

Autonomous Vessels for Towing Tasks in Offshore Fish Farming

Clifford A. Goudey
C.A. Goudey & Associates
21 Marlboro Street
Newburyport, MA 01950
cliffgoudey@gmail.com

William A. Lincoln
Response Marine, Inc.
25 High Street
Newburyport, MA 01950
wal@responsemarine.com

Joseph A. Curcio
Robotic Marine Systems, LLC
139 Cottage Road
Gray, ME 04039
jacurcio@netscape.net

Challenges and Opportunities for Robotics and Automation Applied to Aquaculture
Woods Hole, MA
Jan. 11, 2016

Vessel Use at Offshore Fish Farms

Task	Requirements		
	Speed	Cargo cap.	Tow power
Mooring installation	?	✓	✓
Cage installation	?	?	✓
Stocking	✓	✓	?
Husbandry	✓	✓	?
Harvest	✓	✓	?
Cage towing	?	?	✓

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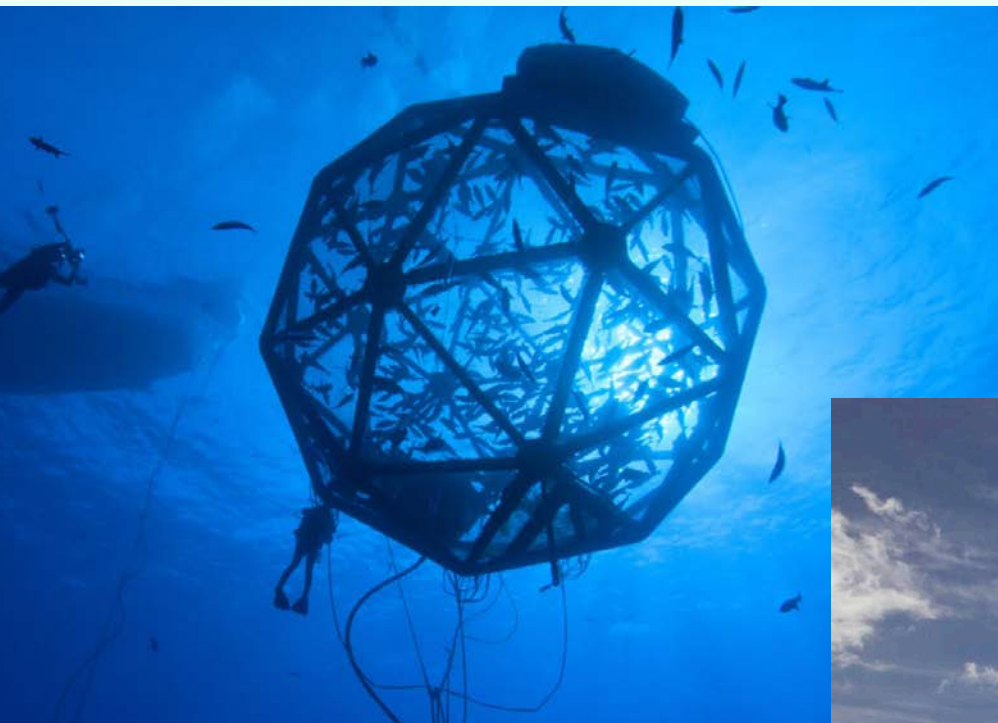
Role of the typical fish-farm service vessel



