DONALD L. BLOUNT AND ASSOCIATES, INC.
NAVAL ARCHITECTS/MARINE ENGINEERS

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OperationsForum
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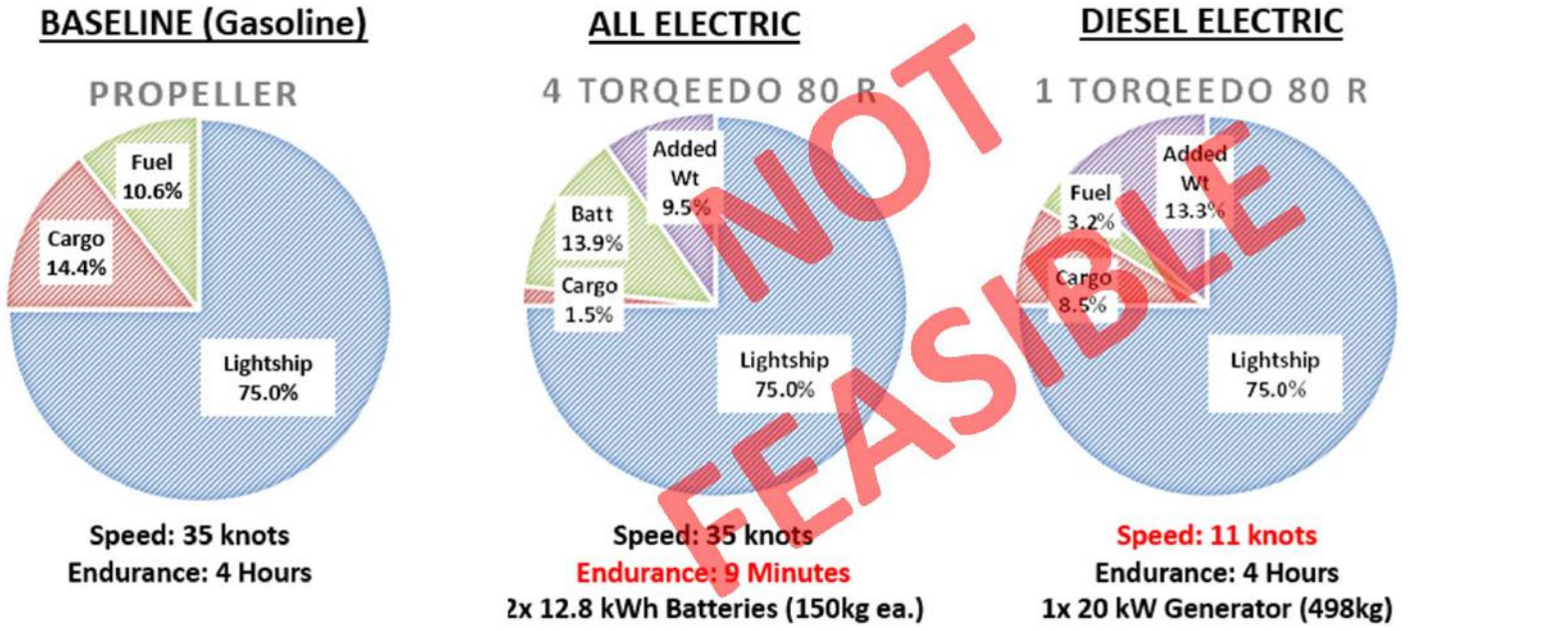
Propulsion Trade Study of a Hybrid USV

Jeffrey Bowles
Technical Director
Donald L. Blount & Associates, Inc.
870 Greenbrier Circle Suite 600
Chesapeake, VA 23320
www.dlba-inc.com

Introduction

- 7 m 35 knot RHIB → **11 m 30 knot USV**
- Investigated Electric, and Diesel Electric Propulsion Options Et al.
  - Compared Relative Endurance at WOT → **95% at 5kts and 5% at WOT**
  - Only Evaluated Propulsion System Structure in Series → **Parallel**



