



HighSpeedBoat OperationsForum

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Diesel, Hybrid, Electric – What Propulsion Options Are Practical Today?

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Setting the Stage

1. Range of Application
2. Mission Identification & Capability Requirements
3. Useful Load Fraction & Platform Sizing
4. Traditional Propulsion Options
5. Advanced Propulsion Options
6. ULF Comparison



Range of Application

1. Small hard chine planing craft
2. LOA = 7-11m
3. Military or paramilitary missions



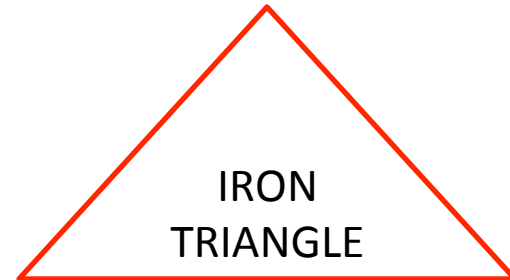
Mission Identification

1. Marine Infrastructure Protection (MIP)
2. Observe Track Intercept Engage (OTIE)
3. Vertical, Board, Search, and Seizure (VBSS)
4. Search and Rescue (SAR)
5. Swimmer/Diver Safety & Support (SDSS)



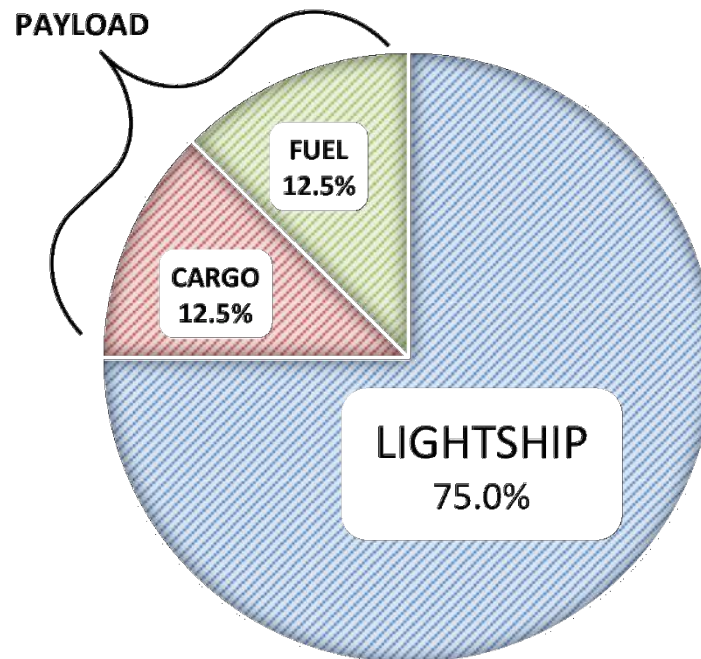
Capability Requirements

1. Purpose of a vehicle is to move goods over a distance in a certain amount of time
 1. Goods = Payload
 2. Distance = Range
 3. Time = Speed
2. Planing craft are “high performance” vessels
 1. Payload and range are limited to enhance speed
3. Must identify critical requirements and avoid over-specifying niceties

