Designing and Building Center Console Boats – A Case Study

CORY WOOD, VICE PRESIDENT
GREG BEERS, P.E., PRESIDENT

BRISTOL HARBOR GROUP, INC.
THE SHEARER GROUP, INC.

SNAME NEW ENGLAND SECTION
29 JANUARY 2020

Bristol Harbor Group, Inc.

- Started by four friends in 1993 while still in college.
- Became self sufficient (read self employed) in 1997.

Bristol Harbor Group, Inc. cont.

- Design everything from 18' fiberglass power boats to 400' long oil tankers.
- Currently employ twelve naval architects and support staff.
- In 2005, partners looked into all manner of business opportunities for diversification from naval architectural services…Bristol Harbor Boats was born.

First Decisions

- What type of boats to build?
- What style to build?
- What size to build?
- How much money are we going to need?

Market Analysis

- Determine total number of boats built in the U.S.
- Determine breakdown of the above.
- Determine what size we wanted to start with.

3.2 Annual retail unit sales estimates

572,300 new boats were sold in 2009; kayaks led unit sales followed by outboard boats.

SOURCE: NMMA

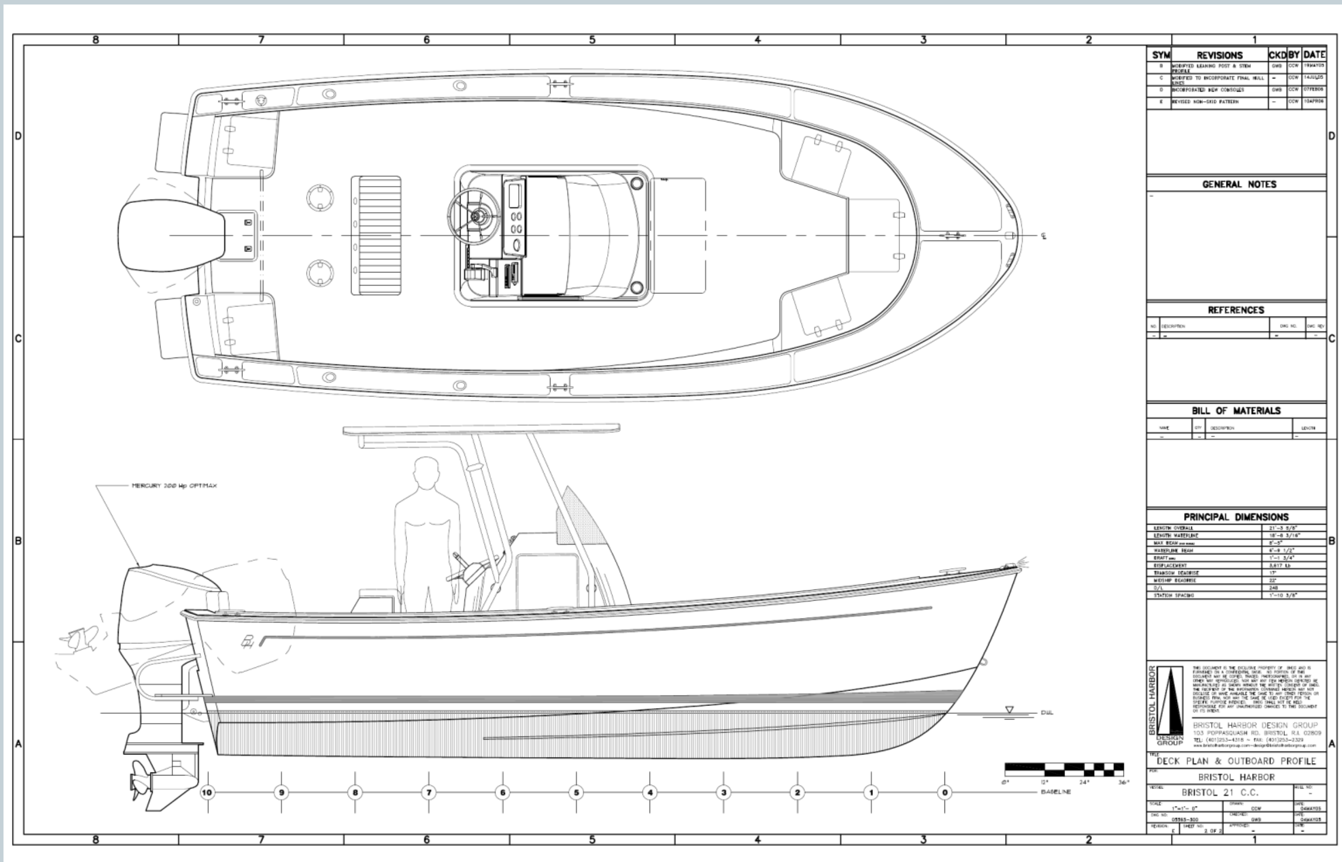
TABLE 3.2

YEAR	OUTBOARD BOATS	INBOARD BOATS	STERNDRIVE BOATS	JET BOATS	PERSONAL WATERCRAFT	SAILBOATS*	CANOES	KAYAKS**	INFLATABLE BOATS***	SAILBOARDS*	ALL BOATS†	BOAT TRAILERS	OUTBOARD ENGINES	STERNDRIVE & INBOARD ENGINES
1980	290,000	8,200	56,000	—	—	73,100	105,000	—	16,400	21,000	**569,700**	176,000	315,000	87,750
1981	281,000	8,400	51,000	—	—	77,100	126,000	—	20,000	31,000	**594,500**	190,000	318,000	81,500
1982	236,000	8,325	55,000	—	—	53,400	101,000	—	18,800	27,000	**499,525**	160,000	293,000	85,650
1983	273,000	11,385	79,000	—	—	43,740	107,000	—	23,600	33,000	**570,725**	184,000	337,000	104,125
1984	317,000	15,280	108,000	—	—	40,750	103,000	—	30,700	43,000	**657,730**	200,000	411,000	148,000
1985	305,000	16,700	115,000	—	—	37,800	78,800	—	33,500	50,000	**636,800**	192,000	392,000	155,000
1986	314,000	18,000	120,000	—	—	37,200	80,200	—	30,600	60,000	**660,000**	194,000	410,000	161,900
1987	342,000	19,700	144,000	—	—	33,500	85,300	—	30,200	70,000	**724,700**	216,000	444,000	210,800
1988	355,000	20,900	148,000	—	—	14,500	89,800	—	32,200	65,000	**725,400**	223,000	460,000	211,900