Cage towing often involves the charter of tugboat



The Valella Project



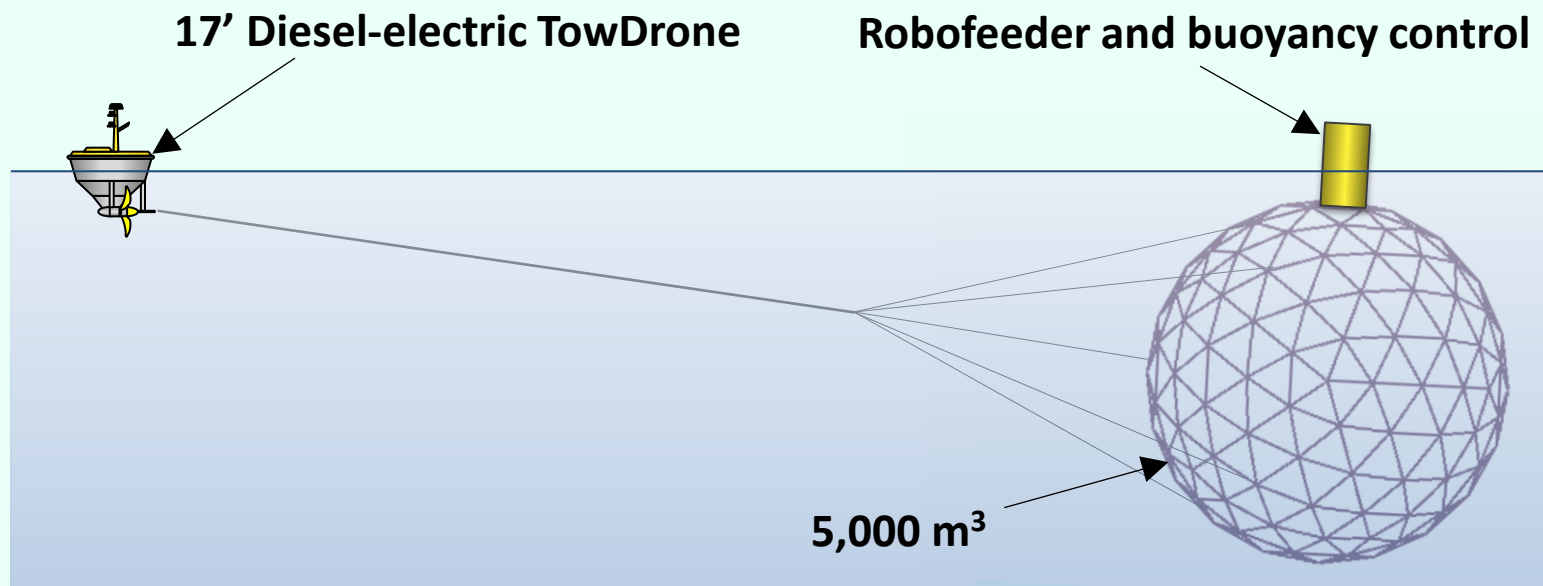
A 65' motorsailer connected to a 22' diameter Aquapod™ cage.

While obviously a pilot effort, it demonstrated that unanchored, drifting cages can be commercially viable.



Is this a more viable approach?

A 17' vessel connected to a 70' diameter, 5,000 m³ Aquapod™



Requires re-supply visits (feed & fuel) every one to two weeks depending on stocking density

TowDrone Specifications

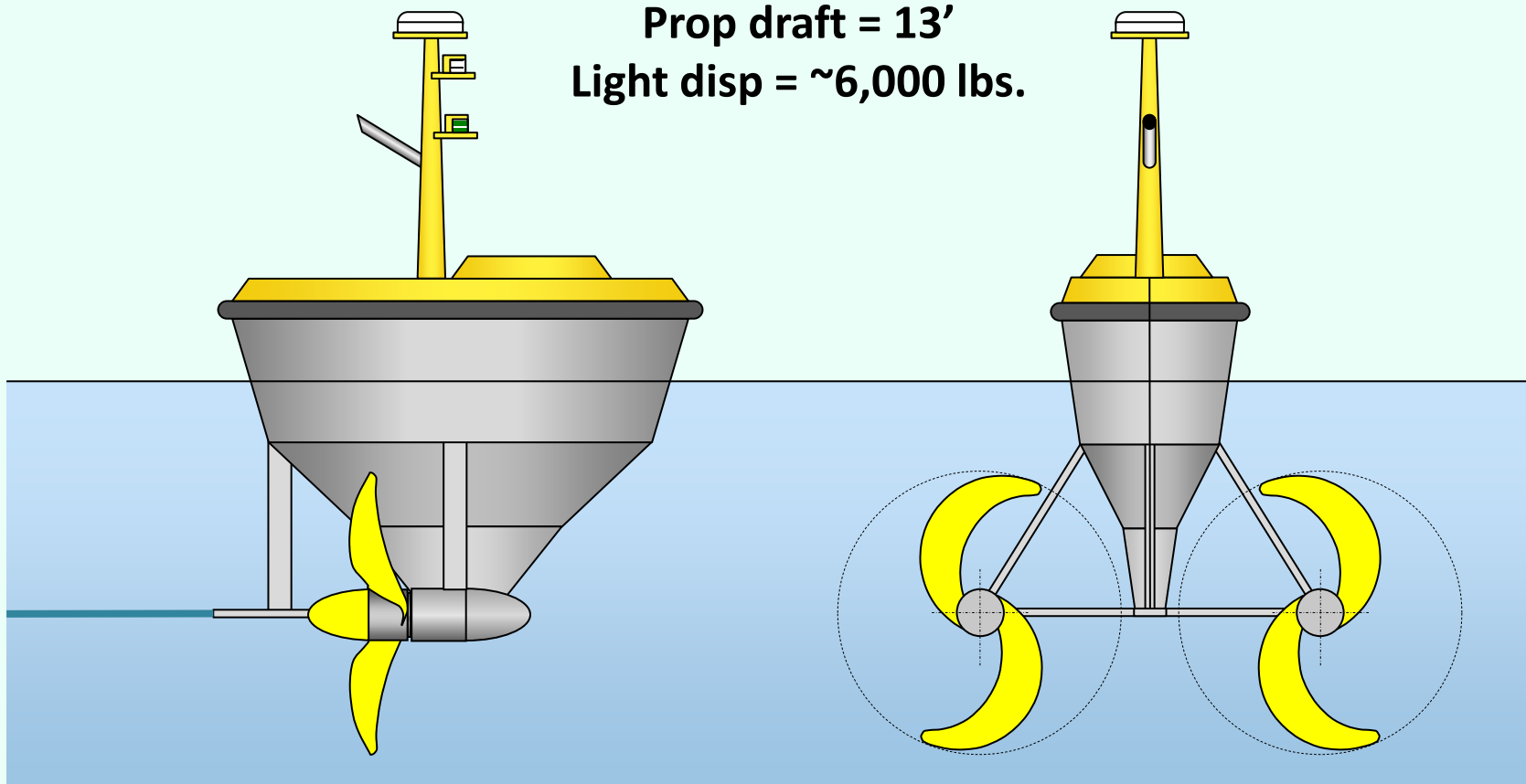
LOA = 17'