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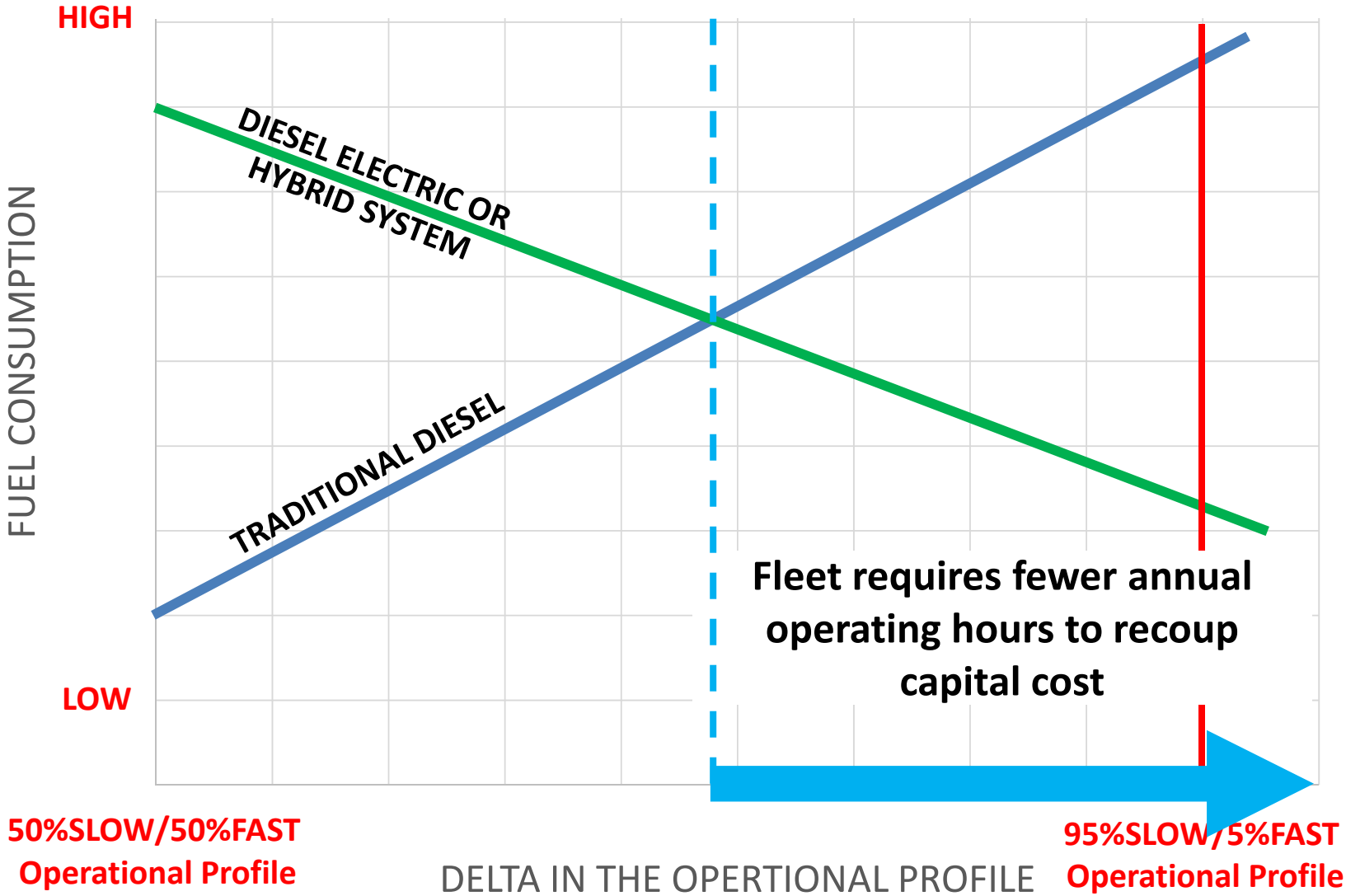
Introduction



Outline

- Trade Study Assumptions
- Types of Hybrid Systems Evaluated
- Results of The Study
- Conclusions

- *NOTE: Maintenance cost and capital cost are beyond the scope of this study.*

Trade Study Assumptions

- 11 m Hard Chine Monohull
  - Aluminum Construction
  - Twin Fixed Pitch Propellers
  - Δ = 8,250 kg
  - V = 30 knots max