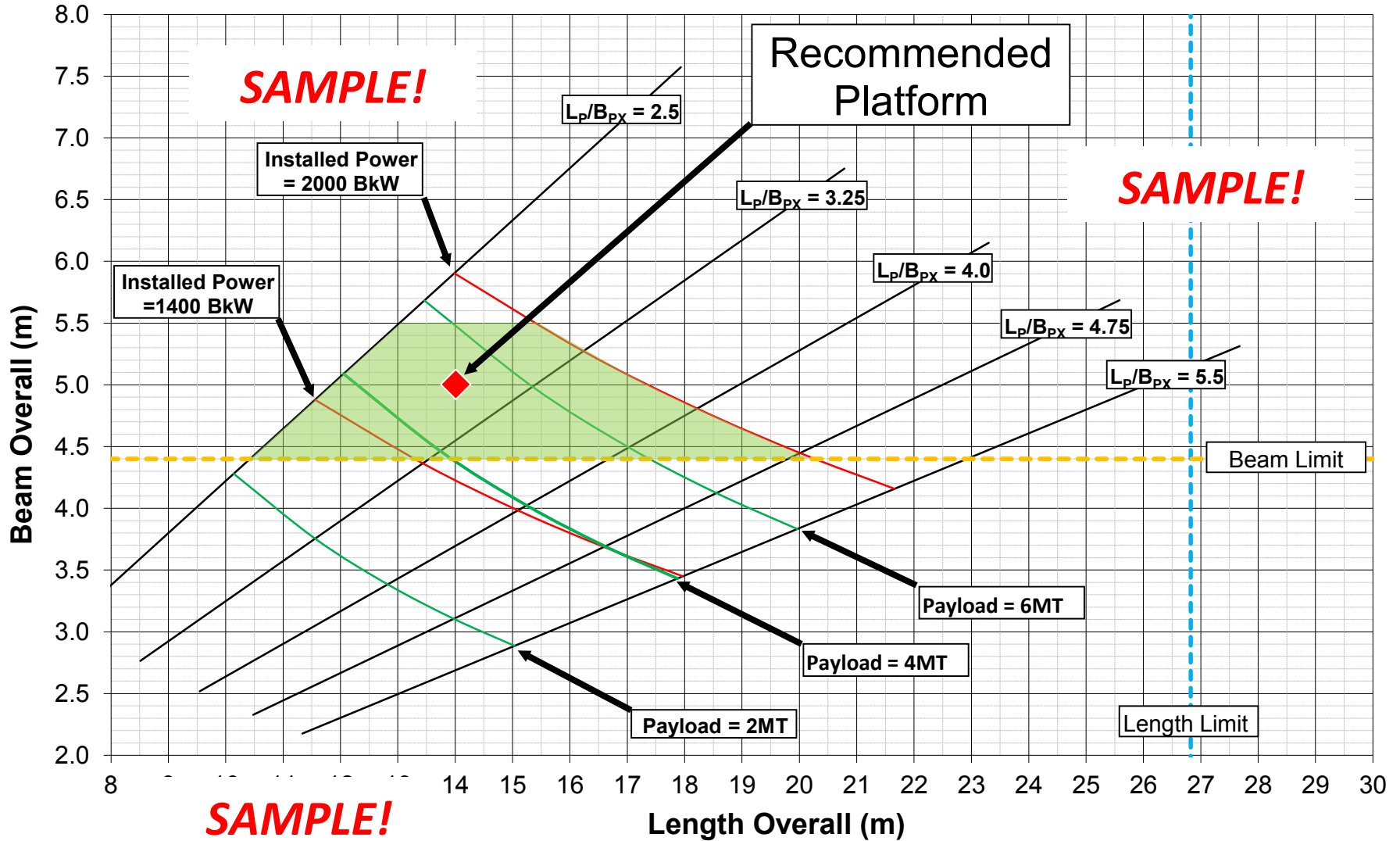


Useful Load Fraction

1. Useful Load Fraction = Payload weight / Total vehicle weight
 1. Payload includes cargo & fuel
 2. Typical values range from 20% to 30% for HSC



