TOTAL BATTERY POWERED SUBMARINE DESIGN, A NEW WAY OF THINKING

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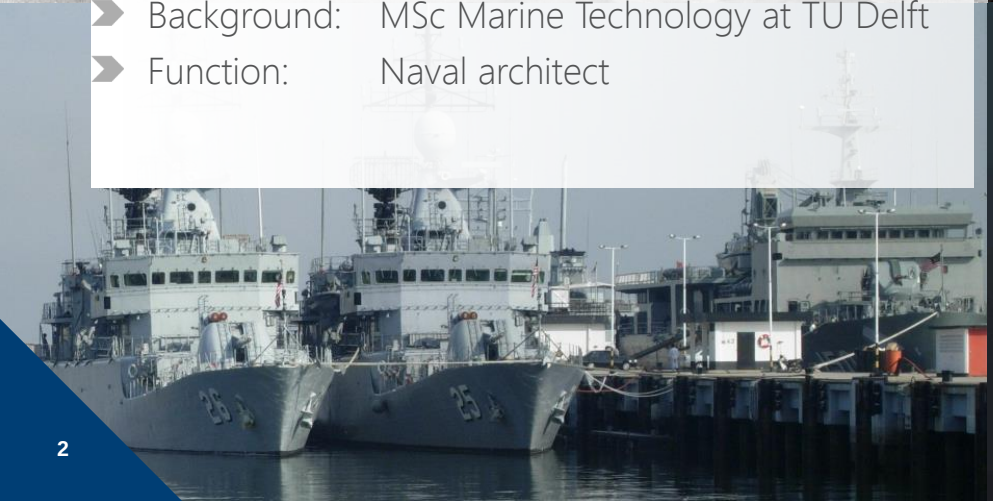
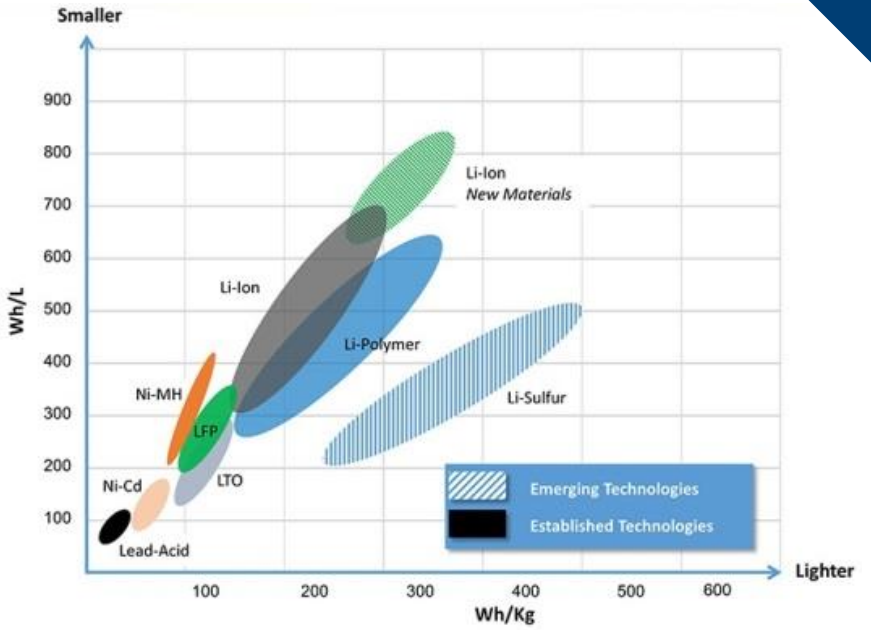


CONTENT

- Introduction
- Potential benefits of total battery powered submarines
- Identified design challenges
- Feasibility study
- Market potentials
- Conclusion