1989	291,000	21,400	133,000	—	—	11,400	80,100	—	29,800	55,000	**621,700**	209,000	430,000	190,700
1990	227,000	15,000	97,000	—	—	11,800	75,300	—	26,600	42,000	**494,700**	165,000	352,000	134,100
1991	195,000	9,800	73,000	—	68,000	8,700	72,300	—	21,200	—	**448,000**	133,000	289,000	92,400
1992	192,000	9,950	75,000	—	79,000	10,600	78,000	—	22,200	—	**466,750**	147,000	272,000	94,600
1993	205,000	10,175	75,000	—	107,000	11,900	89,700	—	—	—	**498,775**	163,000	283,000	94,700
1994	220,000	11,400	90,000	—	142,000	13,000	99,800	—	—	—	**576,200**	176,000	308,000	114,000
1995	231,000	12,360	93,600	14,700	200,000	14,300	97,800	—	—	—	**663,760**	207,000	317,000	120,000
1996	215,000	11,350	94,500	14,100	191,000	15,900	92,900	—	—	—	**634,750**	194,000	308,000	120,000
1997	200,000	12,400	78,800	11,700	176,000	10,500	103,600	—	—	—	**593,000**	181,000	302,000	116,100
1998	213,700	17,600	77,700	10,100	130,000	14,500	107,800	—	—	—	**571,400**	174,000	314,000	104,500
1999	230,200	19,100	79,600	7,800	106,000	18,850	121,000	—	—	—	**582,550**	168,000	331,900	108,500
2000	241,200	23,900	78,400	7,000	92,000	22,500	111,800	—	—	—	**576,800**	158,500	348,700	110,400
2001	217,800	21,900	72,000	6,200	80,900	18,600	105,800	357,100	—	—	**880,300**	135,900	299,000	103,700
2002	212,000	22,300	69,300	5,100	79,300	15,800	100,000	340,300	—	—	**844,100**	141,200	302,100	105,000
2003	207,100	19,200	69,200	5,600	80,600	15,000	86,700	324,000	30,500	—	**837,900**	130,600	305,400	99,000
2004	216,600	20,200	71,100	5,600	79,500	14,300	93,900	337,300	31,600	—	**870,100**	133,400	315,300	103,800
2005	213,300	20,400	72,300	6,700	80,200	14,400	77,200	349,400	30,100	—	**864,000**	134,100	312,000	104,400
2006	204,200	20,000	67,700	6,200	82,200	12,900	99,900	393,400	25,100	—	**911,600**	130,900	301,700	97,900
2007	188,700	18,200	60,400	6,800	79,900	11,800	99,600	346,600	29,400	—	**841,400**	126,200	275,500	90,400
2008	151,400	13,100	38,500	4,900	62,600	9,300	73,700	322,700	28,300	—	**704,500**	92,400	227,000	57,700
2009	**117,500**	**9,500**	**26,550**	**3,550**	**44,500**	**5,400**	**89,600**	**254,000**	**21,700**	—	**572,300**	**56,900**	**180,700**	**40,600**