Platform Sizing - Hydrodynamic and Dimensional Limitations



Traditional Propulsion Options

1. Outboard (Gas)

- Diesel options do exist now, but it is still considered novel/advanced/unique



2. Sterndrive (Gas/Diesel)

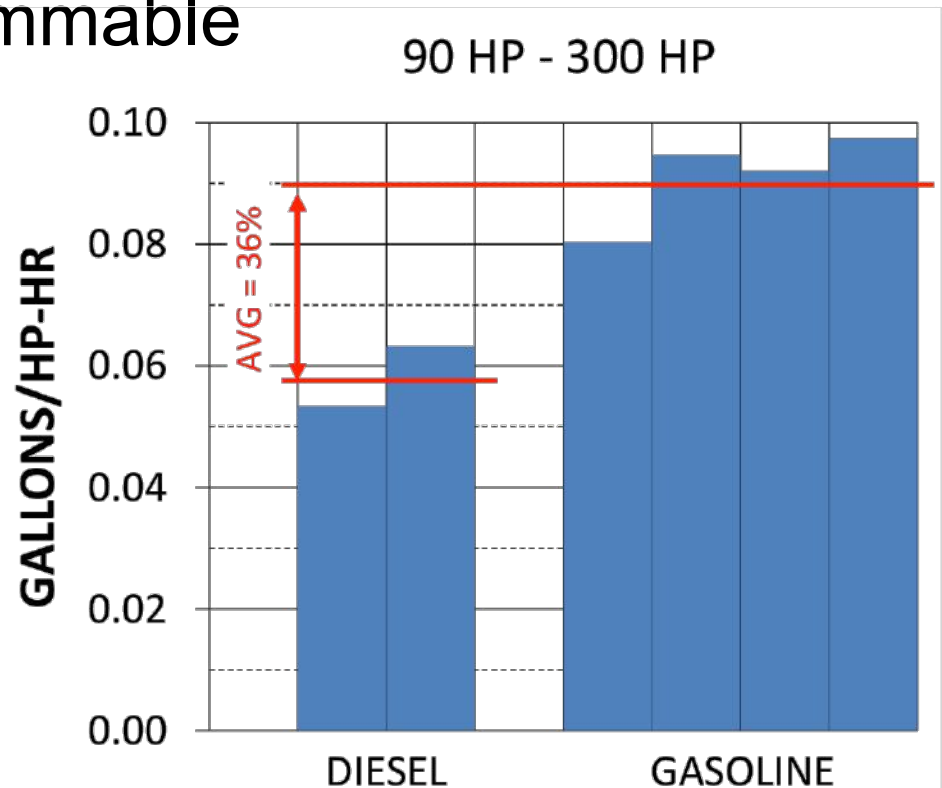


3. Water jet (Gas/Diesel)



Diesel vs. Gasoline

1. Diesel Cycle vs Otto Cycle
2. Combustible vs Flammable
3. Storage
4. Efficiency
5. Emissions
6. Weight
7. Capital Cost



Let's focus on diesel moving forward.



Advanced Propulsion Options

1. Electric
2. Diesel-Electric (DE)
 - i. Parallel Arrangement - DE w/ electric motor PTI
 - ii. Series Arrangement - DE w/ generator and electric motor
3. Hybrid
 - Combination Electric & DE
4. Diesel Outboards
5. Novel Powerplants



Electric Propulsion

1. Energy is Electric Potential instead of Thermal
2. Main Components
 - a) Electric Motor (PM or Other)
 - b) Batteries
 - Lead Acid
 - Lithium-ion (Li-ion)
 - Lithium cobalt oxide (LiCoO₂)
 - Lithium Iron Phosphate (LiFePO₄)
3. Advantages
 1. Noise Free
 2. Emission Free
4. Disadvantages
 1. Weight
 2. Endurance (Storage Capacity)