- Operational Profile
  - 24 hr endurance
  - 5% of operation at wide open throttle
  - 95% of operation at 5 knots
    - *Resistance at 5 knots was assumed to be the same for all of the variants evaluated*

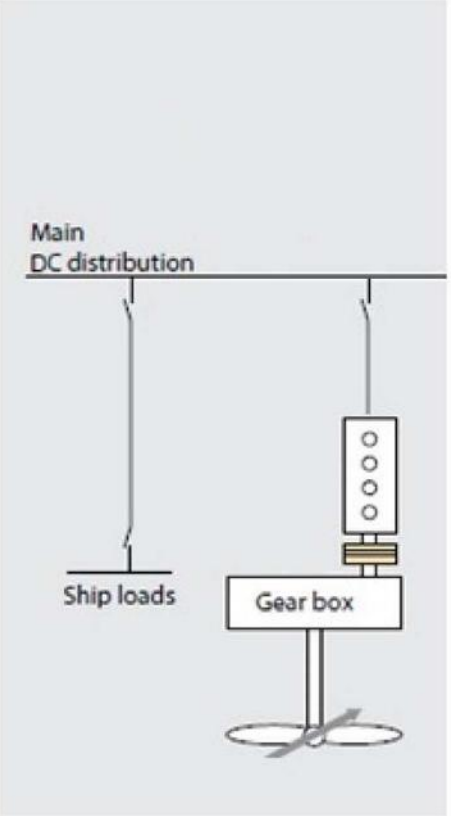
- Fleet Characteristics
  - 5 boats
  - 1 boat down for maintenance per week (oil change or major overhaul)
  - 10 year lifespan
  - 7000 annual operating hours per boat

Types of Propulsion Systems Evaluated

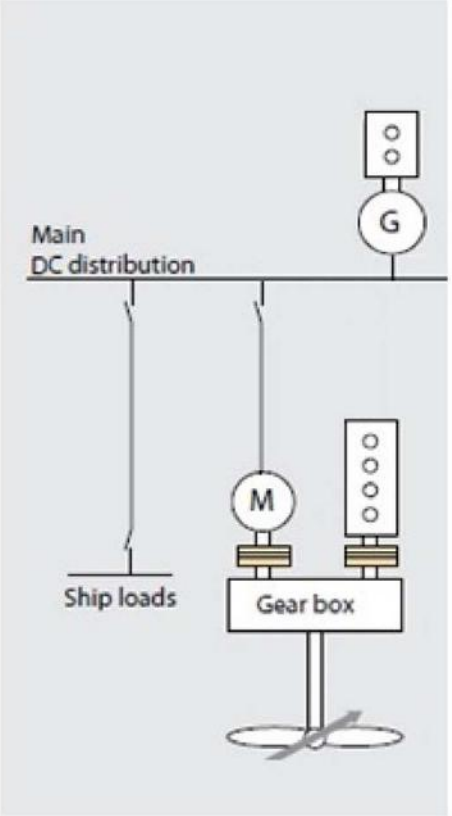
	TYPE	Propulsion System Components					Modes of operation		
		Diesel	PTO Generator	Diesel Generator	Batteries	Electric Motor	Main Prop. Engine	Diesel Electric	Electric / Silent
1	Diesel	✓					✓		
2	CNG	✓					✓		
3	Diesel Electric	✓		✓		✓	✓	✓	
4	Diesel Electric Hybrid (w/dedicated generator)	✓		✓	✓	✓	✓	✓	✓
5	Diesel Electric Hybrid (w/PTO generator)	✓	✓		✓	✓	✓	✓	✓

