EXPERIENCE OF TESTING NOVEL HULL FORMS AND PROPULSION SYSTEMS FOR SUB IMO VESSELS

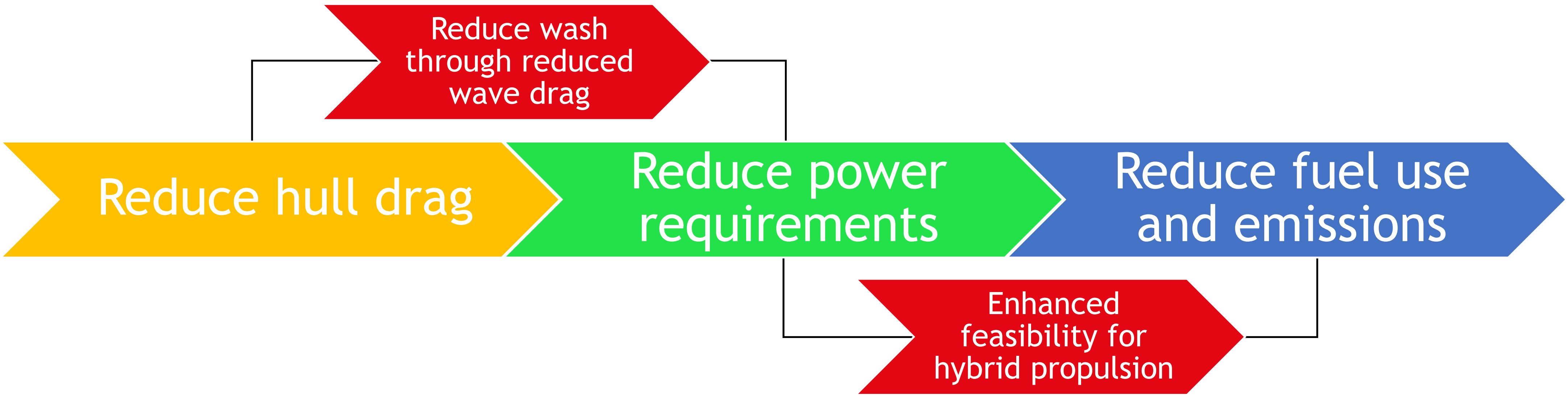
GILES BARKLEY, JONATHAN RIDLEY & JEAN-BAPTISTE SOUPPEZ.

WITH THANKS TO HERMAN FOSTVEDT
AND JACK CUNNINGHAM-BURLEY

INTRODUCTION

Challenges for Sub IMO Vessels

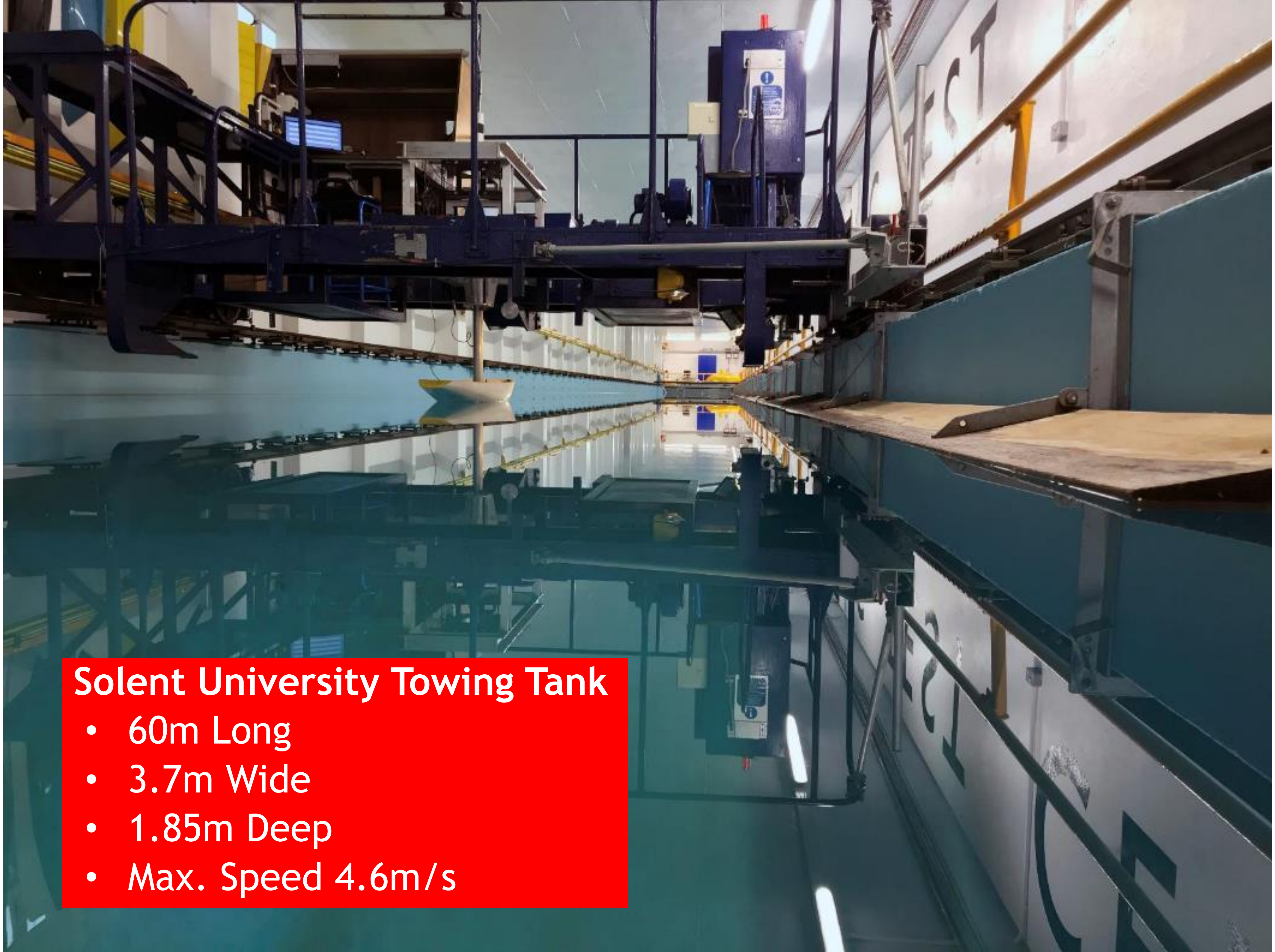
- Current issues
  - Exhaust hydrocarbon emissions – close focus on diesel engines and particulate emissions, NO_x and SO_x.
  - Wash and effects on local environment.
  - Noise pollution.
  - Oily bilge water release.
  - Recycling at the end-of-life.



INTRODUCTION

Recent Relevant Undergraduate Projects

- Pilot vessel with a novel bow design to reduce motions in waves and added resistance due to waves.
- Hydrofoil assisted yachts.
- Drag reduction through forced air flow.
- Use of winglets to enhance performance on a traditional long keel yacht.
- 30’ cruising yacht with no on-board fossil fuel power.
- 14.34m LOA stabilised low drag mono-hull motor vessel.
- High-speed SAR boat with investigation into bow design, drag and sea-keeping.



Solent University Towing Tank

- 60m Long
- 3.7m Wide
- 1.85m Deep
- Max. Speed 4.6m/s

INTRODUCTION

Study Based on Undergraduate Experimental Work

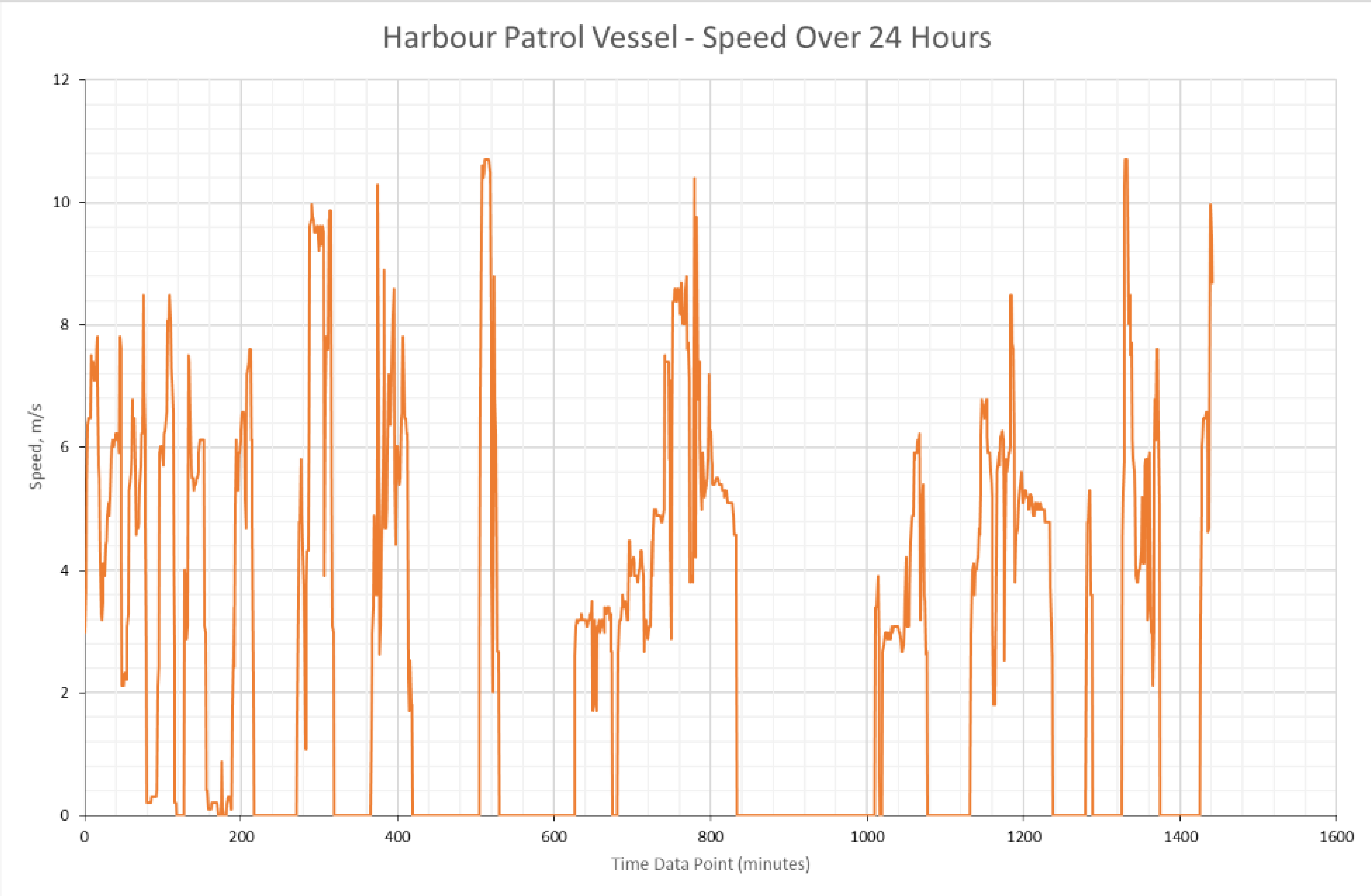
1. Use AIS data to get a “real” duty cycle data-set for two workboats – a pilot launch and harbour patrol vessel.
2. For a series of conventional and “novel” hull forms assess the hull resistance using theoretical methods and data from the towing tank.
3. Use the resistance data and AIS data to estimate the shaft power and daily fuel requirements.
4. Investigate theoretical fuel savings from replacing diesel power with hybrid power for a range of power settings.