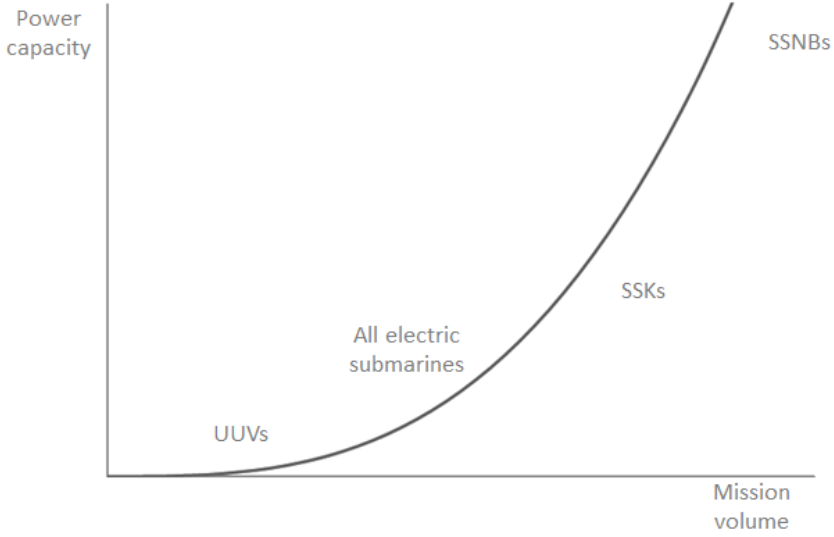
INTRODUCTION

- Past decades; enormous developments in battery technology
- Research into battery technology still ongoing
- New battery technology has a high potential for the undersea defense industry



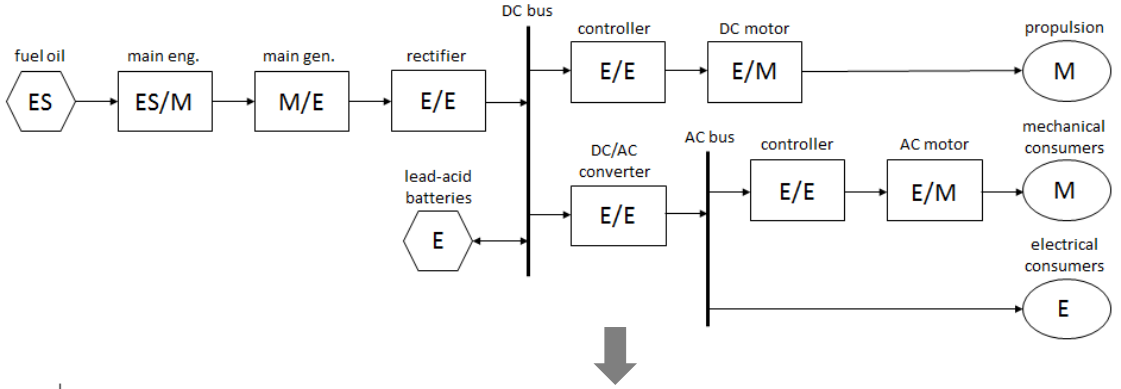
INTRODUCTION

- Improved battery technology led to a revolution in the civil electric vehicle industry and is upcoming in civil shipping industry
- Use of total battery powered vessels in the undersea defense industry limited to UUVs and small manned vehicles
- Improved battery technology is expected to make total battery powered submarines feasible

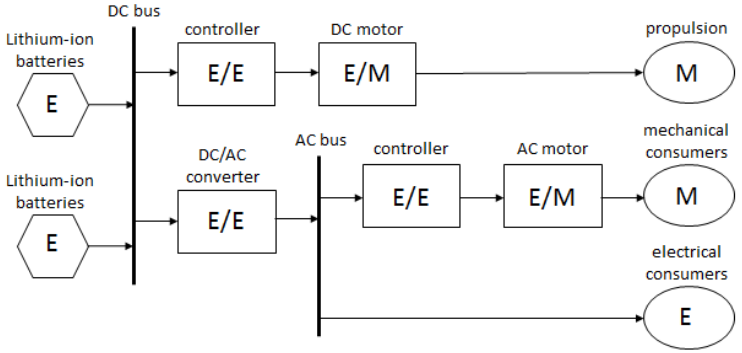


INTRODUCTION

- Diesel electric:



- Total battery powered:



Legend

ES	Energy Source
E	Electric Energy
M	Mechanical Energy
⬡	Source
⬭	Consumer
▭	Transformation

POTENTIAL BENEFITS OF TOTAL BATTERY POWERED SUBMARINES

Tactical advantages

- Air independent propulsion system
- Reduction in signature
  - Thermal
  - Acoustic
  - Visual
  - Radar cross section
- Safety characteristics
  - Lithium battery vs lead acid batteries
  - Less hot machine parts (no combustion engines), which will reduce the risks of fire
  - Less pressure hull penetrations

POTENTIAL BENEFITS OF TOTAL BATTERY POWERED SUBMARINES

Reduction of complexity

- Decrease in amount of systems
  - Decrease of design complexity
  - Reduction in maintenance
  - Reduced workload for submarine crew
  - Improvement in availability and reliability
- Simplification of systems
- Potential for crew size reduction and automatization
  - Simplification of control propulsion plant
  - Simplification of control underwater systems
  - Reduction in required corrective and preventive maintenance

Overview achievable system reduction due to omission of DG-sets
Diesel engines
Generators
Lubrication oil system diesel engines
Fresh water cooling system diesel engines
Seawater cooling system diesel engines
Diesel engine start – stop system
Air intake system
Exhaust gas system
Fuel oil injection system
Fuel oil service and conditioning system
Fuel oil transfer and compensation system

IDENTIFIED DESIGN CHALLENGES

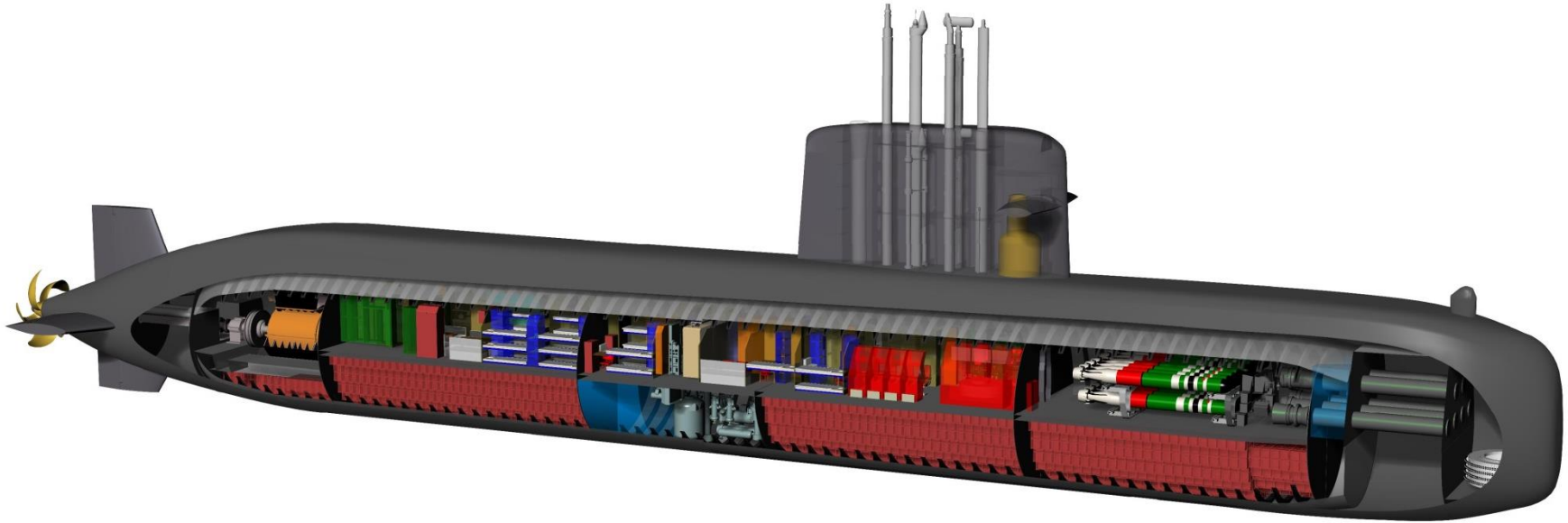
- Density lithium batteries
- Impact on platform design philosophies
- Safety aspects of battery integration
- Air quality control for prolonged submerged periods
- The loss of selfcharging capacity will make powerconsumption management a critical success factor