***Supercapacitors?
Not Till 2030!***



Diesel Electric Propulsion

1. Main Components

- a) Diesel Engine
- b) Electric Generator
- c) Electric Motor

2. Advantages

1. Ability to optimize fuel consumption across operating range

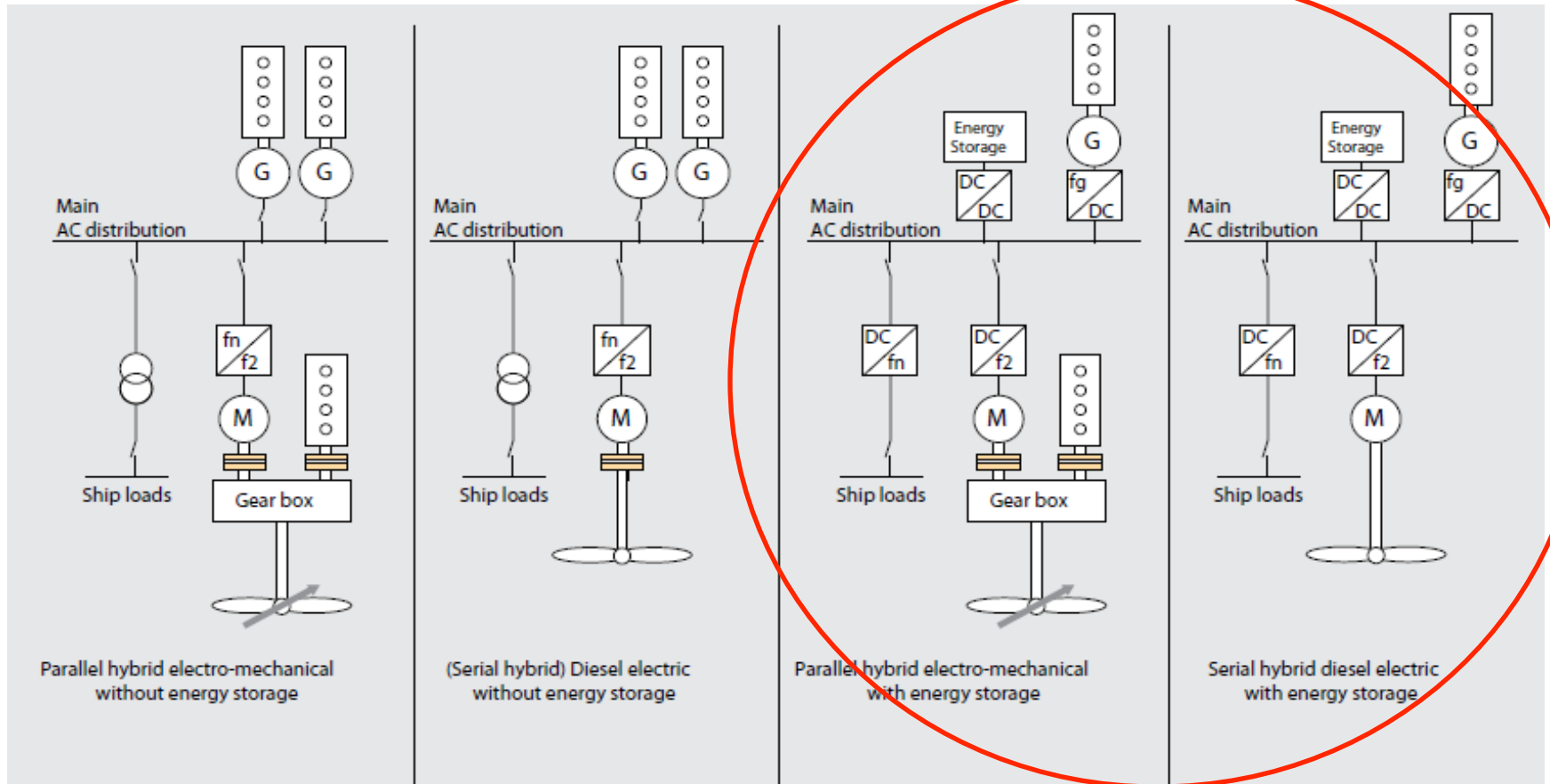
3. Disadvantages

1. Weight
2. Space

Best suited for vessels with high variance in propulsion and hotel loads, which operate many hours per year



DE Propulsion Options



PARALLEL

SERIES

**PARALLEL w/
STORAGE**

**SERIES w/
STORAGE**

HYBRID!



Hybrid ~~Diesel Electric~~ Propulsion

1. Main Components

- a) Diesel Engine
- b) Electric Generator
- c) Electric Motor
- d) Batteries

2. Advantages

- 1. Ability to optimize fuel consumption across operating range
- 2. Silent, emission free operation

3. Disadvantages

- 1. Weight ←—————
- 2. Space
- 3. Capital Cost

Diesel Outboards

1. OXE

1. ~150 kW
2. ~300 kg
3. 42% reduction in fuel consumption than a comparable gas outboard (OXE-diesel.com)



2. Evinrude Multi-fuel

1. ~22 & ~40 kW
2. Kerosene, JP-5, JP-8, etc



Novel Powerplants

1. Micro Turbines

1. Less weight than diesel engines
2. Capstone has 30kW and 65kW models
3. Noise, fuel, temperature impacts



2. Cox Powertrain

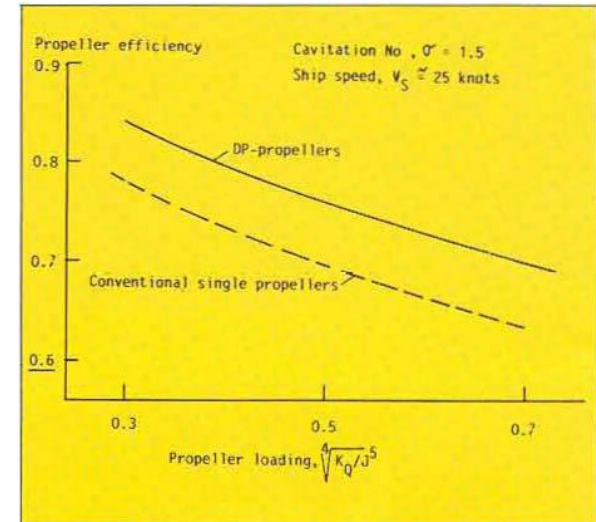
1. 4 Cylinder, 8 Piston, supercharged, 2-stroke, 3.6L diesel
2. Inboard & Outboard units from 150kW – 260kW



