)
- SHORT CIRCUIT MEASUREMENTS
  (direct and indirect)
- CELL & DC/DC CONVERTER TUNING
  (from above mentioned activities results)
- AUXILIARIES SYSTEMS TUNING
  (safety & control systems)

Lessons Learned

Equipment

- ELECTRICAL EQUIPMENT (4)
- EXHAUST FAN (4)
- BATTERY STORAGE CONTAINER (2)
- AIR-TIGHT SUBMERSIBLE BATTERY CASE (1)
- FIRE-EXTINGUISHING EQUIPMENT (1)
- MEASUREMENT / SENSING DEVICE (1)
- BATTERIES (10)

Show less

Probable Cause

- ABNORMAL OPERATIONS (1)
- DESIGN FLAW (1)
- EQUIPMENT FAILURE (1)

What is Lessons Learned?

Hydrogen Explosion in Battery Compartment of Dinner Cruise Boat

First responders were dispatched to the waterfront area to investigate a possible explosion on an 85-foot dinner cruise boat that was moored there. Upon arrival, the incident commander noted that nothing out of the ordinary was visible on the exterior of the boat. A crew was sent to the interior of the boat to investigate. The boat was powered by diesel engines and there were no compressed gas cylinders on board.

After further investigation, it became apparent that the explosion had come from the battery compartment in the hull of the boat. The responders concluded that one of the batteries had been giving off hydrogen gas, which gradually built up inside the compartment. Since the compartment was not vented, the gas had nowhere to go. It found an ignition source (possibly a view more

(since 2001)

Battery Compartment Fire on a Hybrid, Fuel-Cell-Powered Passenger Ship

During a test run of a hybrid, fuel-cell-powered passenger ship, the on-board lead-acid batteries overheated, resulting a fire in the battery compartment. The local fire department was able to quickly put the fire out.The batteries had been replaced a few days prior from the battery supplier and were in the process of being tested for the first time on the river.The batteries are charged slowly from the fuel cell and the power is made available for cast-off and driving maneuvers.It was systematically confirmed that the fire, which was comparable to a conventional cable fire, posed no risk to the fuel cells or the hydrogen storage tanks. There was never a danger to the captain or crew, and the fire department

SUBMIT AN INCIDENT

Latest Reports

- Pressure sensor diaphragm rupture on H2 compressor
- Hydrogen Alarm Activates in Processing Facility
- Temperature Excursion in Environmental Chamber Results in Small Fire
- Failure of Rotameter Causes LFL Analyzer Low Sample Flow
- Concern Identified Regarding Installation and Commissioning of Compressed Gas Systems

PROJECT DEVELOPMENT

Safety Integrity Level (SIL)
of Battery and Battery Management System (BMS)

- IEC 61508
  Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
- MIL Std 882E
  System Safety
- SG270-BV-SAF-010
  High-energy Storage System Safety Manual

PROJECT DEVELOPMENT

APPLICABLE RULES (MANDATORY)	
IEC 62619 (2017)	*Secondary cells and batteries containing alkaline or other non acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in industrial applications*
IEC 62620 (2016)	*Secondary cells and batteries containing alkaline or other non acid electrolytes - Secondary lithium cells and batteries for use in industrial applications*
IEC 61508 Series	*Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems*
DNV GL CG 0339	*Environmental test specification for electrical, electronic and programmable equipment and systems*
BV 2000-2	*Propulsion system for submarines*
BV 3000-2	*Electric system - Design and general guidance for submarines*
BV 3300	*Electric system – Switchgear and switching device for surface ships and submarines*
BV 3400	*Electric plants cable systems for surface ships and submarines*
VDE 0160	*Electronic equipment for use in electrical power installations and their assembly into electrical power installations*