FEASIBILITY STUDY
Research goal and approach

- Research goal;
  - Determining the feasibility of an entirely battery powered submarine design based on available technology
  - Determining the limiting design factors

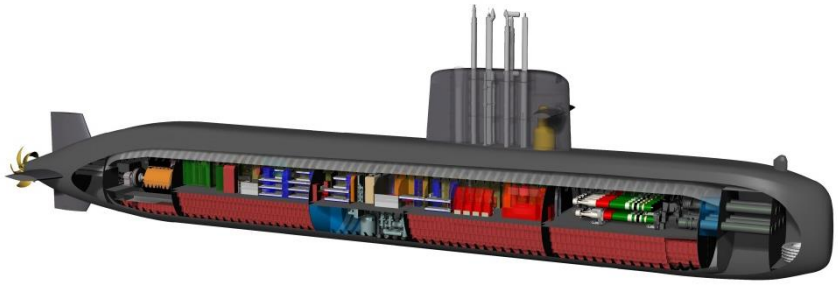
- Approach;
  - Re-designing an existing diesel-electric submarine design into a total battery powered submarine design
  - The MORAY 1800 used as reference design
  - Design volume and all design requirements (except required endurance and range) are kept constant
  - The created total battery powered design is compared with reference design to determine the feasibility

FEASIBILITY STUDY
Created concept design



FEASIBILITY STUDY

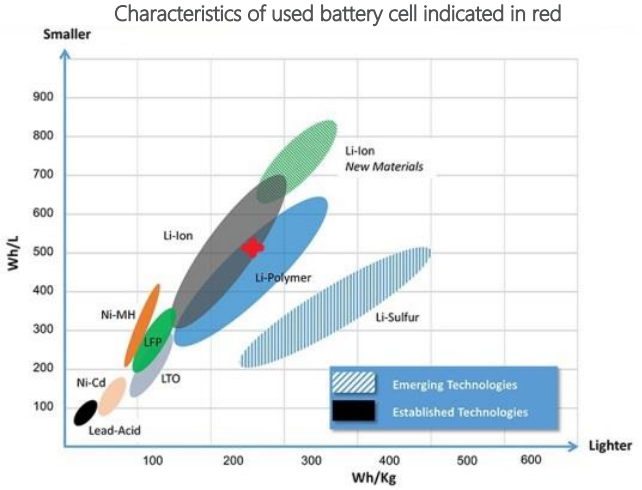
Created concept design – main characteristics