Beam = 7'

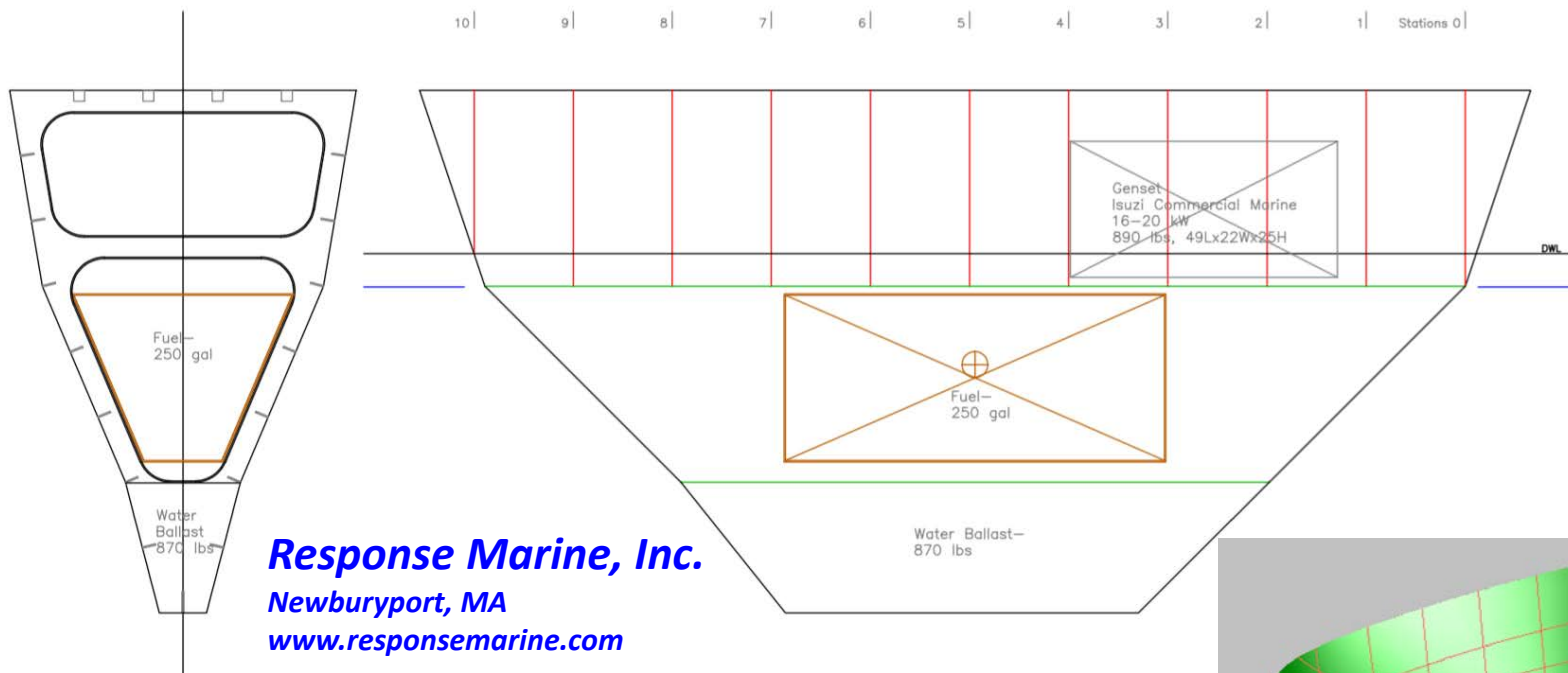
Draft = 9'