Novel? Powerplants

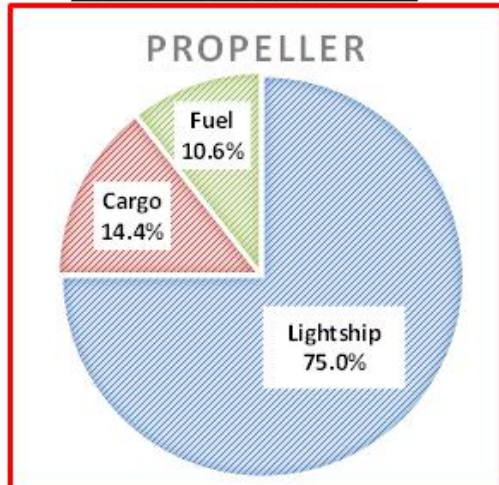
1. Contra-Rotating Propellers

1. ~7.5 % increase in efficiency over conventional propellers
2. Reliability risk due to complexity



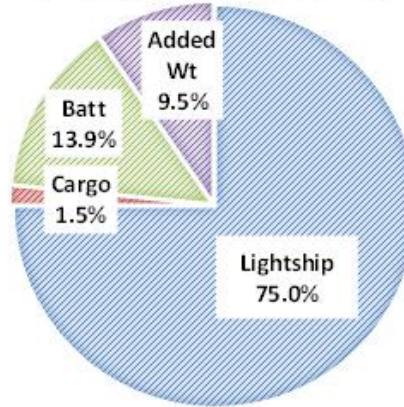
ULF Comparison – 7m RHI @ 35 knots

BASELINE (Gasoline)



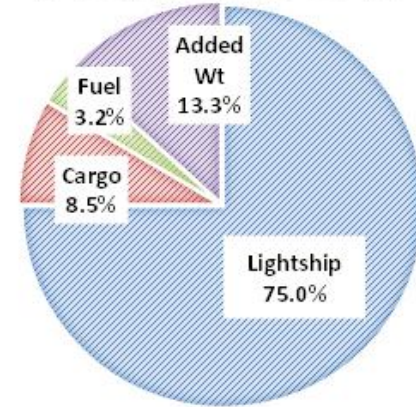
ALL ELECTRIC

4 TORQEEDO 80 R



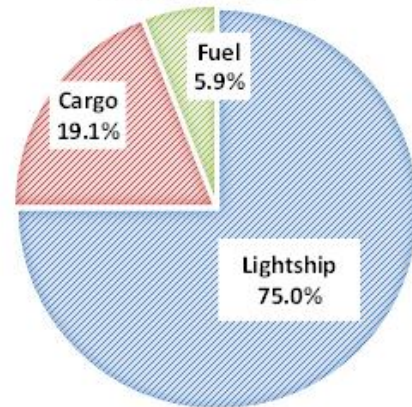
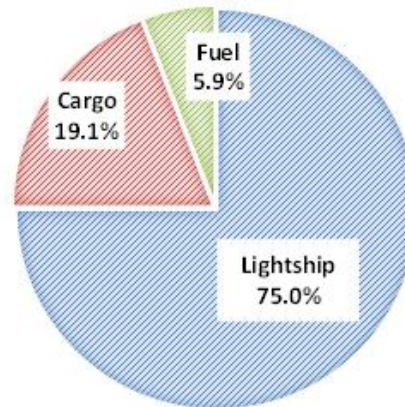
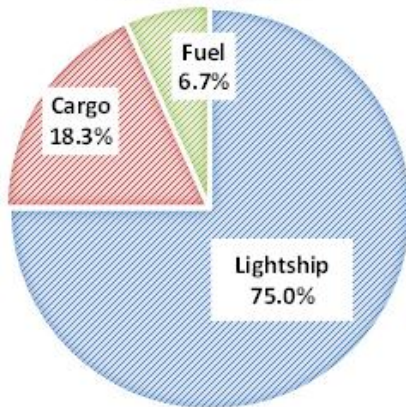
DIESEL ELECTRIC

1 TORQEEDO 80 R



Intercept capability drove the 35 knot comparisons, and is not obtainable with a Series Diesel Electric solution.

DIESEL



Diesel Electric and All Electric Drive systems (*Visual Evaluation of ULF*)



- Diesel Electric Outboard System
 - Torquedo Deep Blue
 - Diesel Generator

- All Electric Outboard System
 - 2x Torquedo Deep Blue
 - Battery Pack



Summary / Conclusions

1. Various propulsion options exist for small HSC
2. Relative to gasoline, diesel provides a 30+% improvement
3. Contra-rotating propellers provides a 7.5% improvement
4. DE can provide marginal improvement, which will only add up with a lot of operating hours
5. Electric and Hybrid are not suitable for planing operation (today), but can enhance loiter endurance and provide a silent mode of operation



QUESTIONS??

THANK YOU!!