PROJECT DEVELOPMENT

REFERENCE RULES (1/2)	
VG 95030	Configuration baseline - Identification and establishment of the configuration baseline
VG 95031	Modification of products
VG 96932-2	Rechargeable Lithium Batteries — Generic specification
BV 0052	Environmental conditions
BV 2000-2	Vessel movements
BV 3000-2	Electric system design and general guidance for submarine
BV 3100	Electric motors, power converter, transformer, for surface ship and submarines
BV 3300	Switchgear and switching device for surface ship and submarine
BV 3400	Electric plants cable systems for surface ship and submarine
BV 0120	Electromagnetic compatibility (EMC) for surface ship and submarine
BV 0240	Vibration Resistance - Experimental Verification; Measurements on Board
BV 0230 & 0430	Shock resistance – Test proof and calculation proof
BV 0440	Experimental and math proof measurements on board for surface ships and submarines

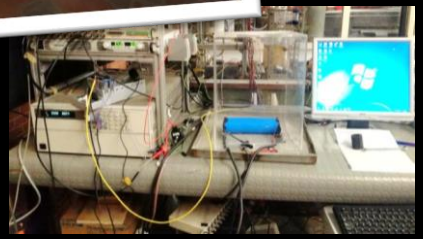
PROJECT DEVELOPMENT

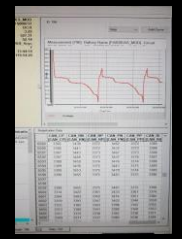
REFERENCE RULES (2/2)	
NAVSEA S9310-AQ-SAF-010	Technical manual for Navy Lithium Battery Safety Program responsibilities and procedures
NAVSEA SG270-BV-SAF-010	High-energy storage system safety manual
IEC 60092	Standard for electrical installations in ships and fixed/mobile marine applications
MIL PRF 32565	Performance specification: battery, rechargeable, sealed, 6t lithium-ion
MIL Std 882E	System Safety
MIL 461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipments
MIL 462	Test method standard for measurement of Electromagnetic Interference characteristics
SG270-BV-SAF-010	High-Energy Storage System Safety Manual

PROJECT DEVELOPMENT

TRL 5 Battery & BMS Prototype alreday running, after:

- CAPACITY TEST ON THE SINGLE CELL
- «SUBMARINE CYCLE» TEST ON THE SINGLE CELL
- EXTERNAL SHORT CIRCUIT TEST
- SHOCK TEST
- PERFORATION TEST
- COMBINED CAPACITY TEST ON THE SINGLE CELL



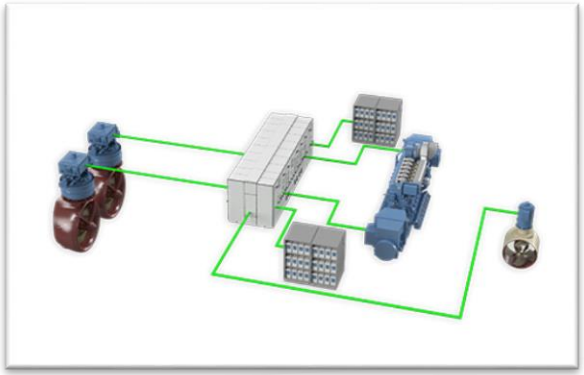


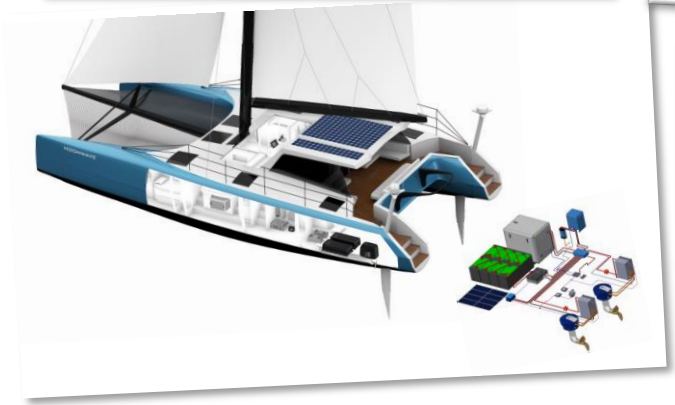
PROJECT DEVELOPMENT

true trials are always the best...

2025÷26

LION BATTERIES COMPLEMENTARY USE





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