Prop draft = 13'

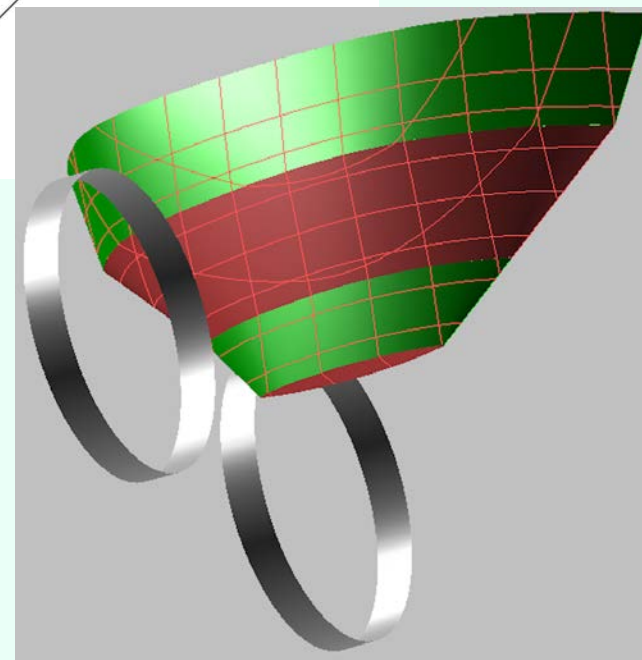
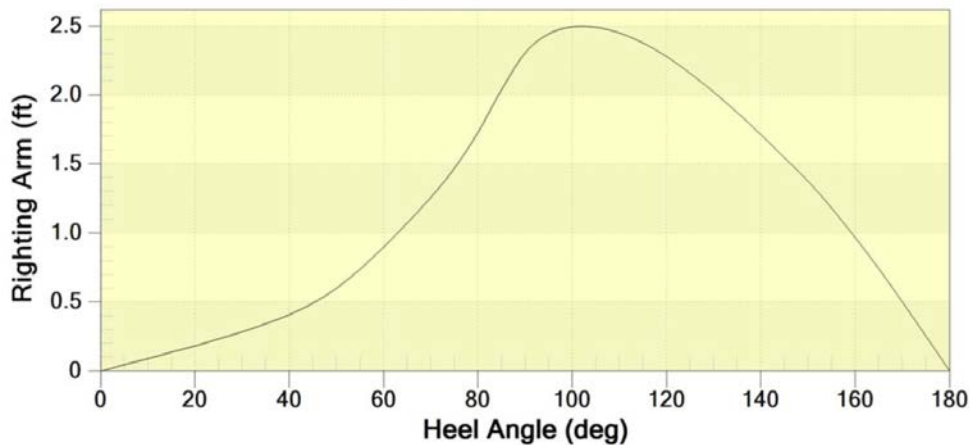
Light disp = ~6,000 lbs.