AIS DERIVED DATA

Pilot Vessel

AIS DERIVED DATA

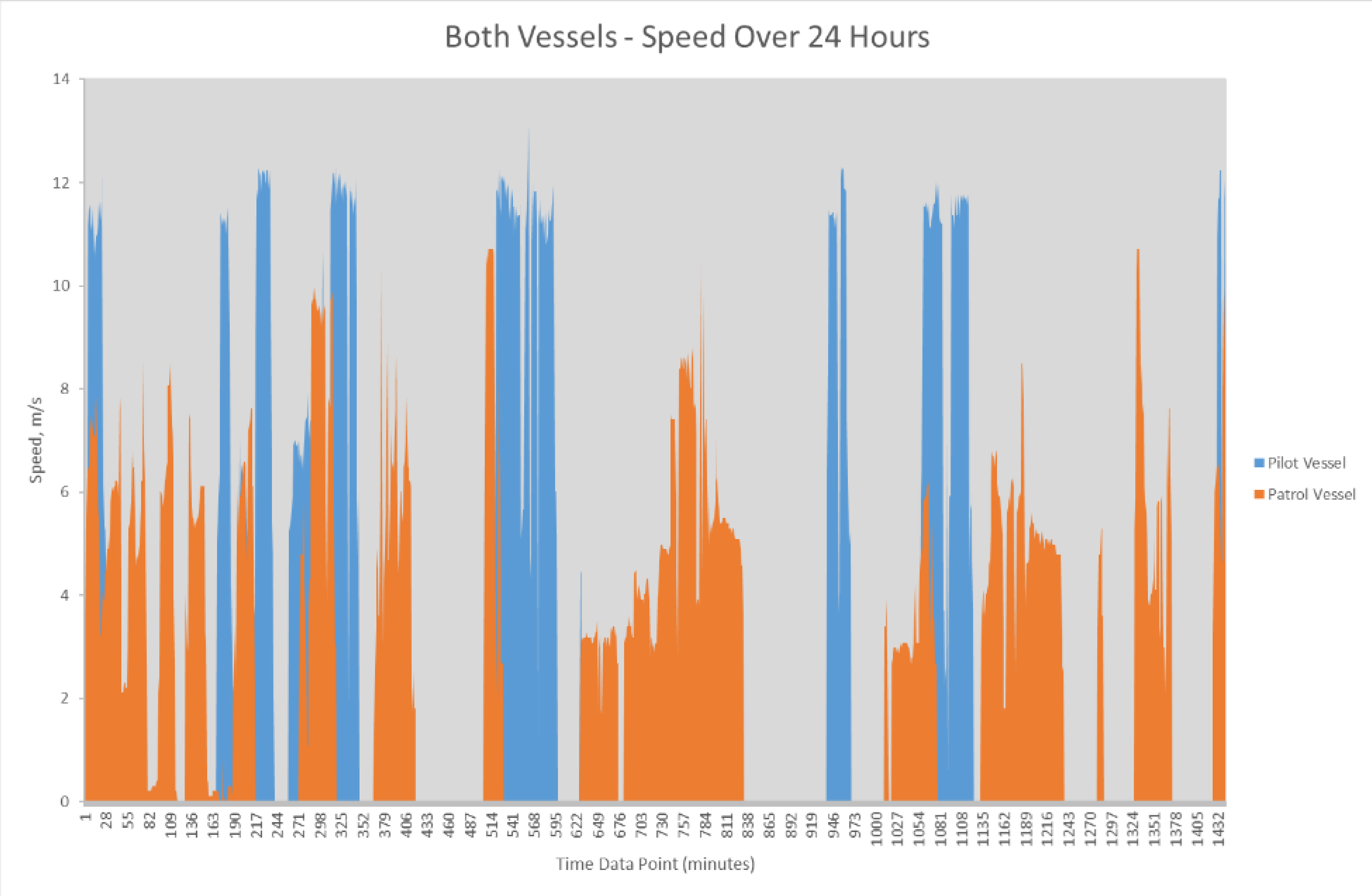
Patrol Vessel



AIS DERIVED DATA

Both Vessels

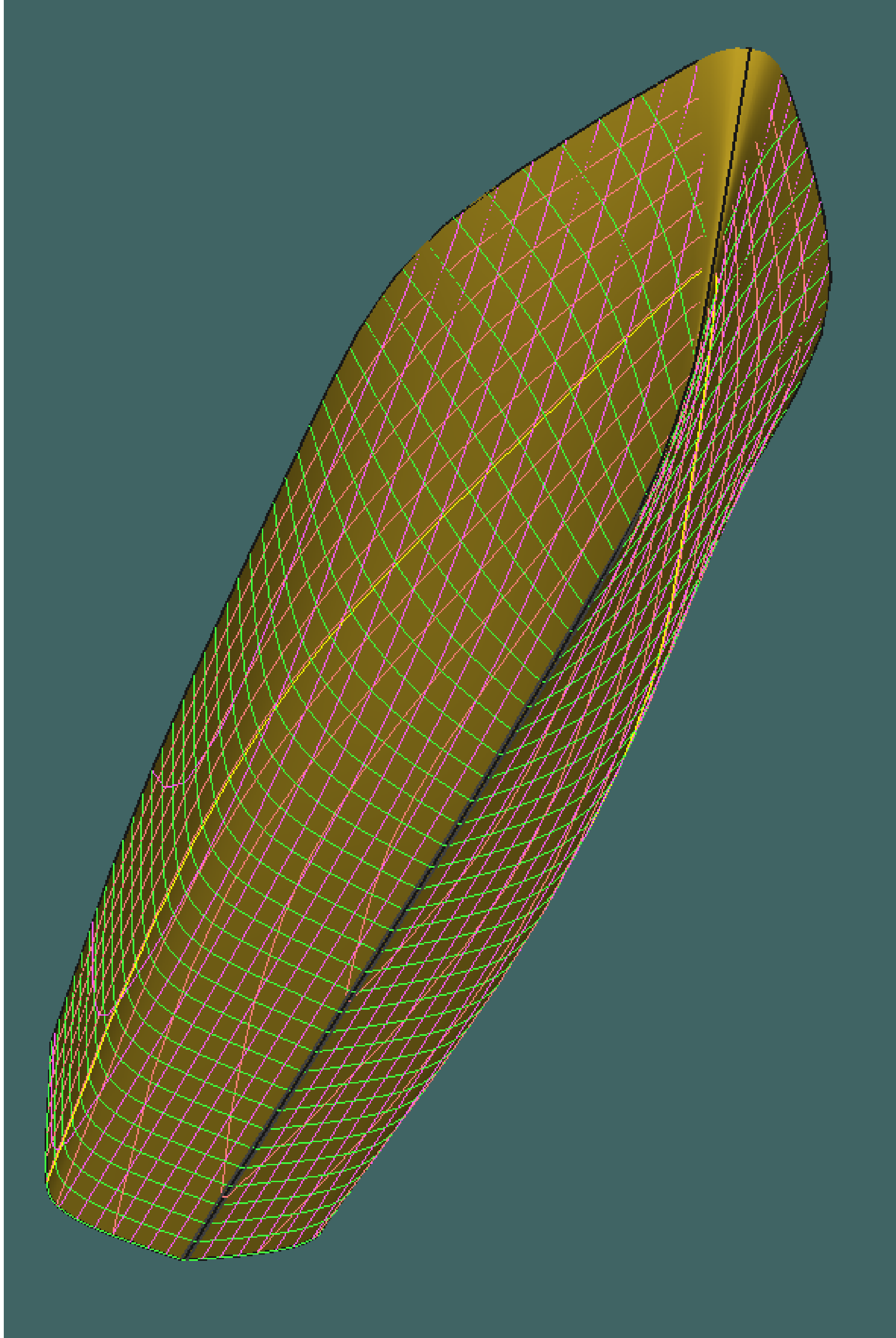
	Pilot	Patrol
Maximum Speed (knots)	25.40	20.80
Mean Speed (including zeros)	2.34	2.65
Mean Speed (underway)	8.90	5.00
Distance (Nautical Miles)	111.5	123.00



CASE STUDY VESSELS

Baseline NPL 100A Hull

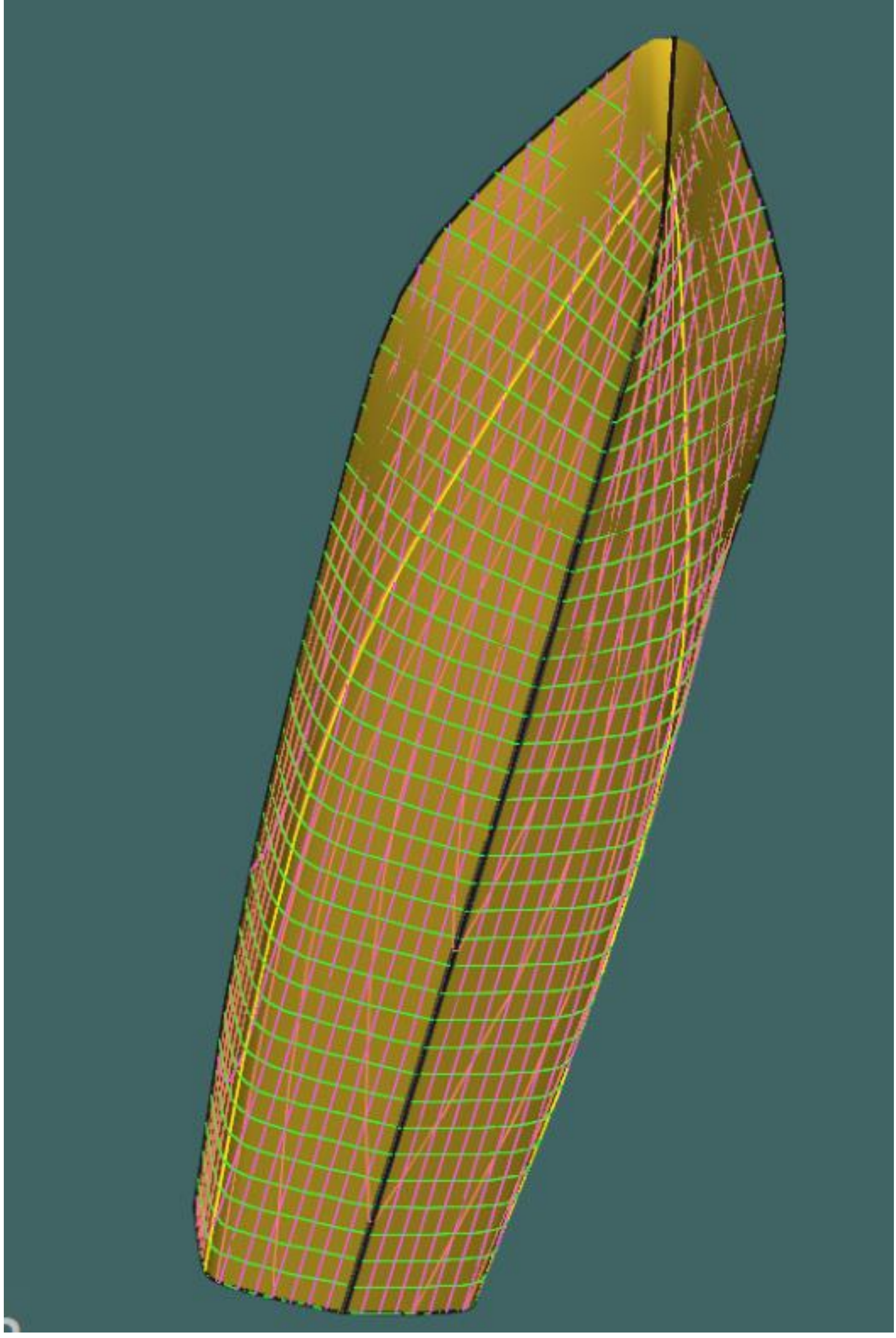
- Bailey, D., 1976, *The NPL High Speed Round Bilge Displacement Hull Series*, Maritime Technology Monograph No. 4., Royal Institution of Naval Architects.
- Scaled to a displacement of 10t giving a LWL of 14.15m.
- Speeds predicted via the Wolfson Unit's Power Prediction Program, including a skeg.
- L/B ratio of 6.27 – low drag but not very representative of vessels in service.

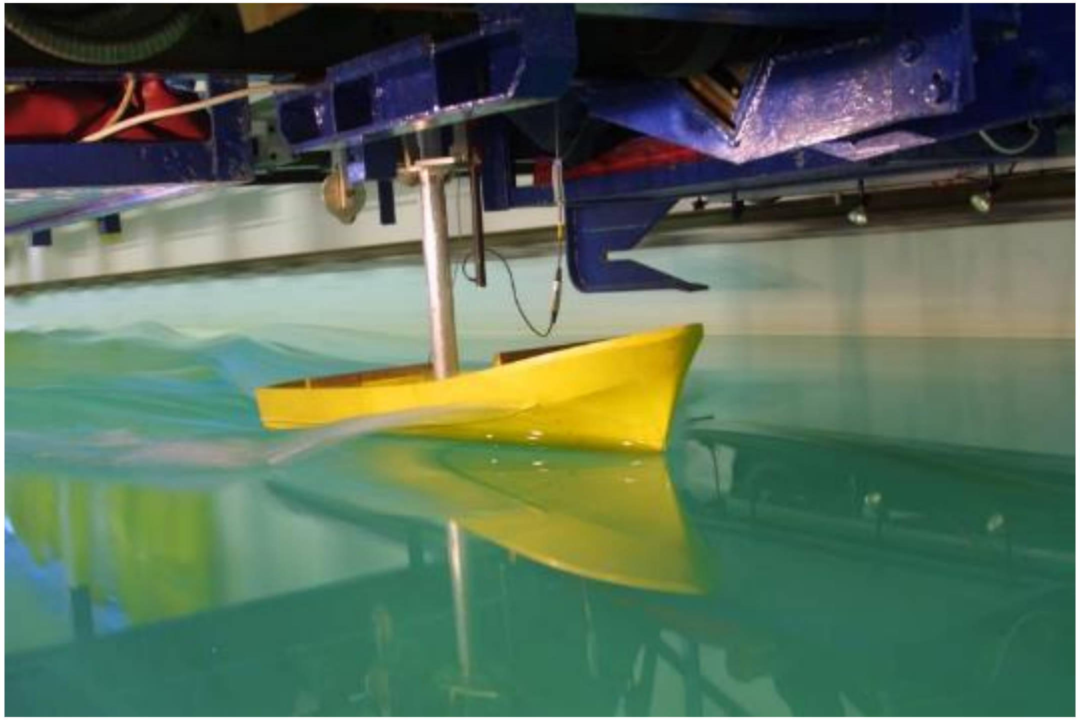


CASE STUDY VESSELS

Traditional Launch Hull

- Based on the NPL 100A but scaled to a L/B ratio of 4.17 representing a more typical workboat/launch.
- Scaled to a displacement of 10t giving a LWL of 12.36m.
- Speeds predicted via the Wolfson Unit's Power Prediction Program, including a skeg.
- Speeds below 6 knots were not available – linear interpolation used instead.