Types of Propulsion Systems Evaluated

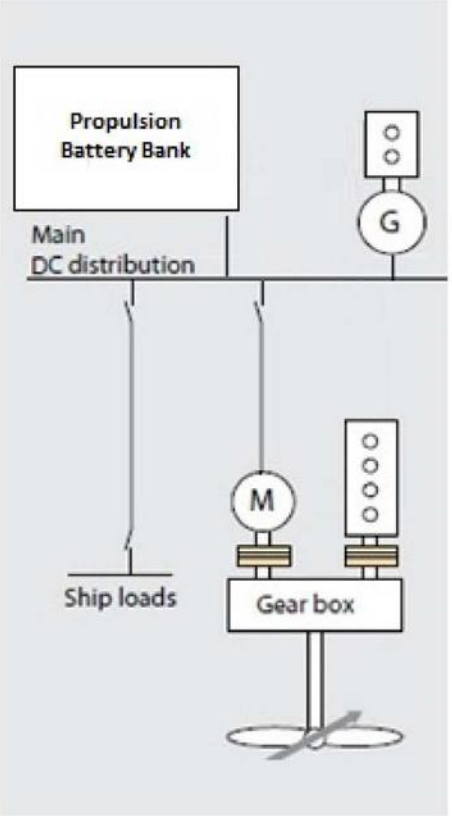
1. DIESEL & 2. CNG



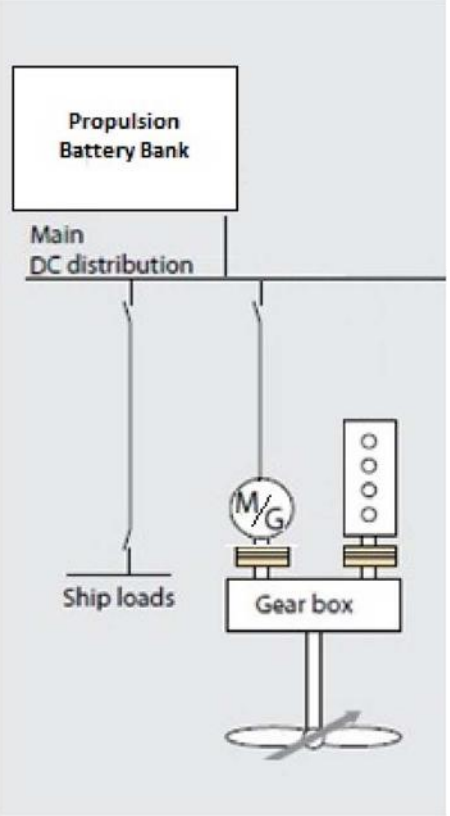
3. DIESEL ELECTRIC



4. DIESEL ELECTRIC HYBRID

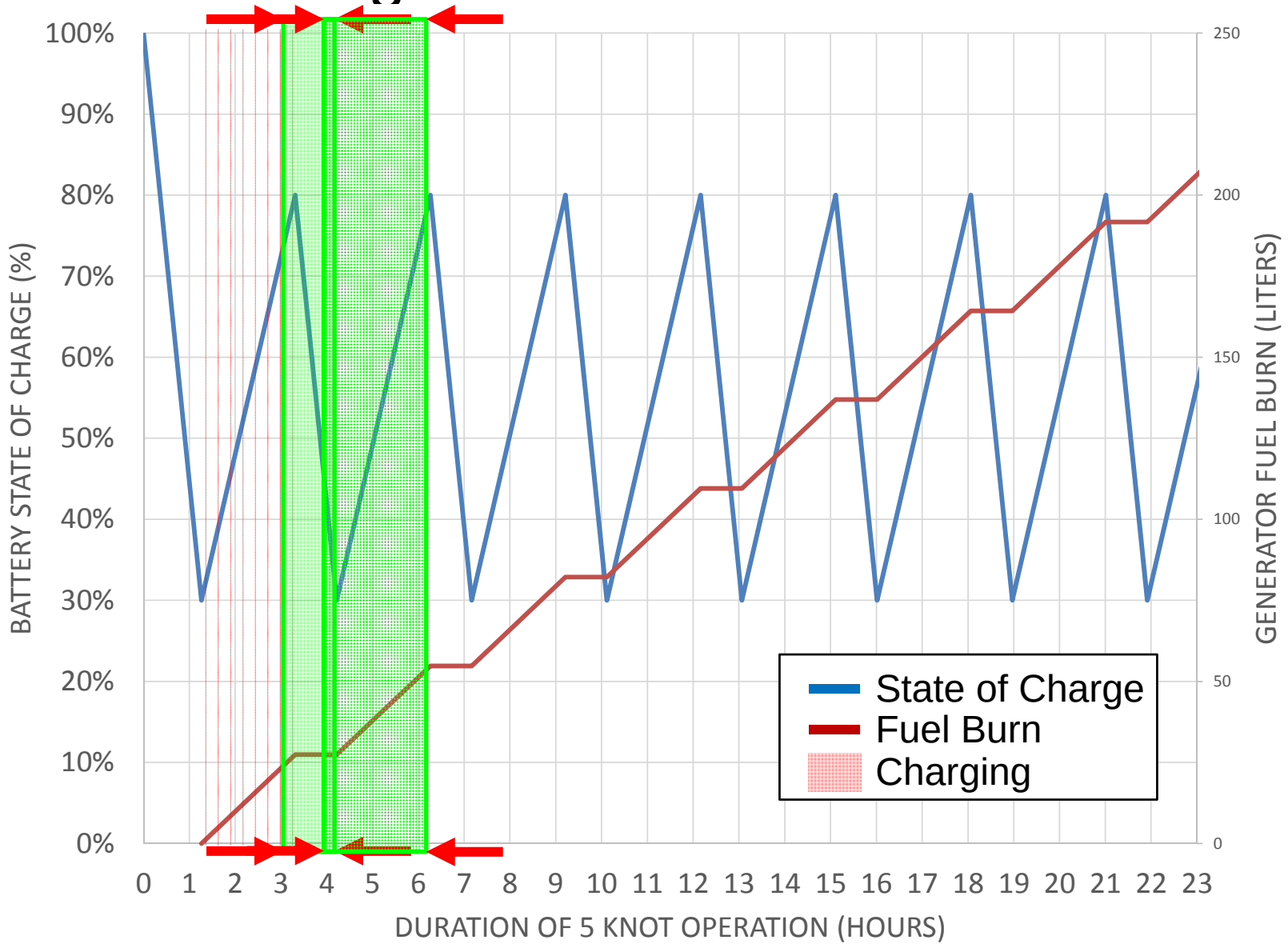


5. DIESEL ELECTRIC HYBRID



(w/dedicated generator) **(w/PTO generator)**

State of Charge Profile



Results of The Study

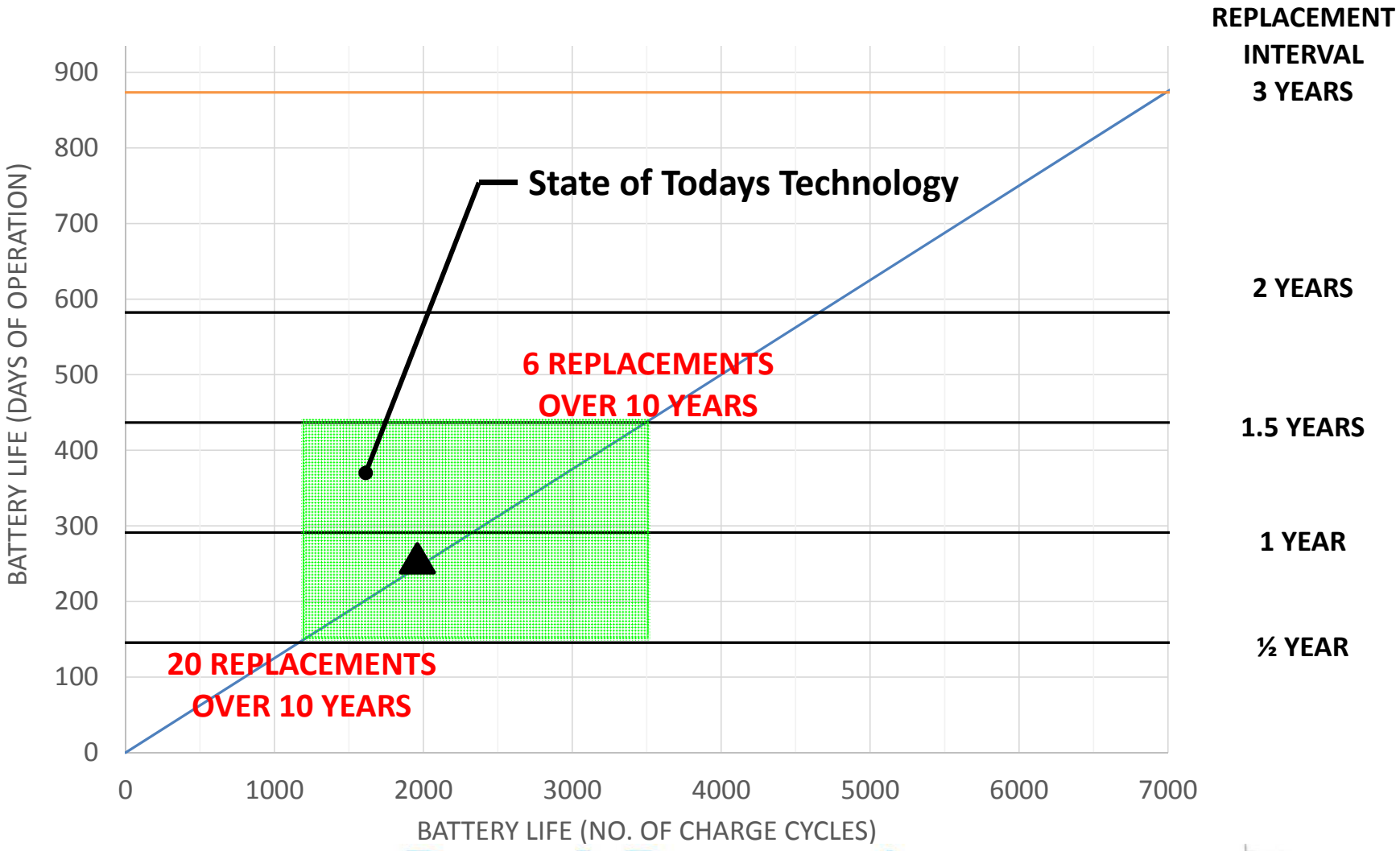
	USV PROPULSION OPTIONS	FLEET REULTS FOR 10 YEARS OF OPERATION					
		Prime Mover x1000 hrs	No. of Oil Changes	Generator x1000 hrs	E-Motor x1000 hrs	Cycles x1000	Battery Replacements
1	Diesel	699	3494				
2	CNG	699	3494				
3	Diesel Electric	35	175	664	664		
4	Diesel Electric Hybrid (w/dedicated generator)	35	175	417	664	102	51
5	Diesel Electric Hybrid (w/PTO generator)	397	1986		664	102	51