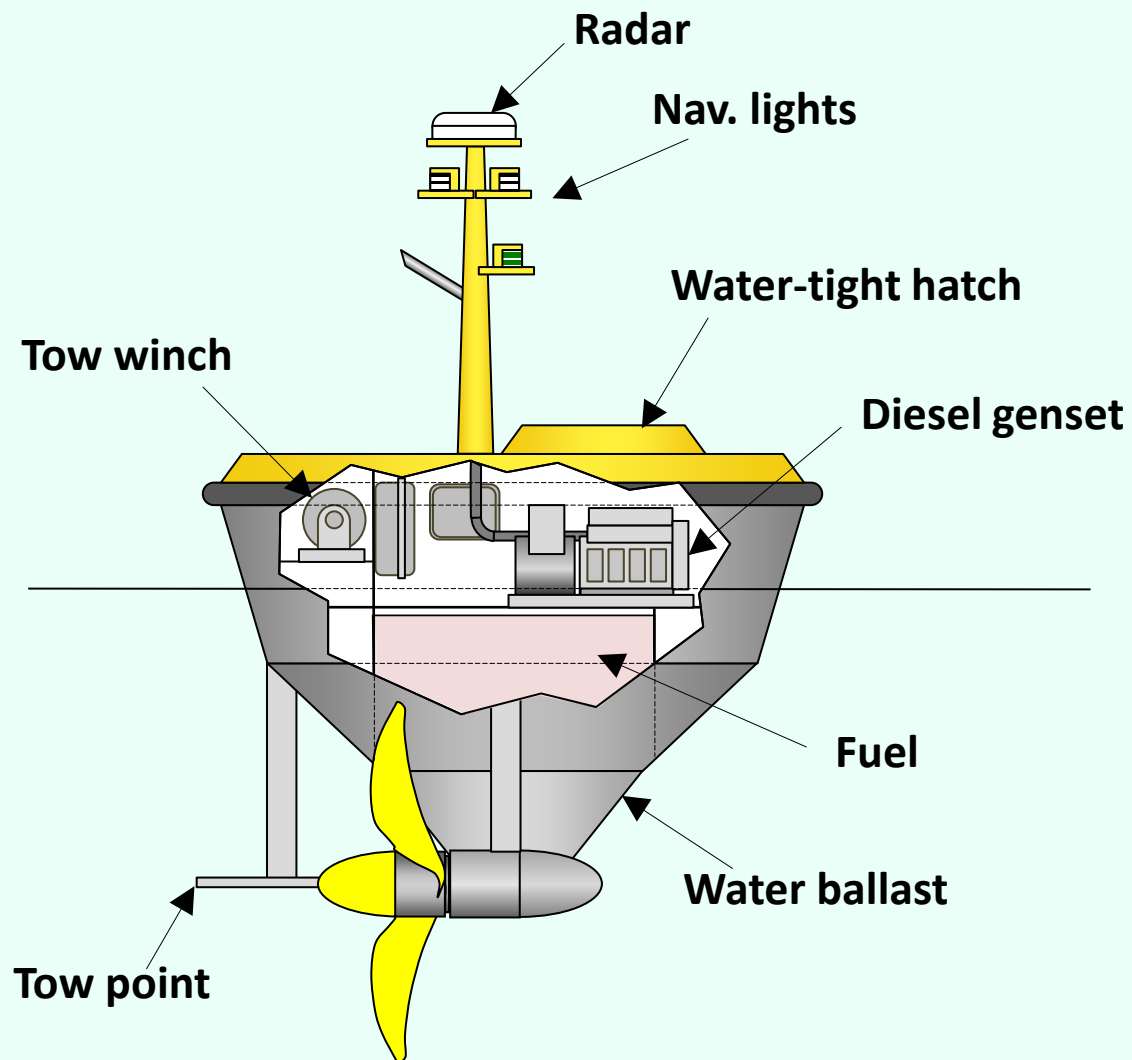
Preliminary design exercise



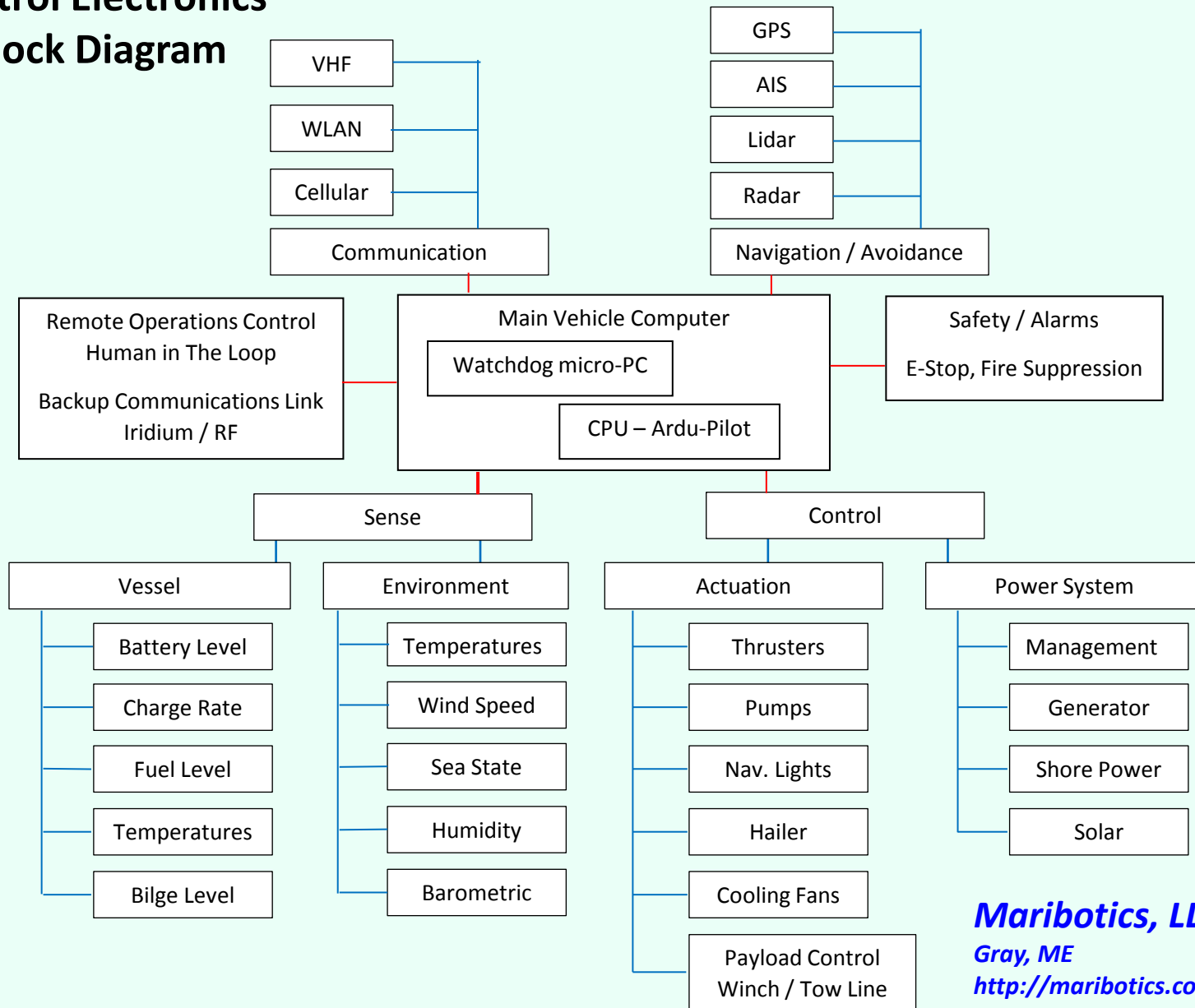