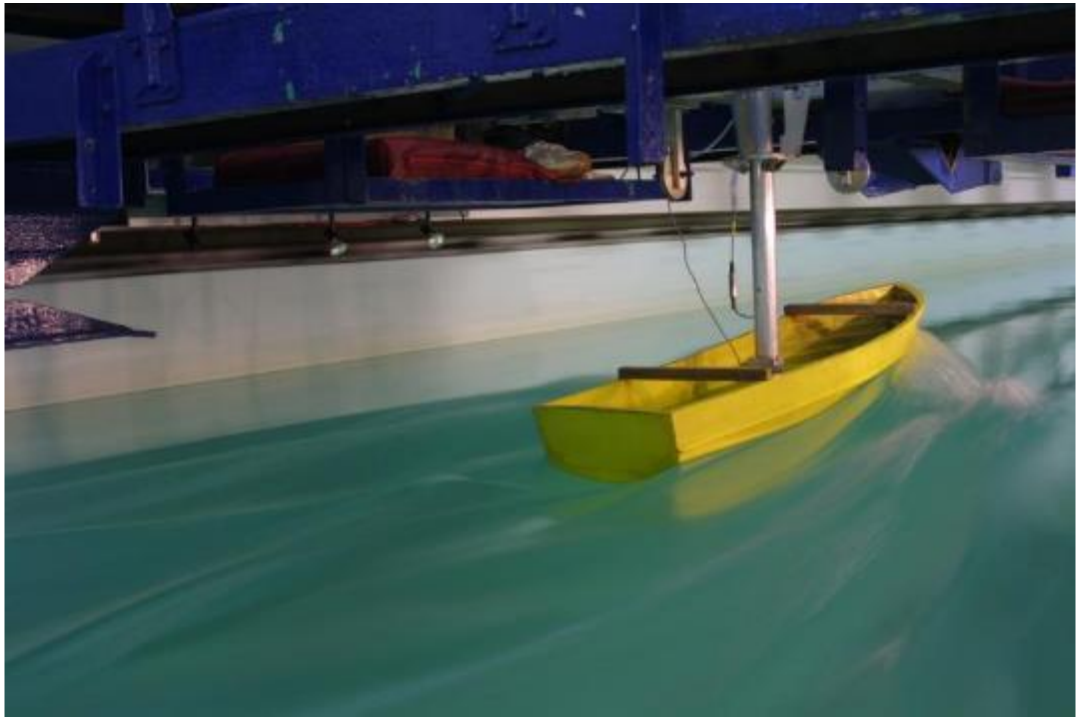




CASE STUDY VESSELS

Laboratory Model

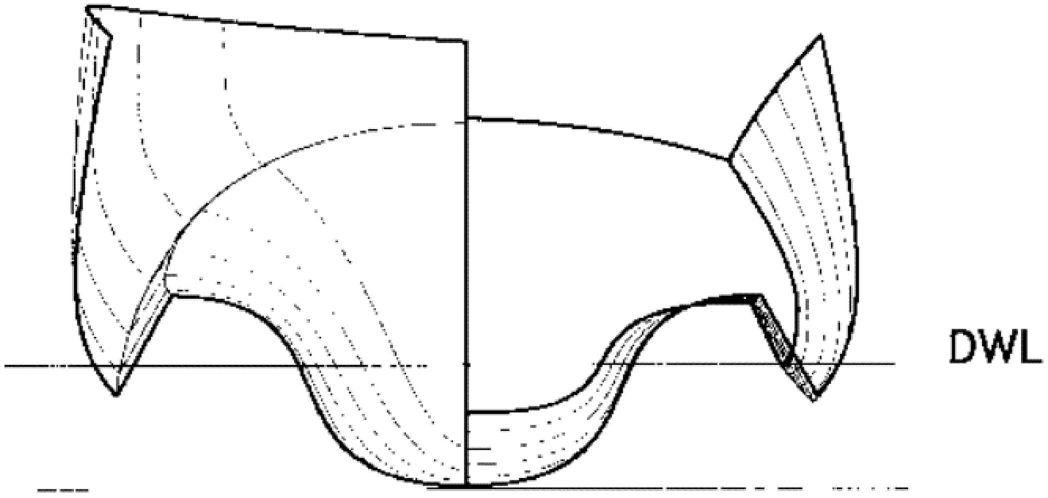
- Model used for student laboratory work.
- Scaled to 10t displacement
- Waterline Length 11.45m

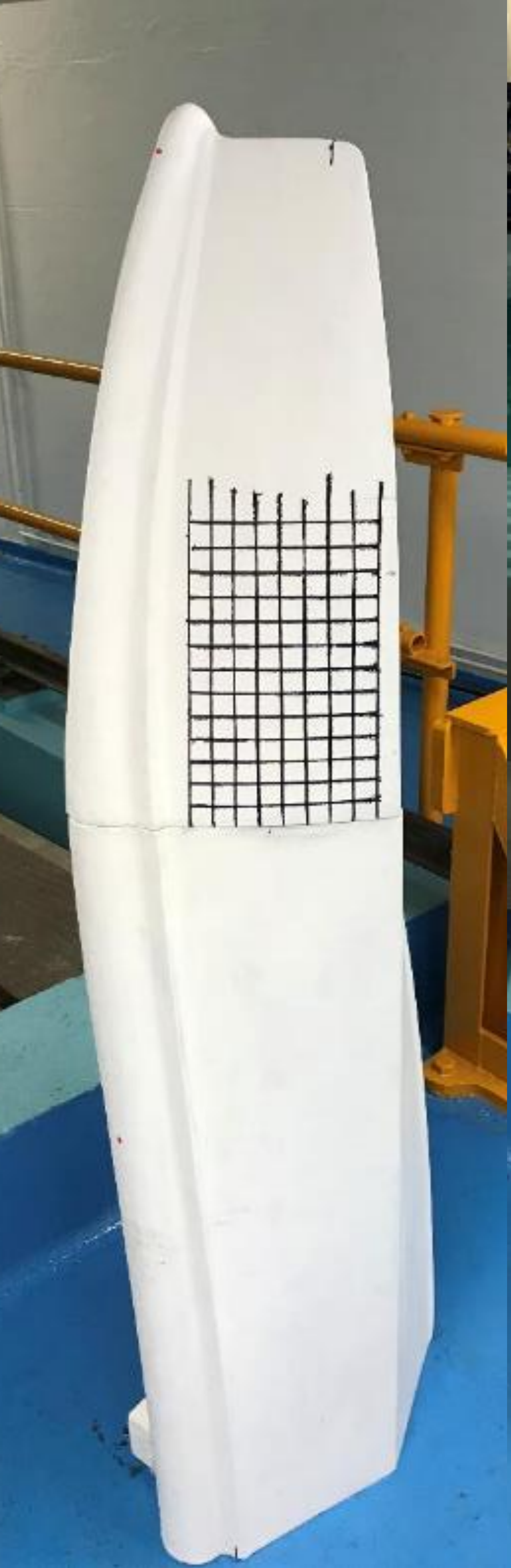


CASE STUDY VESSELS

"Jupiter"

- Stabilised monohull
- Scaled to a displacement of 10t giving a LWL of 14.67m
- Speeds below 4.8 knots and above 23.2 knots were not available – linear interpolation used instead.





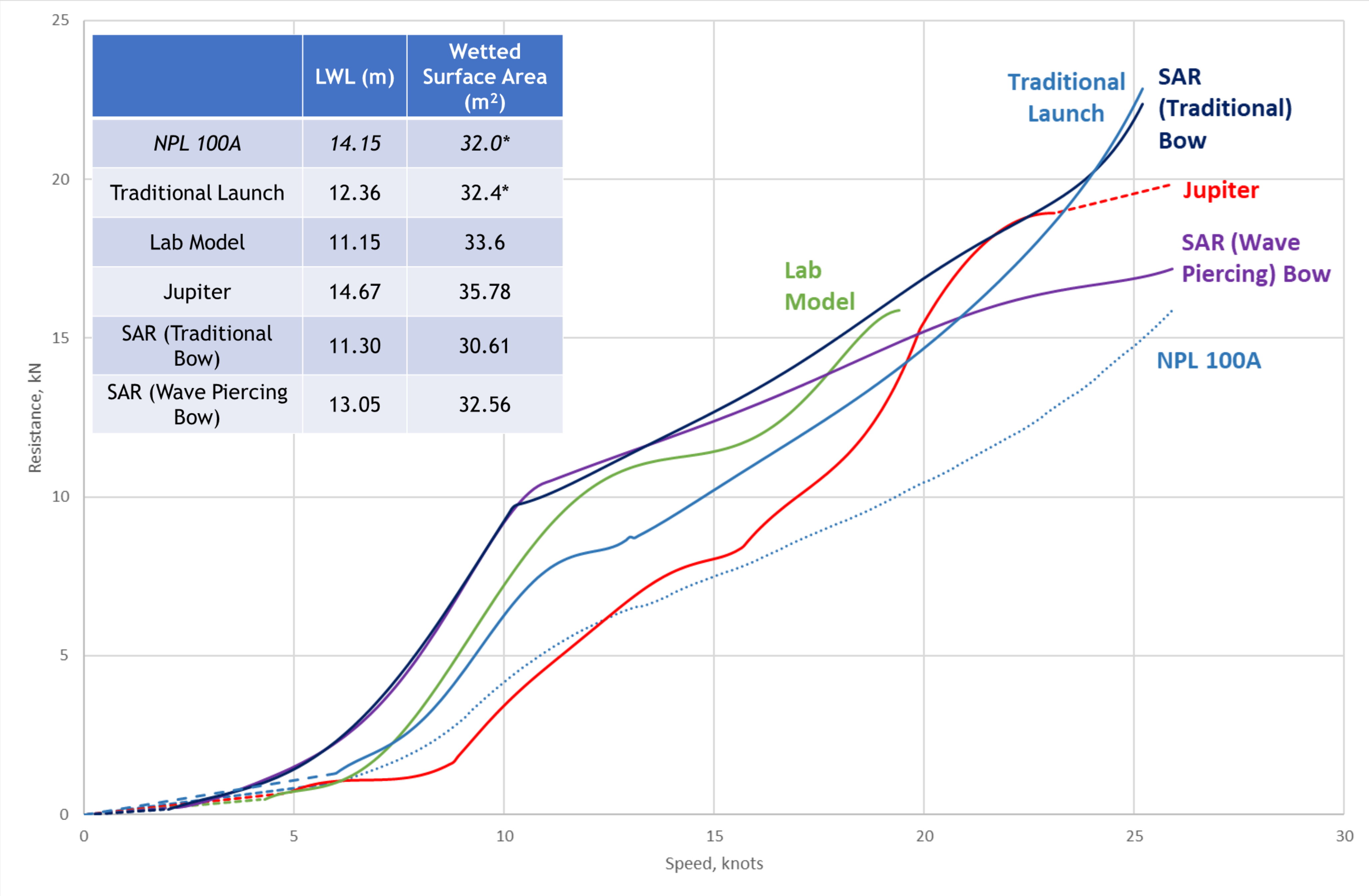
CASE STUDY VESSELS

SAR Rib

- Tested with a "traditional" and "Wave Piercing" bow, creating two data sets.
- Scaled to 10t displacement
- Waterline Length 11.30m. (traditional bow) and 13.06m (wave piercing bow).

CASE STUDY VESSELS

	LWL (m)	Wetted Surface Area (m^2)
NPL 100A	*14.15*	*32.0**
Traditional Launch	12.36	32.4*
Lab Model	11.15	33.6
Jupiter	14.67	35.78
SAR (Traditional Bow)	11.30	30.61
SAR (Wave Piercing Bow)	13.05	32.56



CASE STUDY VESSELS

Comparative Data

	Displacement (t)	LWL (m)	Wetted Surface Area (m^2)	Max. Shaft Power (Patrol Cycle) (kW)	Max. Shaft Power (Pilot Cycle) (kW)
NPL 100A	*10*	*14.15*	*32.0**	*219*	*370*
Traditional Launch	10	12.36	32.4*	310	554
Lab Model	10	11.15	33.6	295**	295**
Jupiter	10	14.67	35.78	340	478
SAR (Traditional Bow)	10	11.30	30.61	350	543
SAR (Wave Piercing Bow)	10	13.05	32.56	311	411

* Excludes Skeg
** Limited to 19.4 knots

CASE STUDY VESSELS

Comparative Data

	Max. Shaft Power (Patrol Cycle) (kW)	Daily Fuel Requirement (Patrol Cycle) (kg)	Max. Shaft Power (Pilot Cycle) (kW)	Daily Fuel Requirement (Pilot Cycle) (kg)
NPL 100A	*219*	*129*	*370*	*235*
Traditional Launch	310	182	554	340
Lab Model	295*	207	295*	276
Jupiter	340	138	478	341
SAR (Traditional Bow)	350	239	543	371
SAR (Wave Piercing Bow)	311	234	411	326