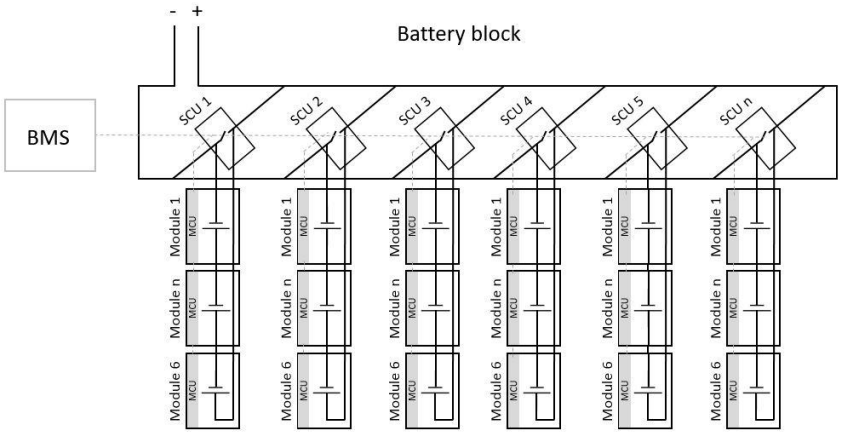
Dimensions	Length	66.5 m
	Hull diameter	6.5 m
Displacement	Surfaced	1700 ton
	Submerged	1900 ton
Diving depth	Max. operational	300 m
Combat	Launching tubes	6
	weapons	20
Speed	Max for one hour	20 kn
	Burst	21.5 kn
Accommodations	Crew & trainees	34+4

FEASIBILITY STUDY
Battery design

- Applied battery technology
  - NMC chemistry lithium batteries
  - Specific energy modules: 200 Wh/kg
  - Energy density modules: 314 Wh/l

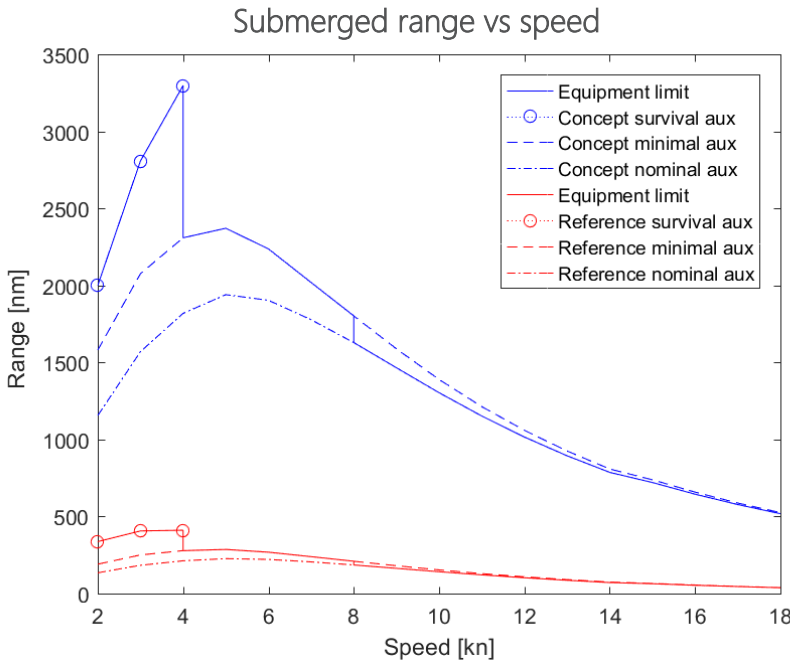


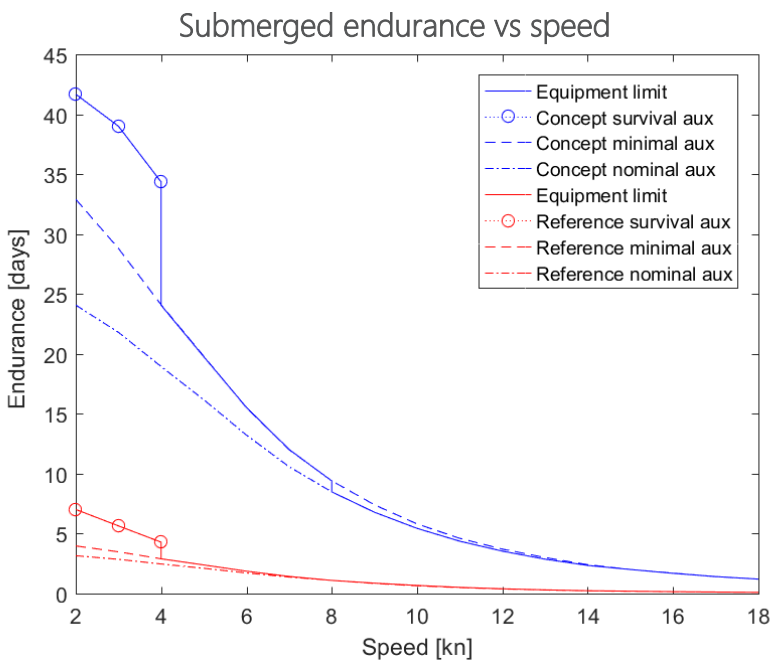
- Applied battery topology
  - Four battery blocks
  - Total amount of battery strings: 1476
  - Total installed battery capacity: 88.5 MWh