Righting Arm Curve



TowDrone Preliminary Design

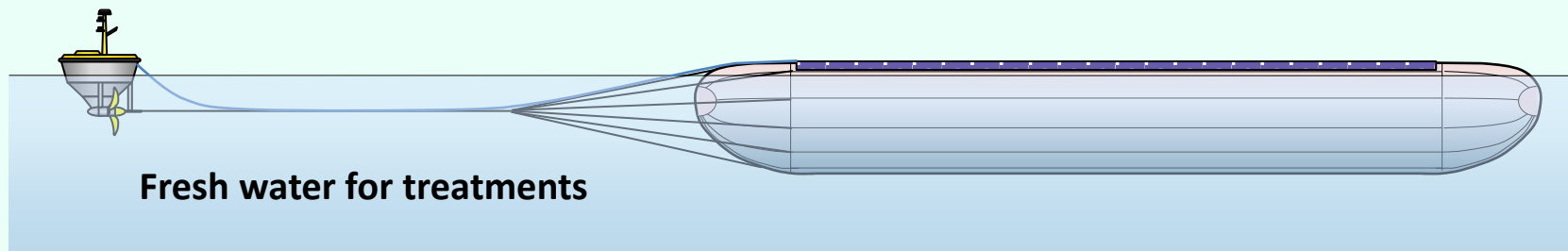
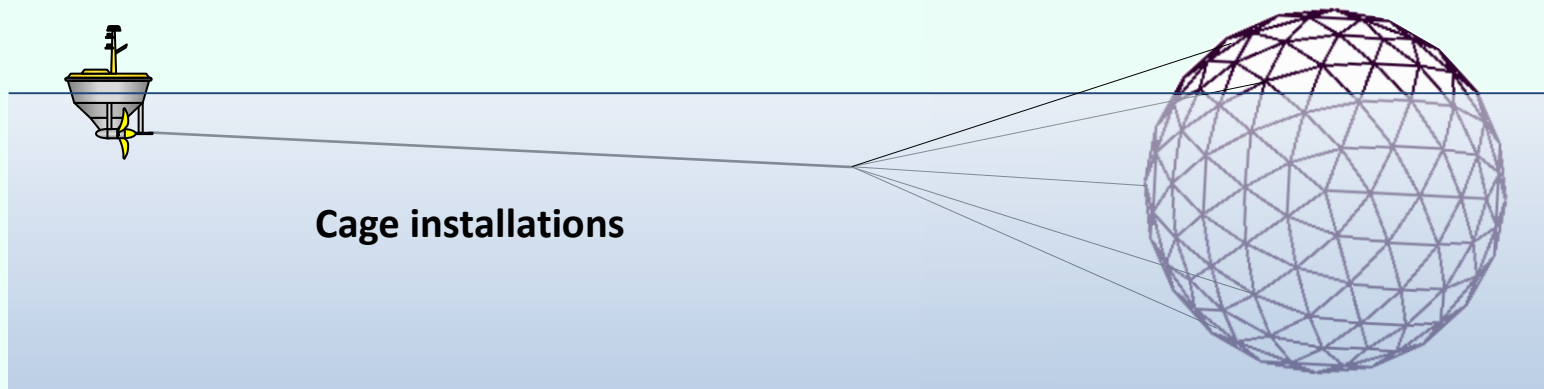