* Limited to 19.4 knots

HYBRID POWER REQUIREMENTS

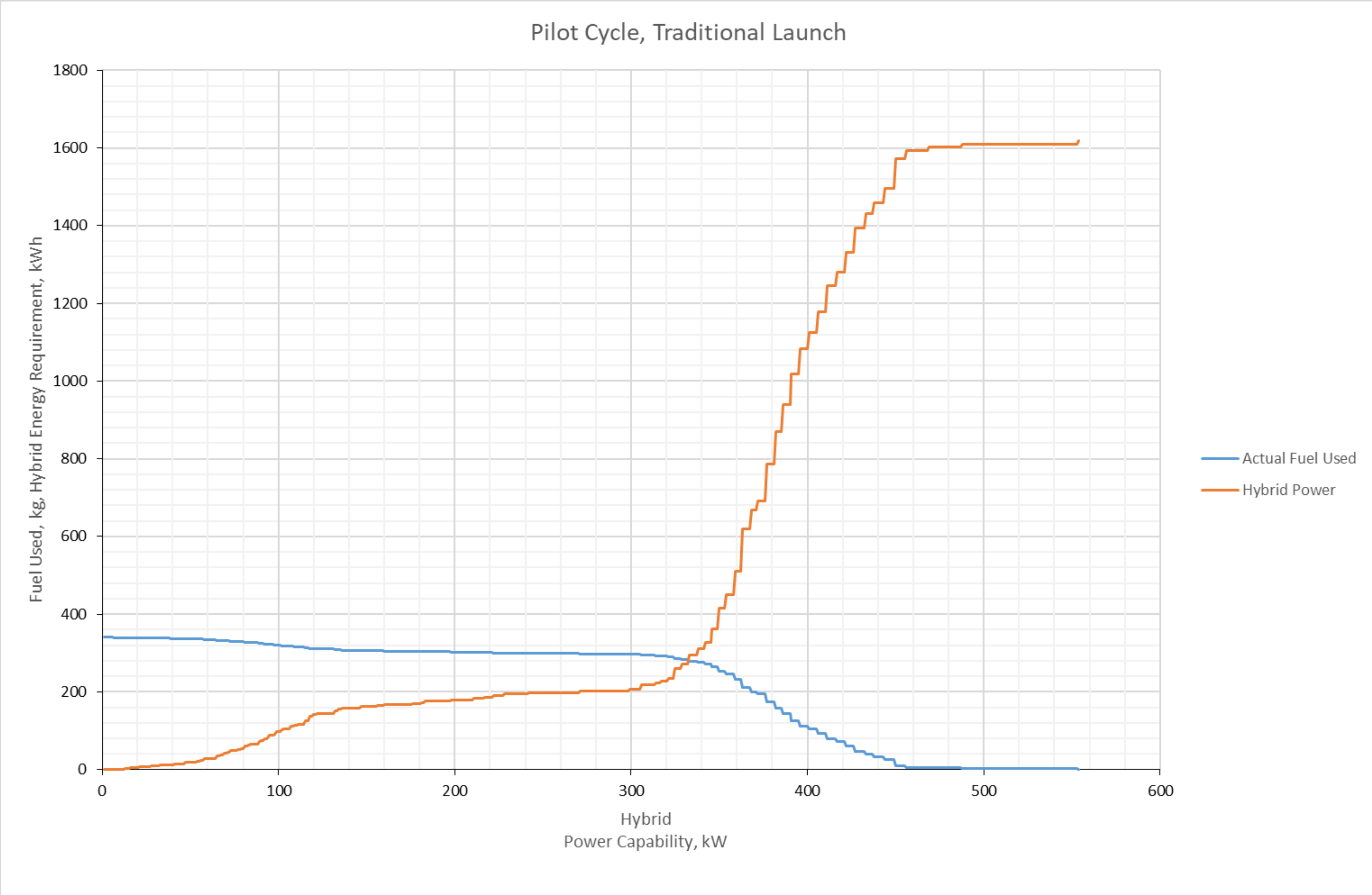
Important Assumptions

- At low power settings electrical propulsion only is used
- At a threshold setting, diesel power only is used
- Assumed QPC 0.55, SFC 210g/kWh

Traditional Hull Hybrid Power Available in kW	Daily Diesel Fuel Requirement (Patrol Cycle) (kg)	Daily Electrical Power Requirement (Patrol Cycle) (kWh)	Daily Diesel Fuel Requirement (Pilot Cycle) (kg)	Daily Electrical Power Requirement (Pilot Cycle) (kWh)
0	182	0	340	0
25	174	42.2	339	7.1
50	162	95.9	339	18.7
75	139	208.0	330	46.6
100	103	378.4	320	96.9