Depends on:

- **State of Charge Profile**
- **Depth of Discharge**
- **Selected battery chemistry**

Battery Replacement Interval

- Battery life depends on selected chemistry, depth of discharge
- Replacement interval depends on # of cycles per op and # of op/year



Results of The Study

	USV PROPULSION OPTIONS	FLEET REULTS FOR 10 YEARS OF OPERATION				
		Total Fuel Burn x1000 Liters	CO_2 x1000 MT	CO_2 Reduction	Cost of Fuel $	Fuel Savings
1	**Diesel** *$0.52/liter*	7005	18.61	0%	$ 3,664,172	0%
2	**CNG** *$3.70/mmbtu*	60542	23.25	-25%	$ 1,373,000	63%
3	**Diesel Electric**	5628	14.95	20%	$ 2,943,579	20%
4	**Diesel Electric Hybrid (w/dedicated generator)**	6252	16.61	11%	$ 3,270,309	11%
5	**Diesel Electric Hybrid (w/PTO generator)**	6356	16.88	9%	$ 3,324,439	9%

Conclusions

- Series diesel electric/hybrid structures are not feasible on small HSC
  - Weight of electric motor and ancillaries to provide +30 kts is prohibitive
- Parallel diesel electric/hybrid structures are feasible on small HSC
- There are feasible operational profiles with less delta than the one analyzed herein i.e. (95%/5%)
  - The designer has to determine the feasibility crossover point
- All diesel electric/hybrid option reduce operating hours on the main diesel engines
- CNG offers reduced annual operating cost with less capital cost than the diesel electric/hybrid systems
- Only the diesel electric/hybrid systems offer reductions in CO2

Conclusions

- State of charge profiles are very important
  - Directly impacts battery life span, battery bank size, generator loading, and generator op hours
- A dedicated generator is a more efficient means than a PTO for this specific application
  - An additional investigation could explore the impact of using only one diesel engine at a time providing propulsion, charging the batteries and enough power to drive the electric motor on the other drive shaft.

QUESTIONS?

THANK YOU!!!