Control Electronics Block Diagram



Maribotics, LLC
 Gray, ME
<http://maribotics.com/>

TowDrone uses in conventional offshore fish farming



Most marine propellers are diameter limited due to draft constraints and the need for a broad range of operating speeds. A kort nozzle slightly improves a bad situation.

The key to efficient towing is a large-diameter, slow-turning propeller

By turning to the wastewater-treatment sector we find systems intended for mixing that offer the sort of thruster efficiency needed.

Flygt, a Swedish company and a subsidiary of Xylem, Inc. of NY has a range of low-speed mixers with AC power up to 8.0 kW.



By selecting the combination of blade length, RPM, and motor size we can achieve optimal performance.

RPM	30			32			35			38			42		
Propeller diameter, mm	F _{thrust} N	P _{in} kW	Prop code	F _{thrust} N	P _{in} kW	Prop code	F _{thrust} N	P _{in} kW	Prop code	F _{thrust} N	P _{in} kW	Prop code	F _{thrust} N	P _{in} kW	Prop code
2500	2190	2,44	440	2470	2,89	400	2780	3,57	450	3080	4,20	410	3630	5,44	460
2200	1880	2,20	441	2180	2,61	401	2530	3,24	451	2880	3,88	411	3380	4,94	461
2000	1510	1,89	442	1740	2,21	402	2050	2,75	452	2460	3,29	412	2770	4,17	462
1800	1120	1,56	443	1290	1,81	403	1540	2,25	453	1750	2,65	413	2130	3,42	463
1700	980	1,44	444	1140	1,67	404	1340	2,05	454	1540	2,40	414	1860	3,07	464
1600	850	1,32	445	990	1,52	405	1160	1,85	455	1340	2,14	415	1610	2,72	465
1500	720	1,18	446	820	1,36	406	970	1,64	456	1120	1,90	416	1350	2,37	466
1400	580	1,04	447	670	1,19	407	790	1,43	457	900	1,65	417	1110	2,01	467

RPM	47			49			55		
Propeller diameter, mm	F _{thrust} N	P _{in} kW	Prop code	F _{thrust} N	P _{in} kW	Prop code	F _{thrust} N	P _{in} kW	Prop code
2500									
2200									
2000									
1800	2640	4,67	423	2850	5,27	473			
1700	2310	4,20	424	2510	4,75	474			
1600	2010	3,72	425	2160	4,21	475			
1500	1690	3,21	426	1820	3,63	476	2200	4,95	436
1400	1370	2,69	427	1490	3,05	477	1830	4,16	437

Maximum thrust comes with a 2,500 mm (98") dia prop spinning at 42 RPM and drawing 5.44 kW (7.3 hp)

Experience to date: demonstration of a self-propelled aquaculture cage to enable deep-ocean fish farming in cooperation with OFT and Snapperfarm off Culebra, PR.