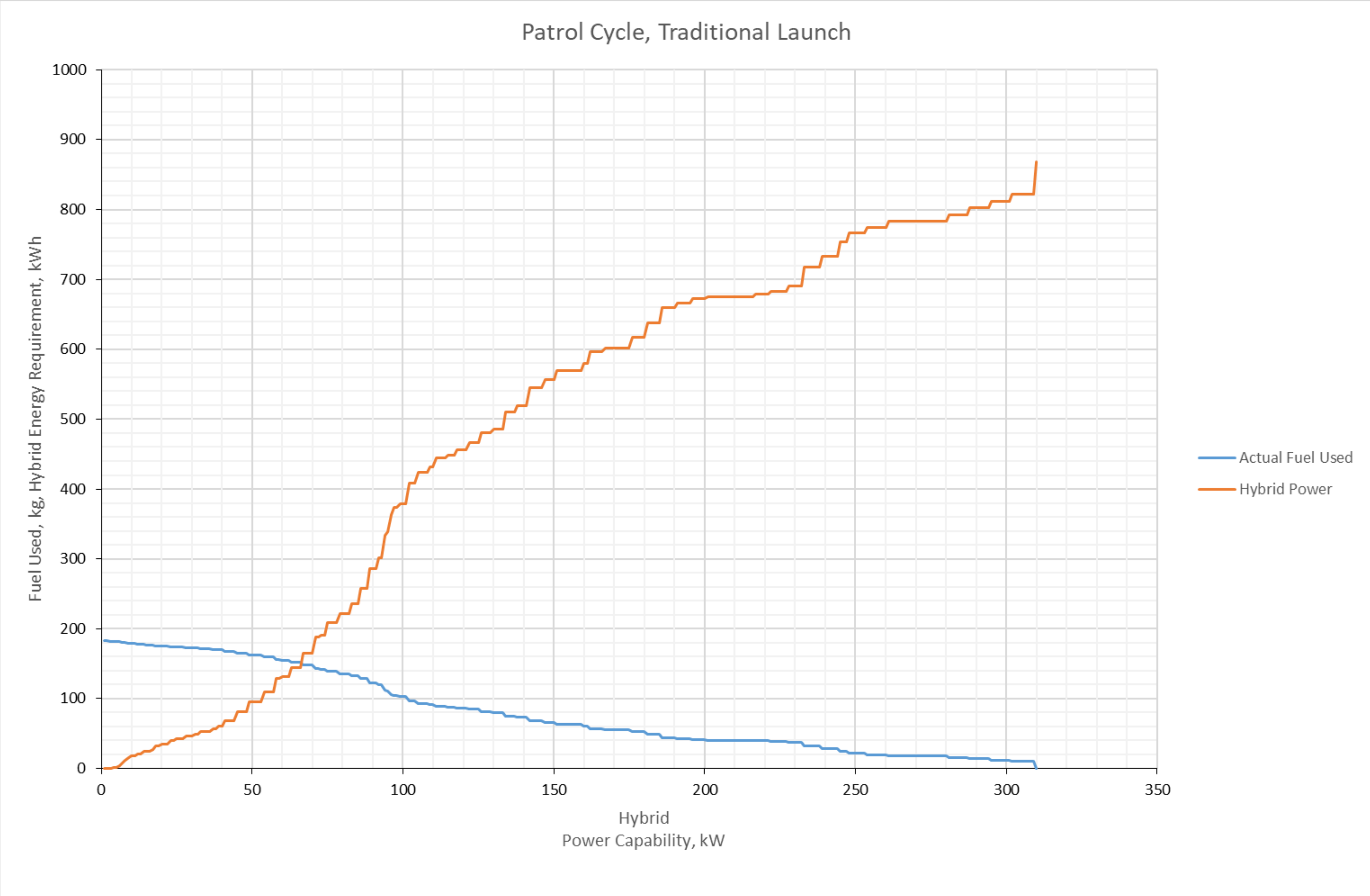
HYBRID POWER REQUIREMENTS

Traditional Launch, Pilot Cycle



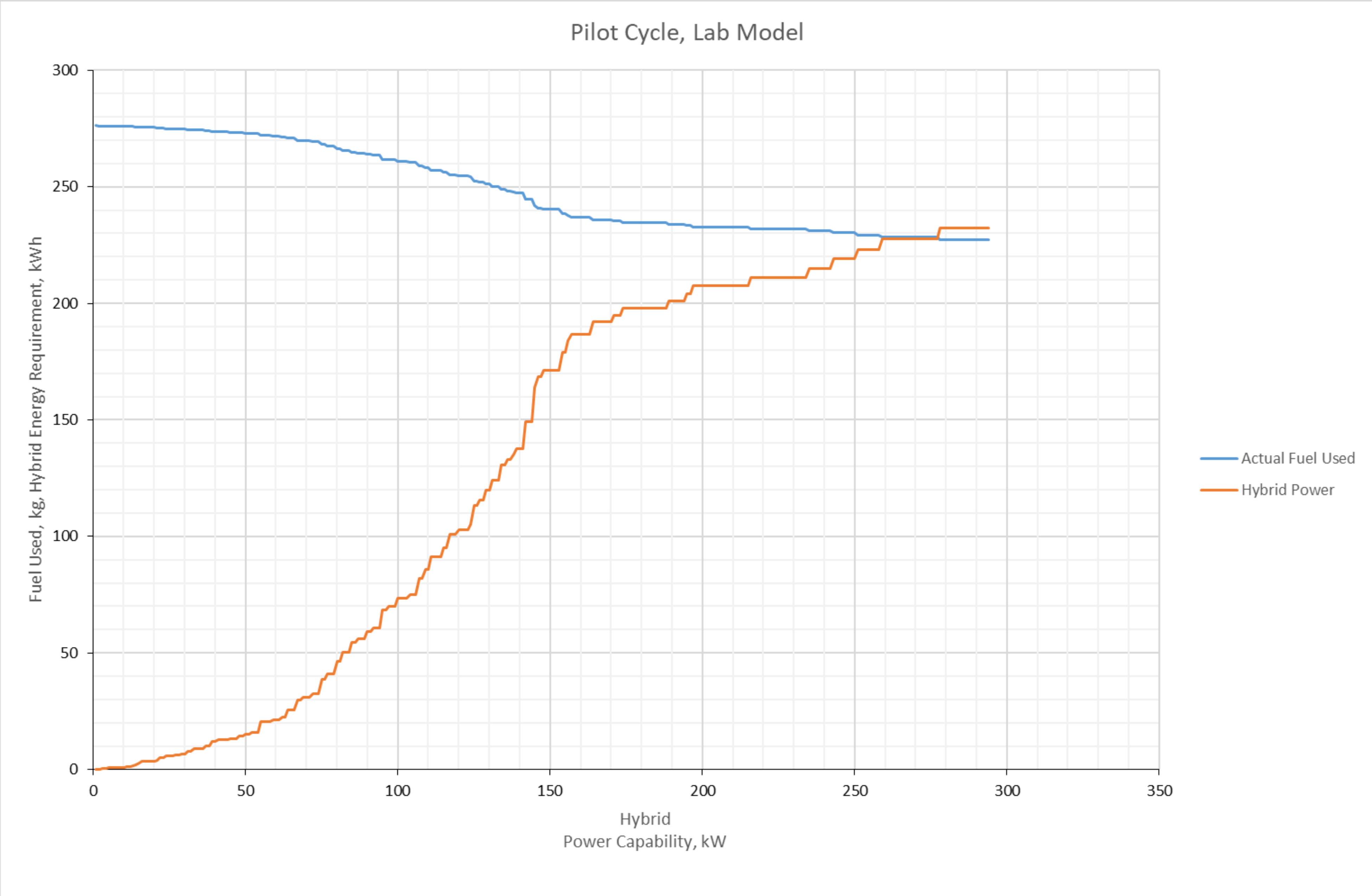
HYBRID POWER REQUIREMENTS

Traditional Launch, Patrol Cycle



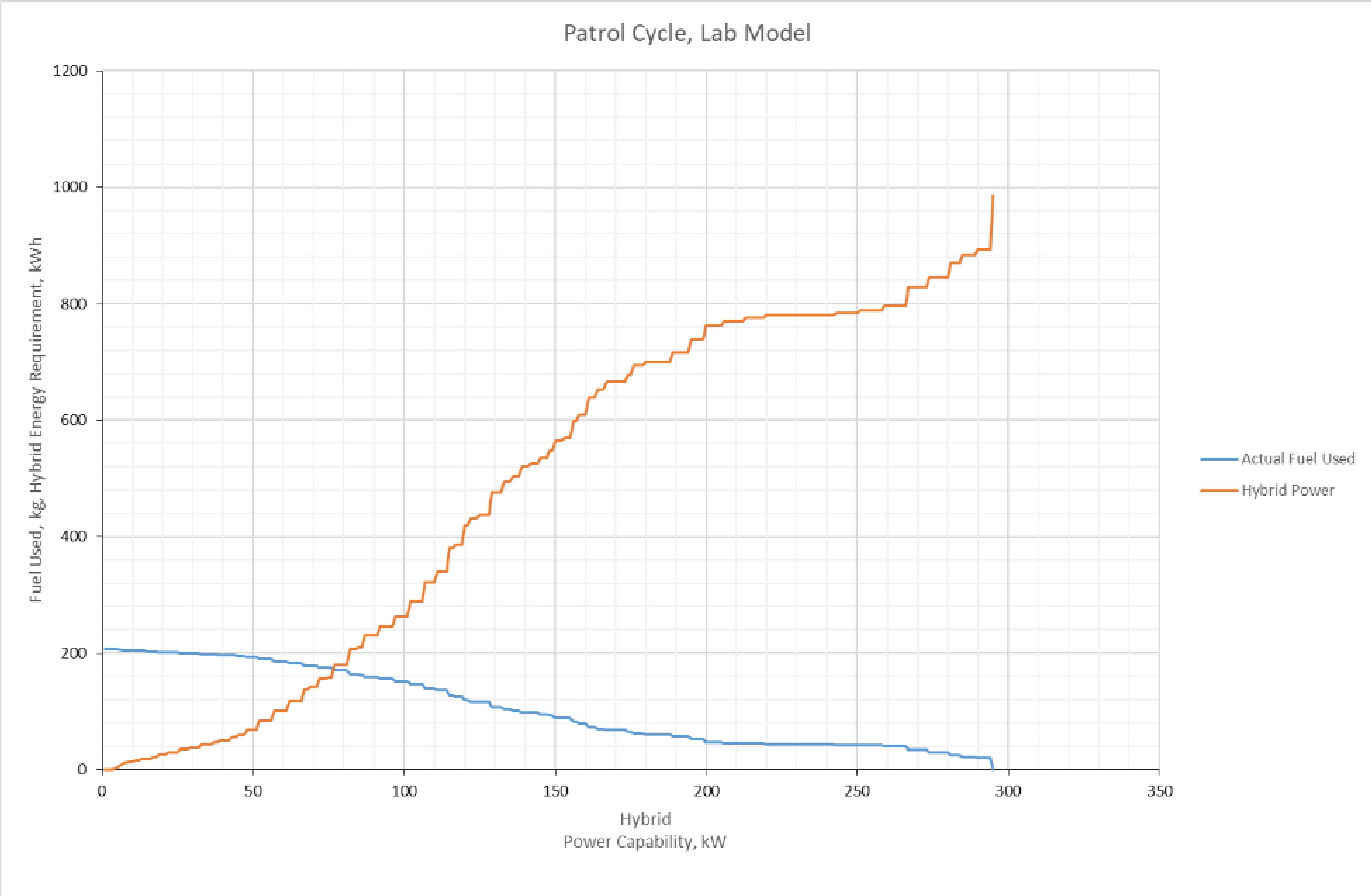
HYBRID POWER REQUIREMENTS

Lab Model Hull, Pilot Cycle



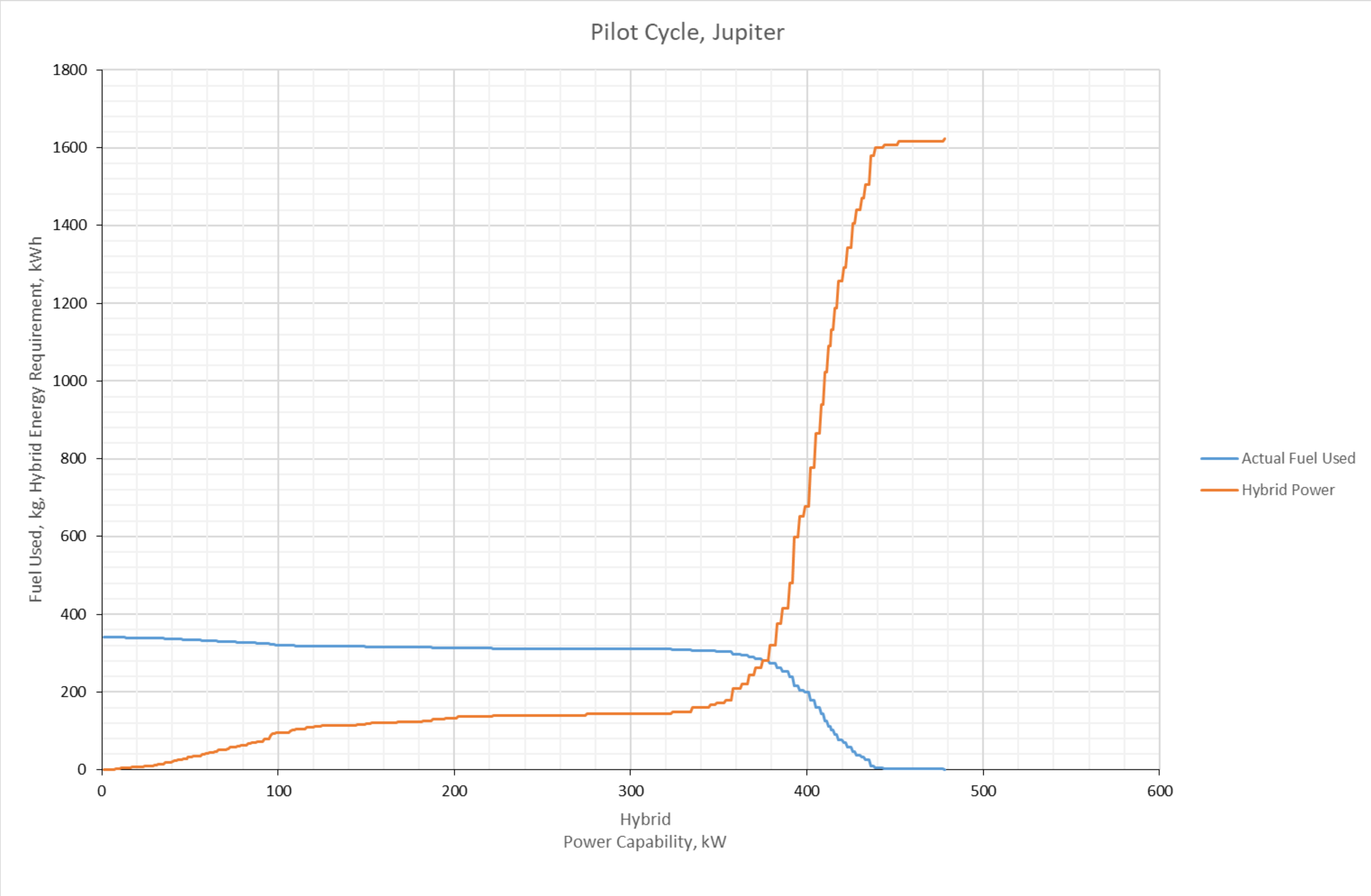
HYBRID POWER REQUIREMENTS

Lab Model Hull, Patrol Cycle



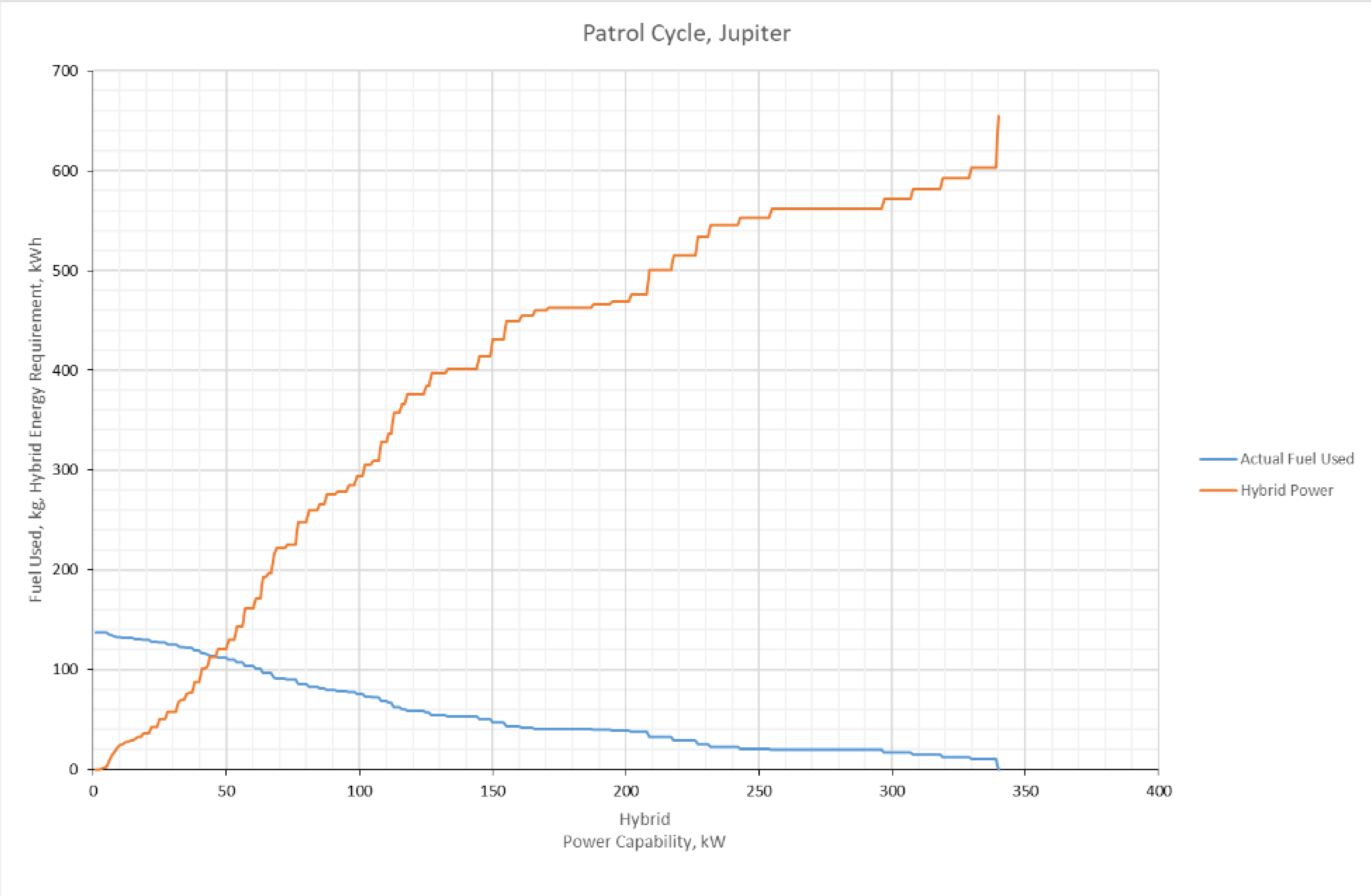
HYBRID POWER REQUIREMENTS

Jupiter Hull, Pilot Cycle



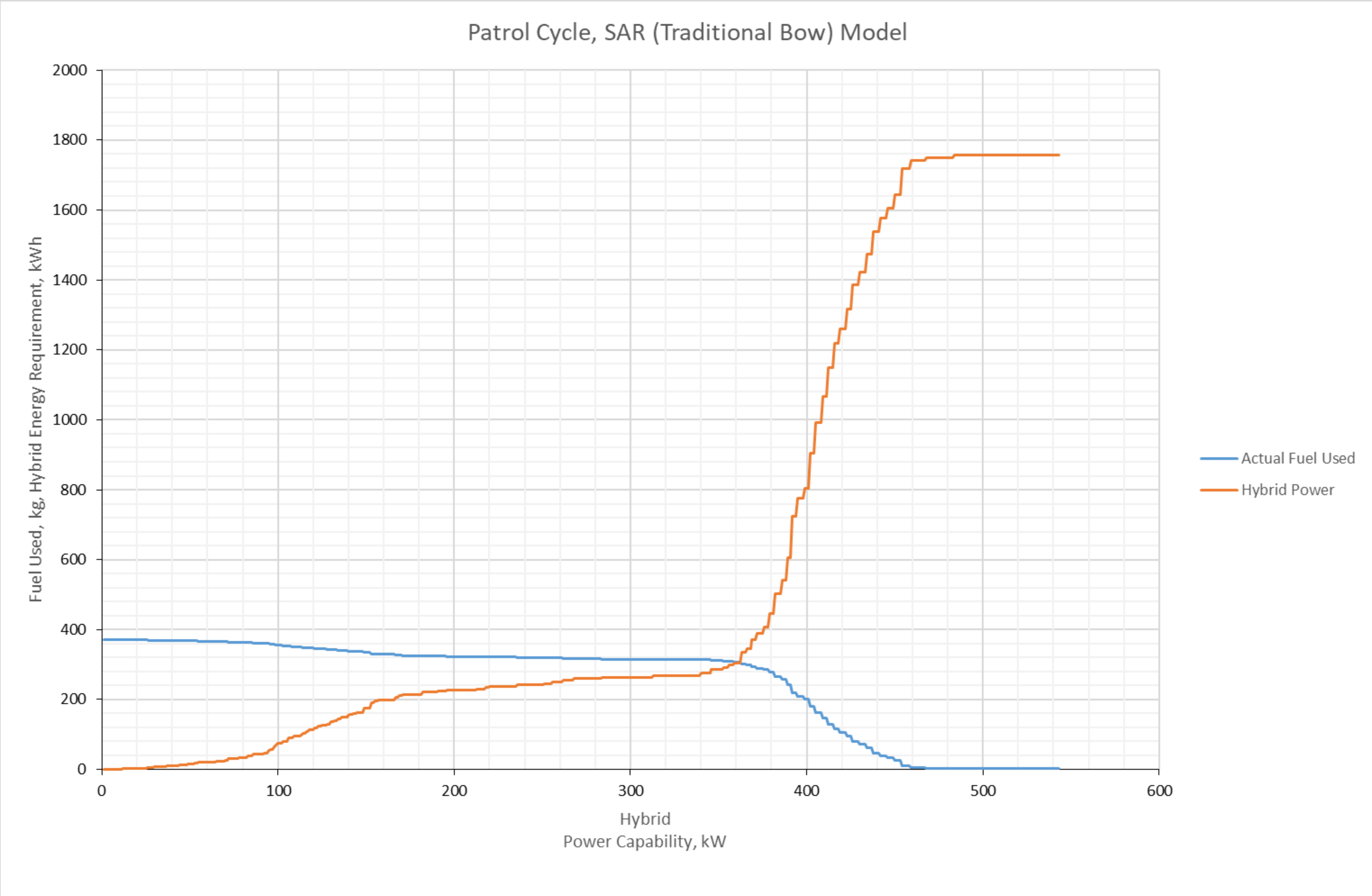
HYBRID POWER REQUIREMENTS

Jupiter Hull, Patrol Cycle



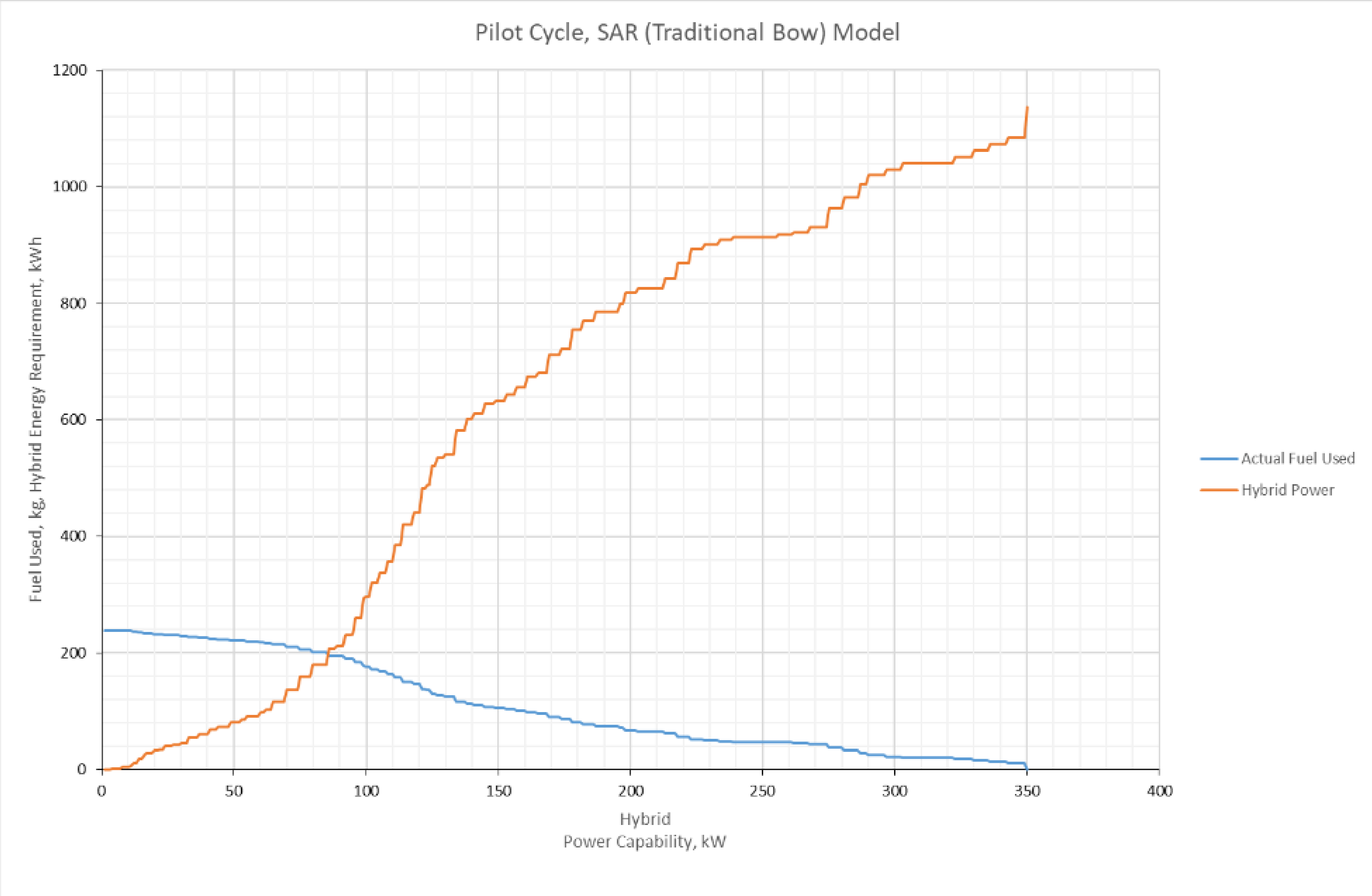
HYBRID POWER REQUIREMENTS

SAR (Traditional Bow) Hull, Pilot Cycle



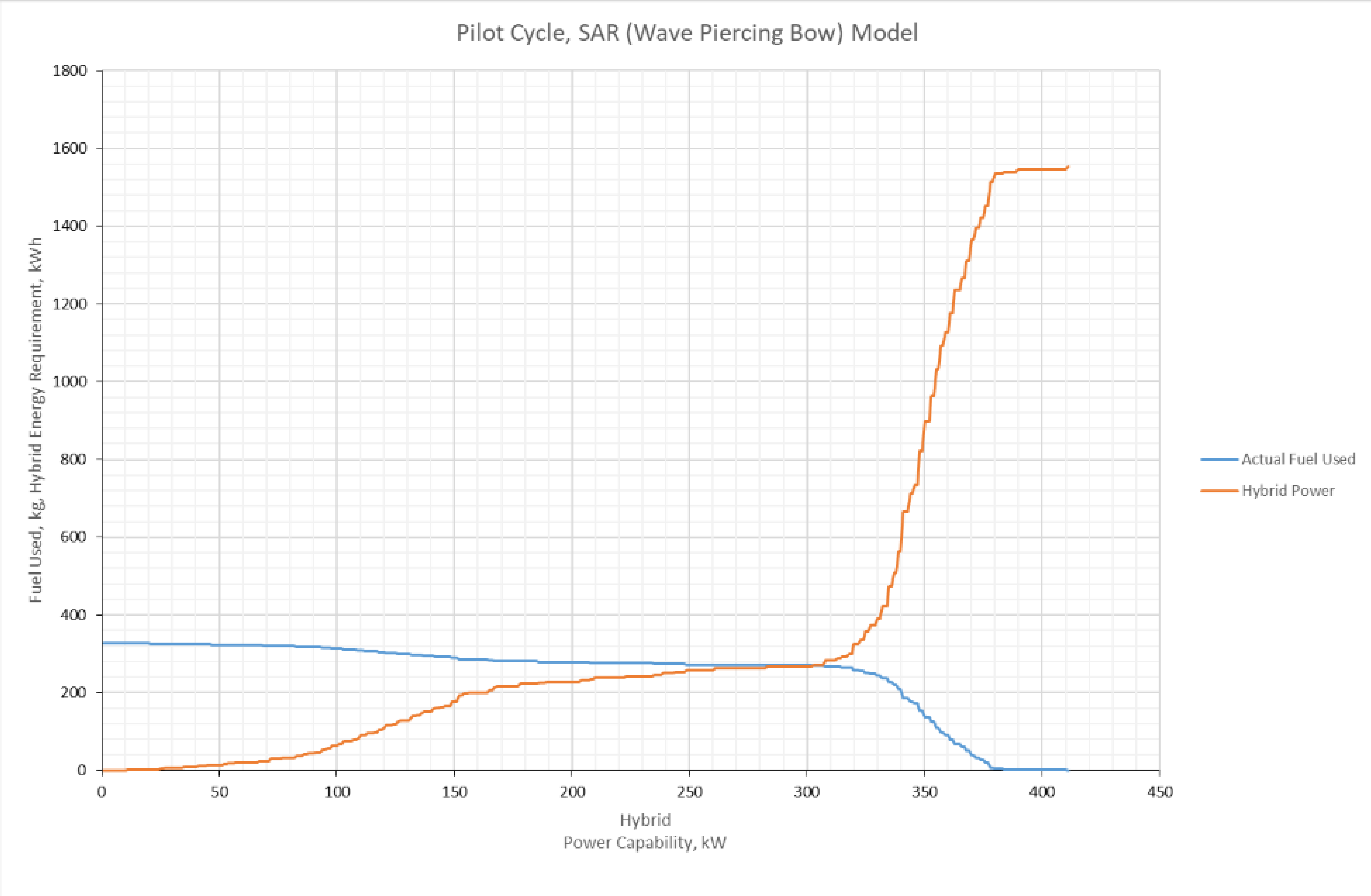
HYBRID POWER REQUIREMENTS

SAR (Traditional Bow) Hull, Patrol Cycle



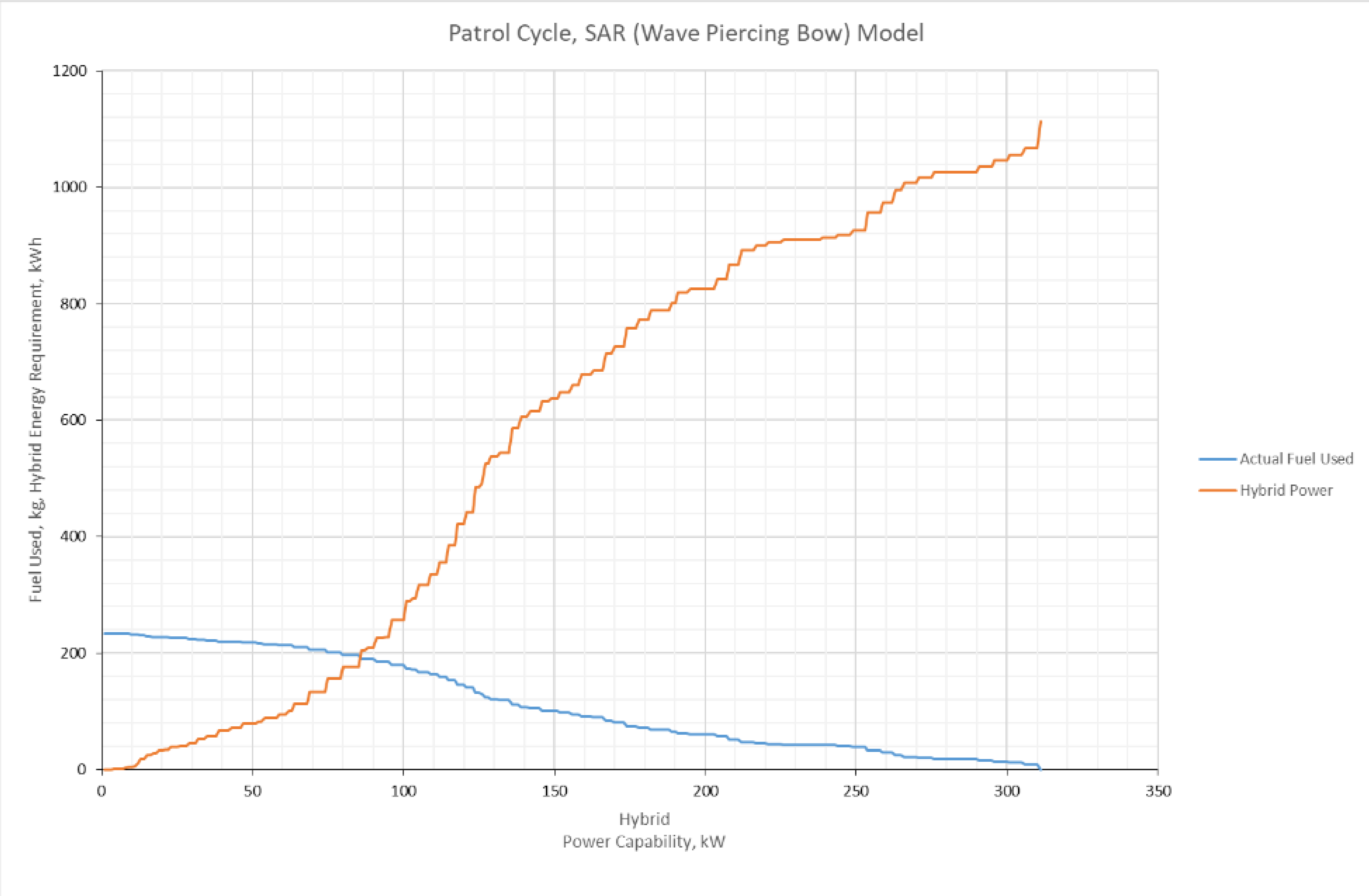
HYBRID POWER REQUIREMENTS

SAR (Wave Piercing Bow) Hull, Pilot Cycle



HYBRID POWER REQUIREMENTS

SAR (Wave Piercing Bow) Hull, Patrol Cycle



HYBRID POWER REQUIREMENTS

Fuel and Energy Summary

24 Hour Cycle Fuel Requirements, kg										
Hybrid	**Traditional Workboat**		**Lab Model**		**Jupiter**		**SAR (Traditional)**		**SAR (Wave Piercing)**	
Power, kW	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol
0	340	182	276	207	341	137	371	239	326	234
25	339	174	275	201	339	127	370	230	325	226
50	336	162	273	193	334	112	368	222	323	217