FEASIBILITY STUDY
Operational capability study

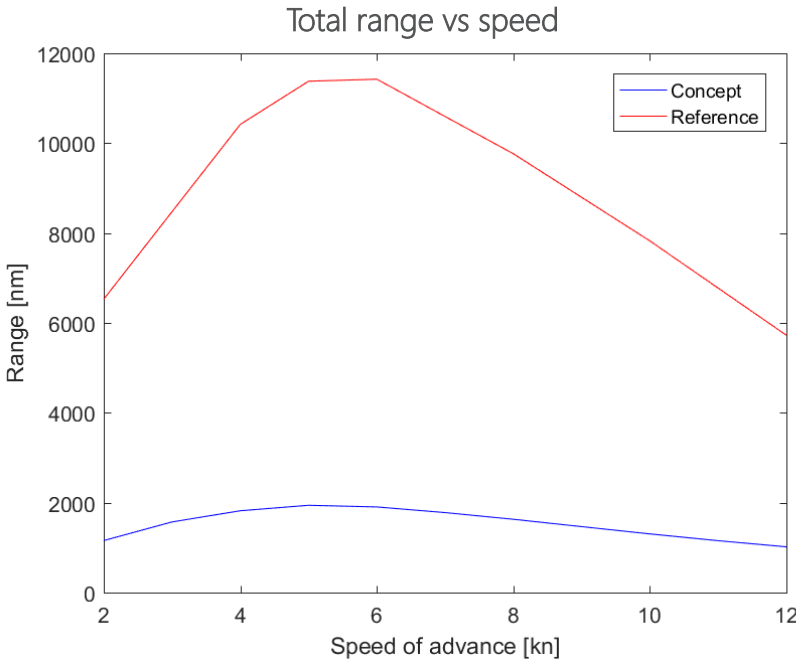
- Submerged range and endurance comparison between concept and reference design