**A pair of 98"-diameter, 5.44 kW Flygt thrusters
for "twin-screw" operation**

**Installed at the equator
of a 3,250 m³ Aquapod
30' underwater**



View from stern

View from
underside



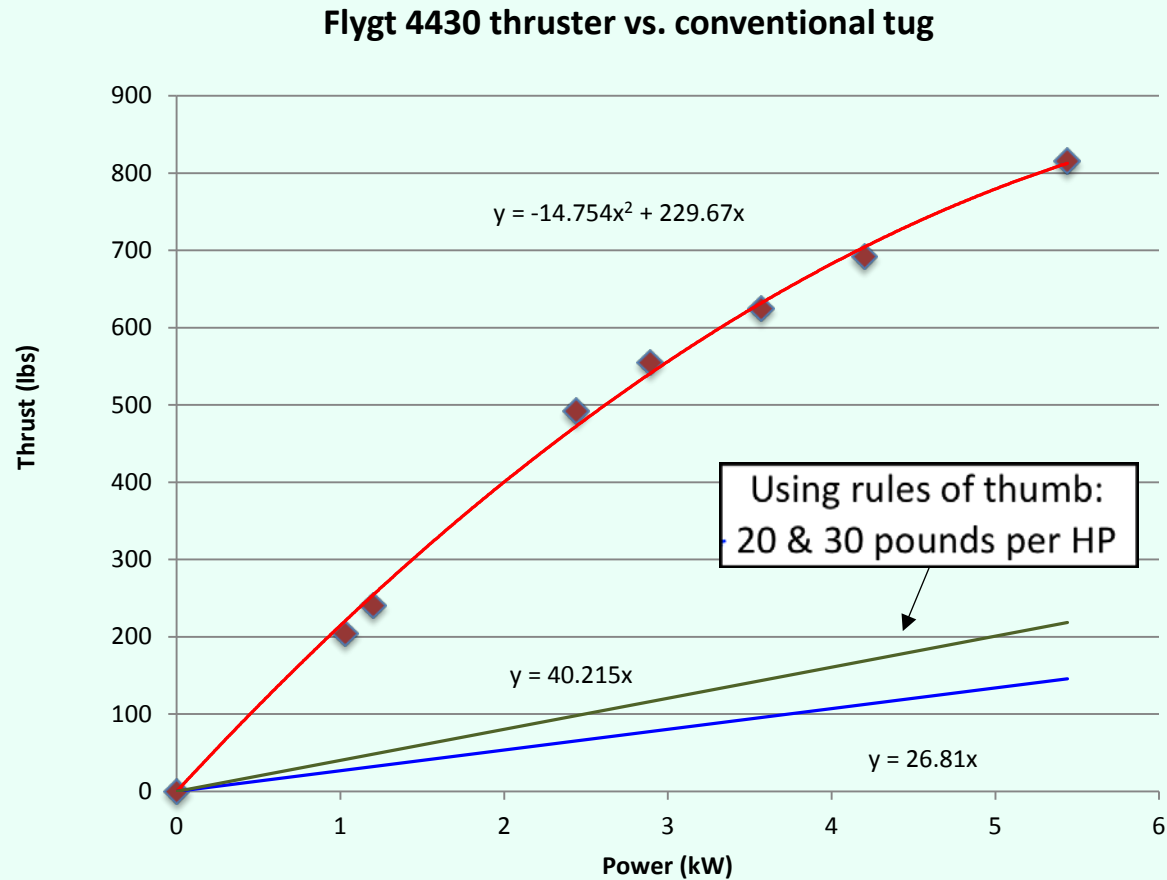
**Bollard tests against
mooring to verify thrust
then self-propelled tests
achieving 0.5 to 0.6 kts**

Thruster operation during bollard tests



Scuba air used for flow visualization

Conventional tugboats and trawlers offer 20 to 30 pounds of thrust per horsepower.
The Flygt thrusters offered 5.6 to 7.5 times that thrust ratio.



The TowDrone offers the following:

- 1. Fuel efficient towing**
- 2. Autonomous or remotely-piloted operation**
- 3. Eliminates the human urgency for speed**
- 4. Slow cage towing is better for cages and fish**
- 5. Extended endurance**
- 6. Battery powered version is feasible**
- 7. Can serve as a security patrol**
- 8. Zero carbon footprint using biofuels**

Work to be done

- Determine off-design propeller performance**
- Develop towline dynamics solutions**
- Examine propeller options**
- Need clockwise rotation model**
- Final design, construction, sea trials**

Thanks for your attention.

Questions?

Clifford A. Goudey
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Response Marine, Inc.
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