75	330	139	268	174	329	90	364	205	320	201
100	320	103	261	152	321	76	355	176	313	180

24 Hour Hybrid Power Requirements, kWh										
Hybrid	**Traditional Workboat**		**Lab Model**		**Jupiter**		**SAR (Traditional)**		**SAR (Wave Piercing)**	
Power, kW	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol
0	0	0	0	0	0	0	0	0	0	0
25	7.1	42.2	5.8	29.6	8.9	50.1	3.4	39.8	4.1	38.8
50	18.7	95.9	15.0	68.2	32.5	120.7	15.2	80.9	14.7	78.2
75	46.6	208	38.5	157.1	58.5	225.1	31.0	158.7	30.3	155.4
100	96.9	378.4	73.3	263.4	94.1	293.6	73.9	296.4	63.2	256.4

HYBRID POWER REQUIREMENTS

Fuel and Energy Summary

24 Hour Cycle Fuel Savings, kg										
Hybrid	Traditional Workboat		Lab Model		Jupiter		SAR (Traditional)		SAR (Wave Piercing)	
Power, kW	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol
0	0	0	0	0	0	0	0	0	0	0
25	1	8	1	6	2	10	1	9	1	8
50	4	20	3	14	7	25	3	17	3	17
75	10	43	8	33	12	47	7	34	6	33
100	20	79	15	55	20	61	16	63	13	54

24 Hour Hybrid Power Requirements, kWh										
Hybrid	Traditional Workboat		Lab Model		Jupiter		SAR (Traditional)		SAR (Wave Piercing)	
Power, kW	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol
0	0	0	0	0	0	0	0	0	0	0
25	7.1	42.2	5.8	29.6	8.9	50.1	3.4	39.8	4.1	38.8
50	18.7	95.9	15.0	68.2	32.5	120.7	15.2	80.9	14.7	78.2
75	46.6	208.2	38.5	157.1	58.5	225.1	31.0	158.7	30.3	155.4
100	96.9	378.4	73.3	263.4	94.1	293.6	73.9	296.4	63.2	256.4