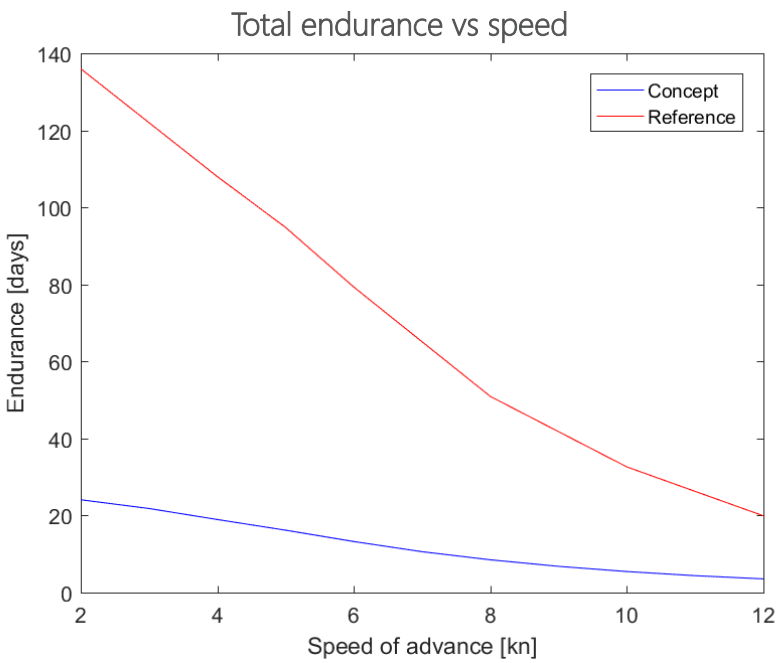




FEASIBILITY STUDY
Operational capability study

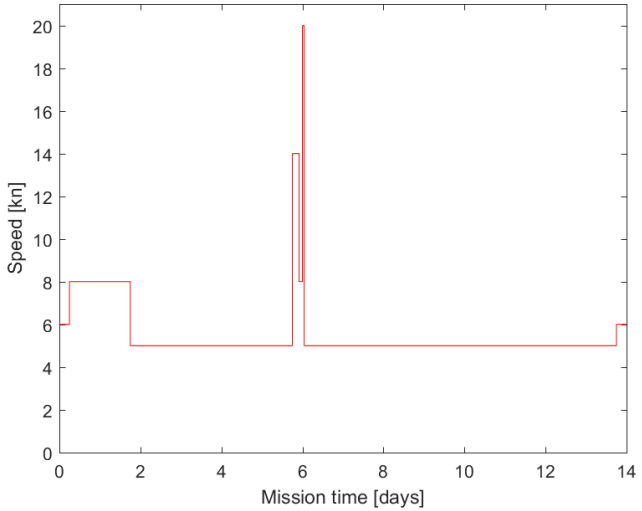
- Total range and endurance comparison between concept and reference design





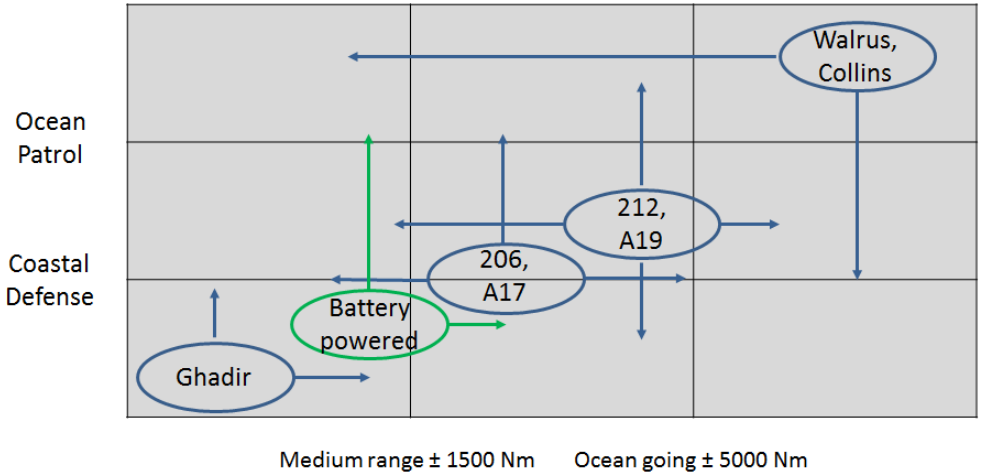
FEASIBILITY STUDY
Mission capabilities

- Local to medium range mission feasible for total battery powered design
- Example of two week mission given below:



MARKET POTENTIALS

- Total battery powered design; most suitable for coastal defense missions
- Low design complexity, which leads to a less complex production and maintenance
- Improvement in availability and reliability
- Expected reduction in investment and lifecycle costs
- Battery technology is still improving; potential of total battery powered design will increase



CONCLUSION
Conclusion

- Total battery powered submarines can been seen as new players in the market of naval submarines
  - High potential for small displacement submarines used for coastal defense missions
  - They will have advantage from a design, maintenance, costs and operational perspective

- The option of a total battery powered submarine should be kept in mind when the design/purchase process of new submarines is started

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