HYBRID POWER REQUIREMENTS

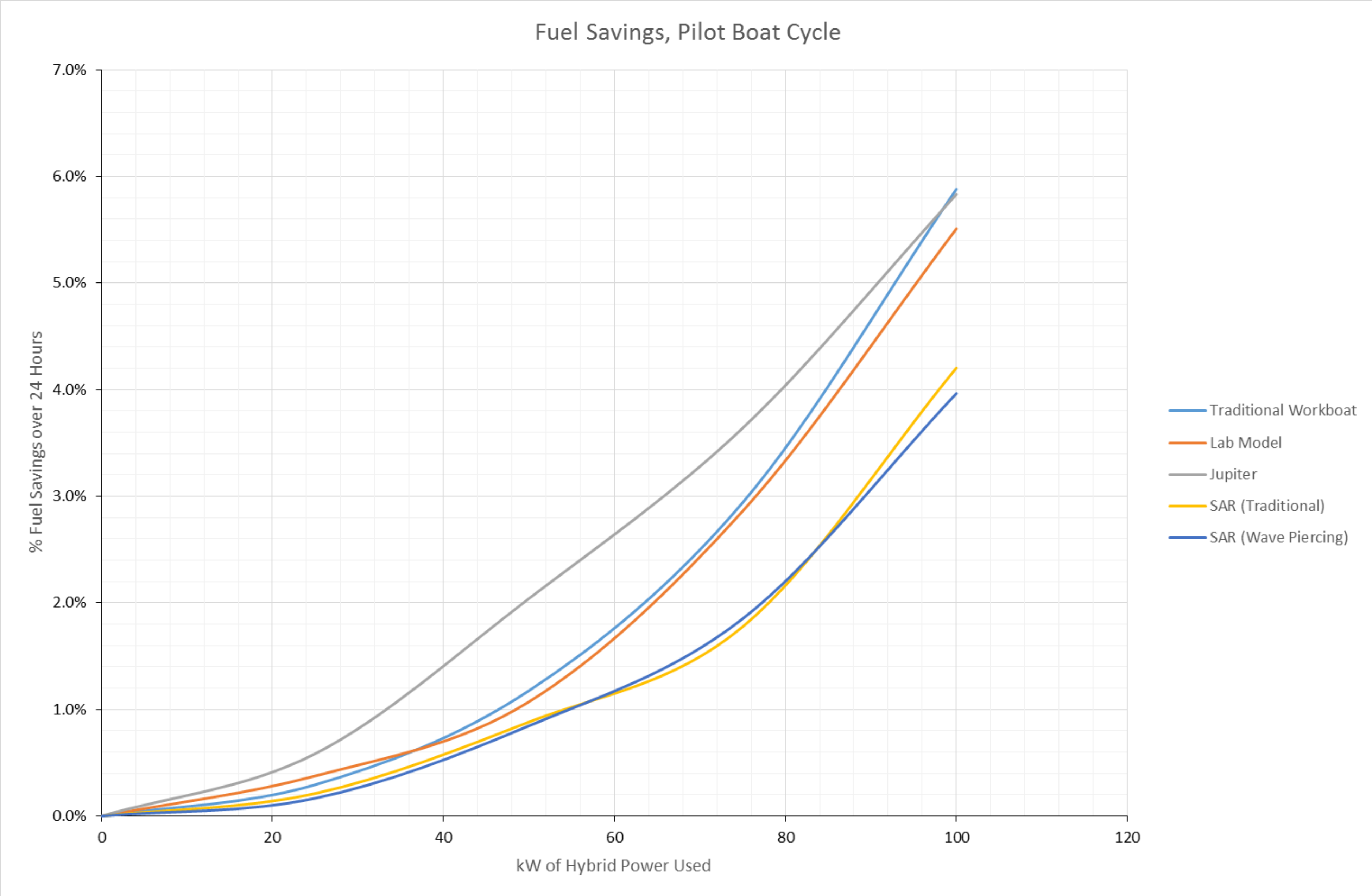
Fuel and Energy Summary

24 Hour Cycle Fuel Savings, %										
Hybrid	Traditional Workboat		Lab Model		Jupiter		SAR (Traditional)		SAR (Wave Piercing)	
Power, kW	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol
0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
25	0.3%	4.6%	0.4%	2.9%	0.6%	7.4%	0.2%	3.6%	0.2%	3.6%
50	1.2%	10.8%	1.1%	6.8%	2.0%	18.2%	0.9%	7.2%	0.8%	7.1%
75	2.9%	23.8%	2.9%	15.8%	3.6%	34.1%	1.8%	14.1%	1.9%	14.1%
100	5.9%	43.4%	5.5%	26.6%	5.8%	44.6%	4.2%	26.2%	4.0%	23.2%

24 Hour Hybrid Power Requirements, kWh										
Hybrid	Traditional Workboat		Lab Model		Jupiter		SAR (Traditional)		SAR (Wave Piercing)	
Power, kW	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol	Pilot	Patrol
0	0	0	0	0	0	0	0	0	0	0
25	7.1	42.2	5.8	29.6	8.9	50.1	3.4	39.8	4.1	38.8
50	18.7	95.9	15.0	68.2	32.5	120.7	15.2	80.9	14.7	78.2
75	46.6	208.2	38.5	157.1	58.5	225.1	31.0	158.7	30.3	155.4
100	96.9	378.4	73.3	263.4	94.1	293.6	73.9	296.4	63.2	256.4

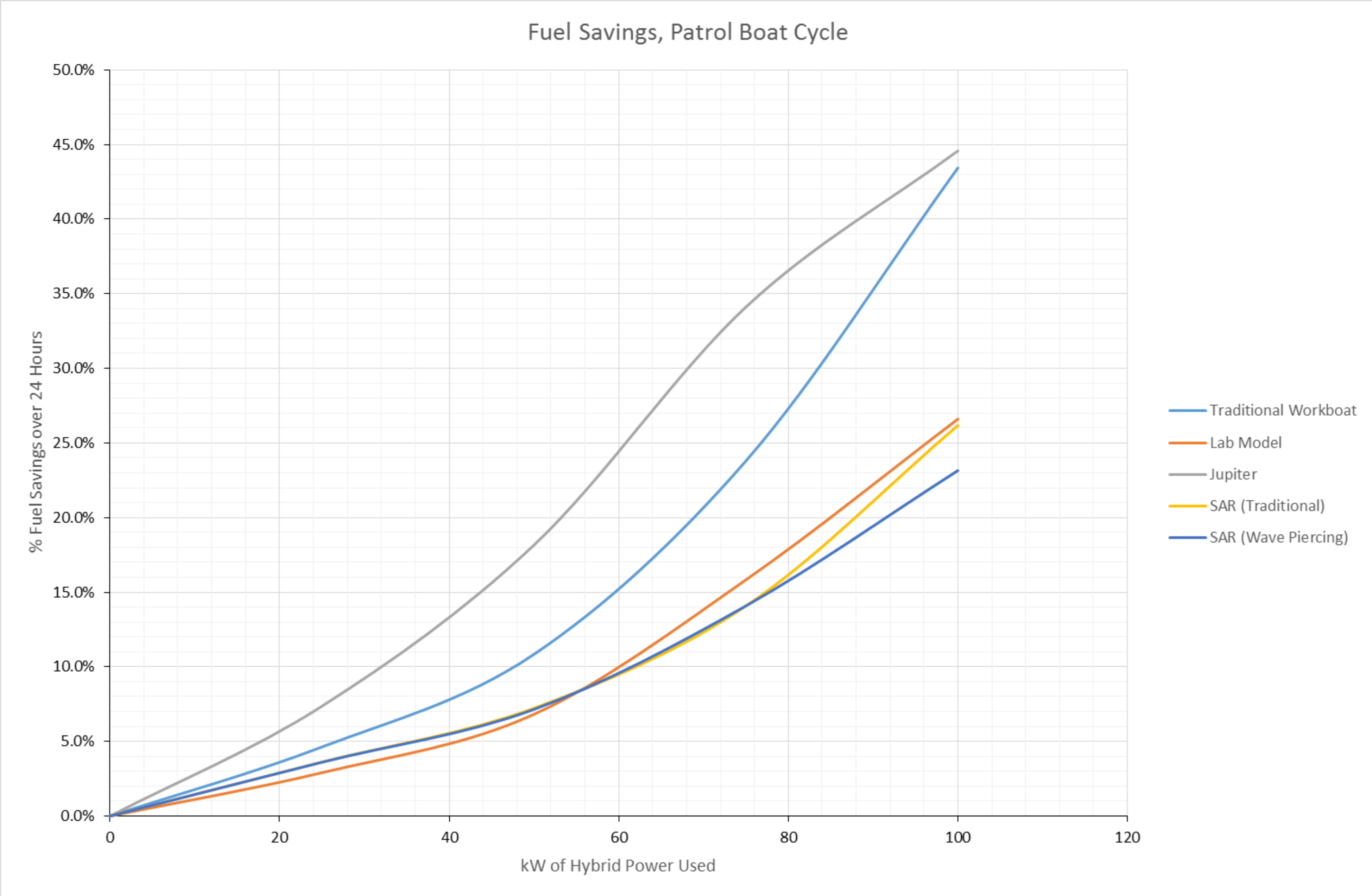
HYBRID POWER REQUIREMENTS

Fuel and Energy Summary



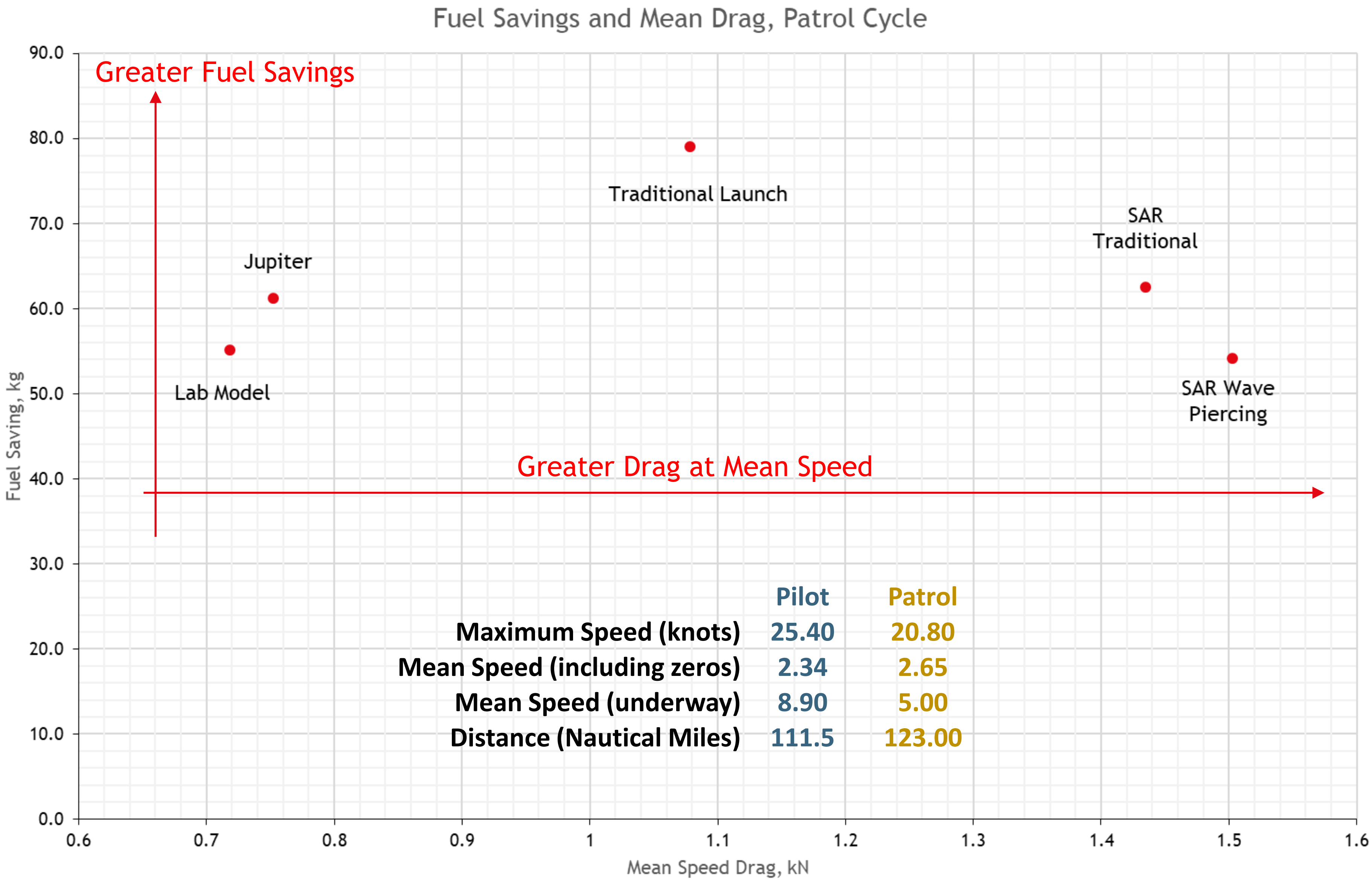
HYBRID POWER REQUIREMENTS

Fuel and Energy Summary



HYBRID POWER REQUIREMENTS

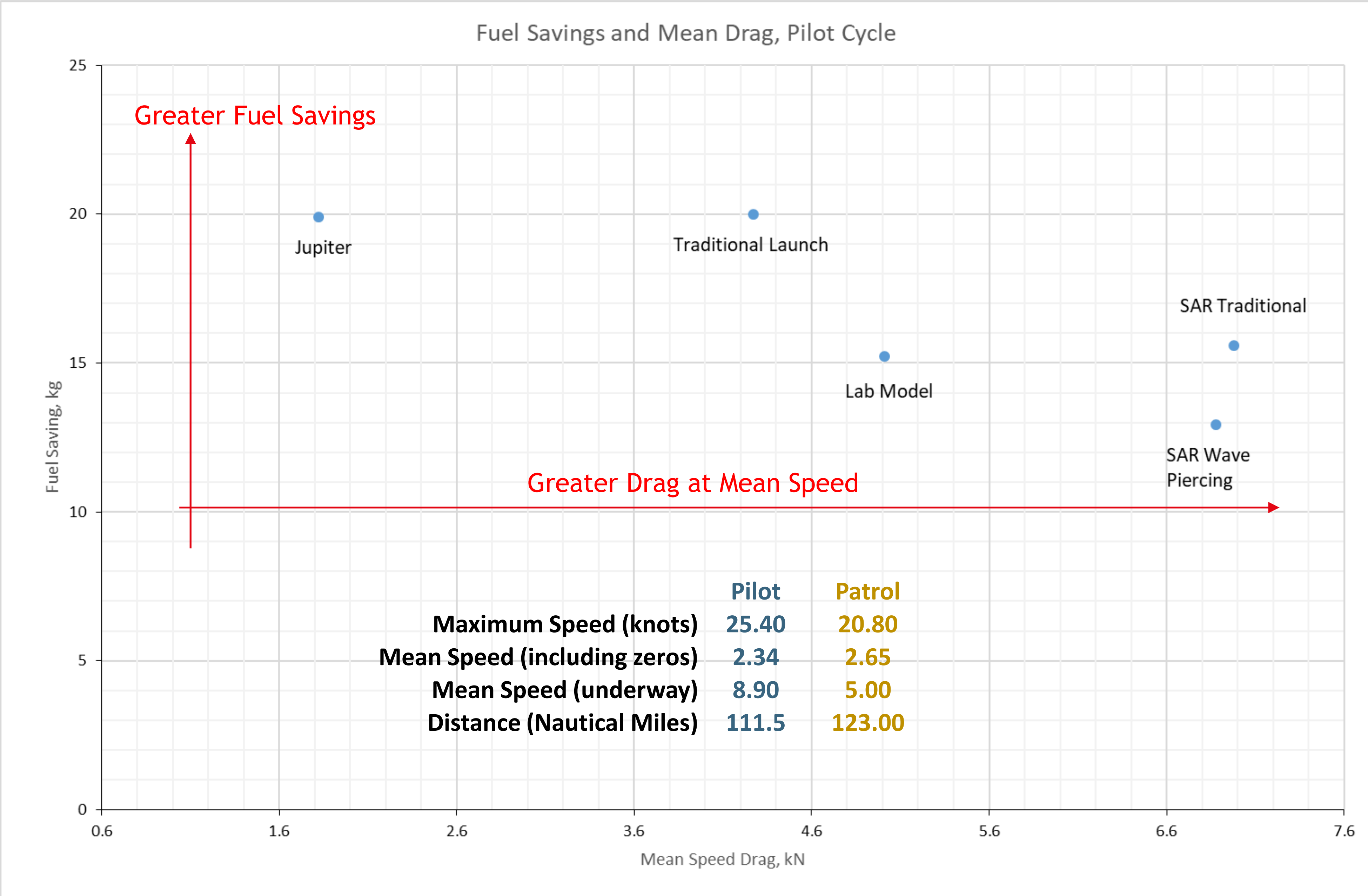
Fuel Savings, Patrol Cycle, 100kW



	Pilot	Patrol
Maximum Speed (knots)	25.40	20.80
Mean Speed (including zeros)	2.34	2.65
Mean Speed (underway)	8.90	5.00
Distance (Nautical Miles)	111.5	123.00

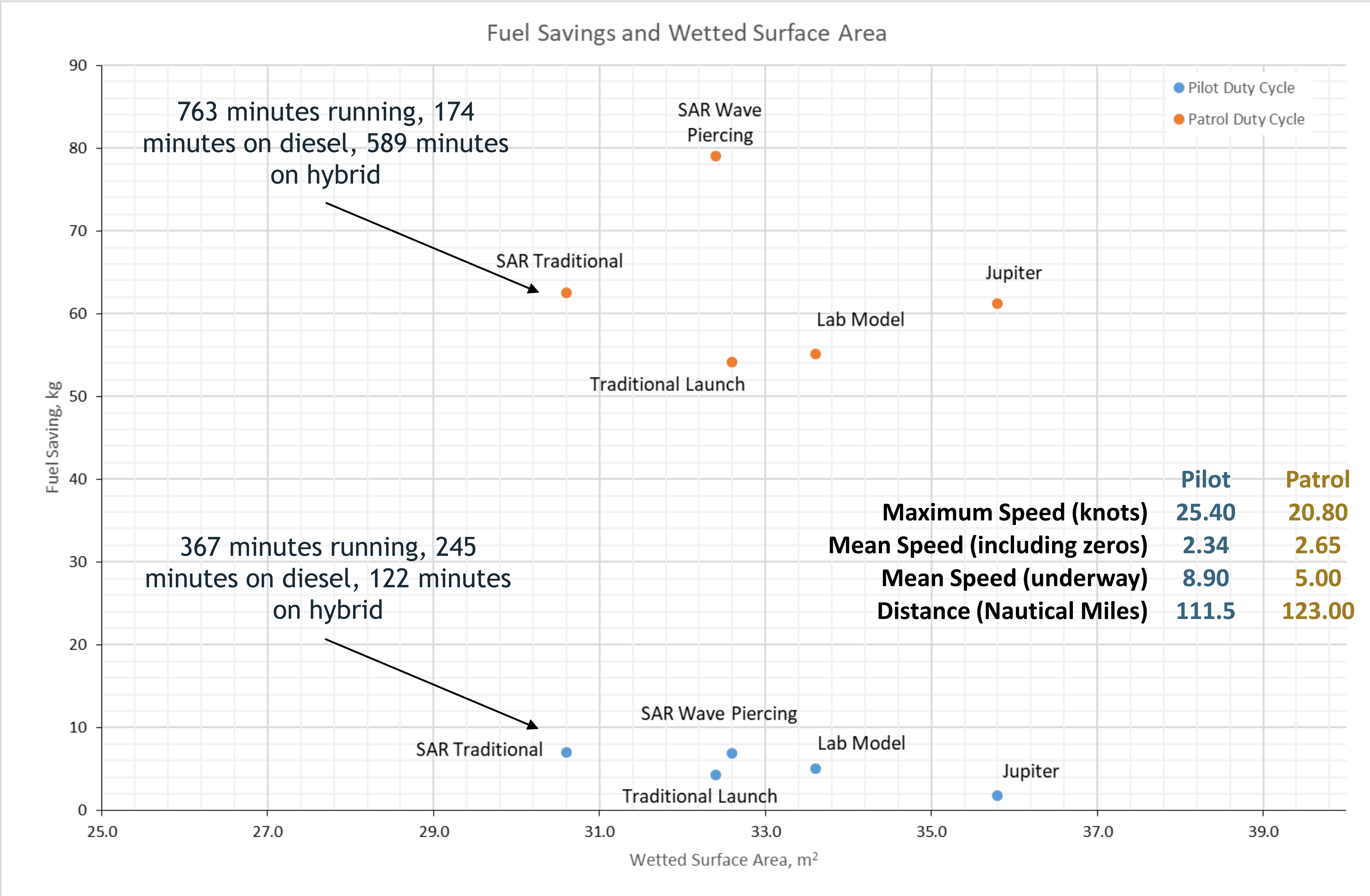
HYBRID POWER REQUIREMENTS

Fuel Savings, Pilot Cycle, 100kW



HYBRID POWER REQUIREMENTS

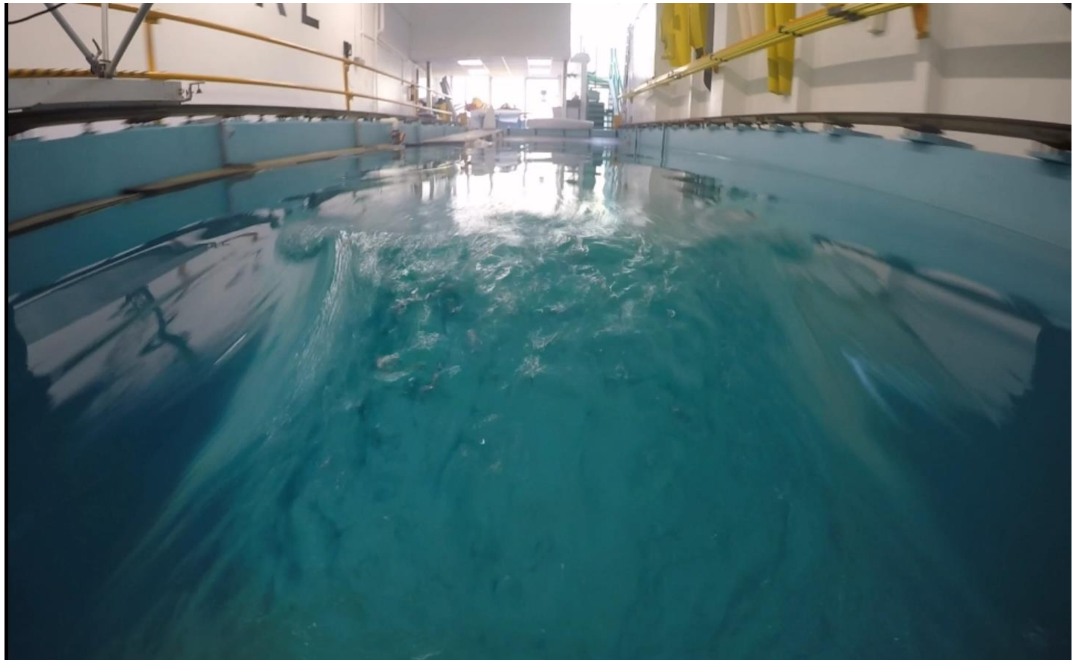
Fuel Savings, Both Cycles, 100kW

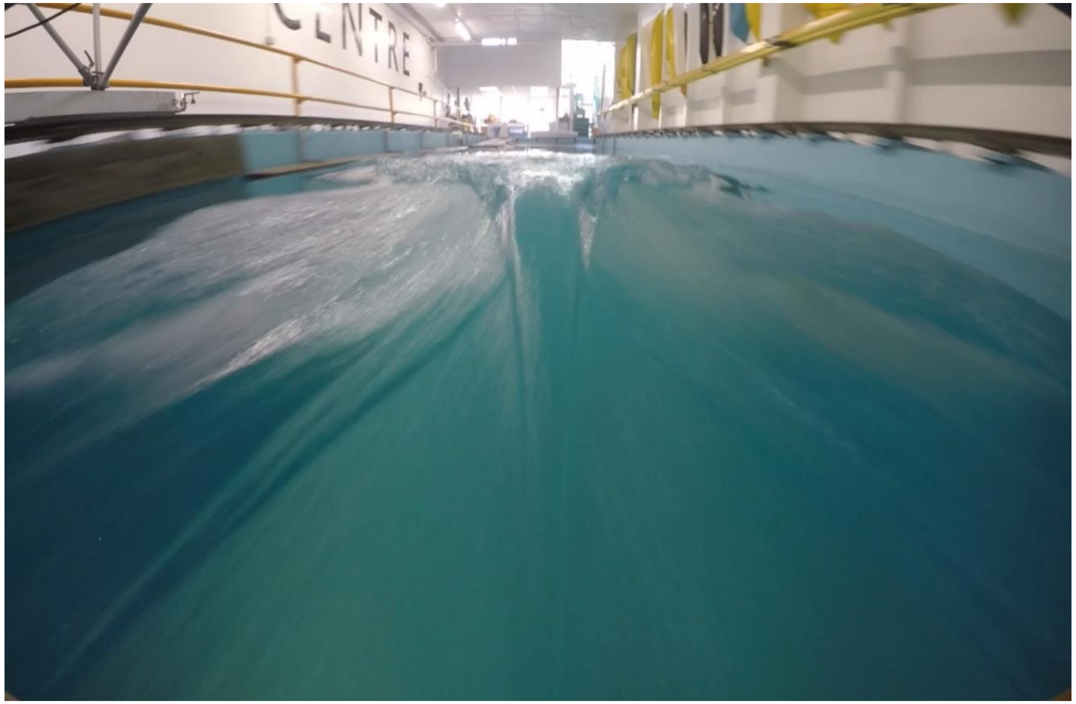


CONCLUSION

Summary

- Fuel savings are clearly dependent on hull forms.
- Lower service speeds are far more effective for hybrid fuel savings.
- Lower wetted surface areas are more effective at higher speeds - for low mean speeds immersed transoms and additional drag may need optimising.





CONCLUSION

Summary

- More work is needed on:
  - Realistic duty cycles with greater confidence in applicability.
  - Emissions modelling to further understand effects.
  - More accurate modelling of drag with changes in displacement from using fuel and retro-fitting hybrid systems.
  - More accurate modelling of efficiencies in the propulsion system.
  - Optimising hull forms to reduce resistance for the displacement at typical mean service speeds.
  - Effects of added resistance in waves for Sub-IMO commercial vessels.
  - Life Cycle Assessment of hybrid options.

Thank You - Any Questions?

Southampton SOLENT University