—Data not available.
*Sailboats data source: The Sailing Company's Annual Sailing Business Review.
**Kayak category added in 2001.
***Inflatable boat data added back to the category in 2003.
† Total does not include houseboats.

Style Options

- Classic vs. Euro vs. Modern

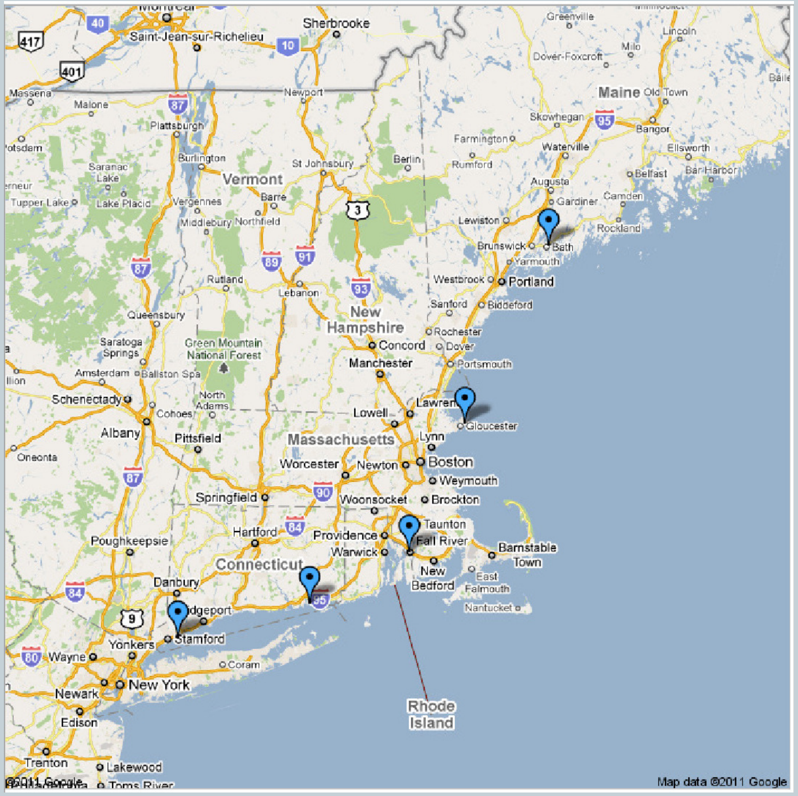


It's the Supply Chain Stupid

- The concept for Bristol Harbor Boats was developed around an innovative supply chain.
- Rhode Island company, but only do in the State that which makes SENSE to do in Little Rhody:
  - Design
  - Market
  - Assemble
  - Rig
- FRP (fiberglass) work done by a third party.
- Innovative supply chain, boat parts fit INSIDE standard 53' trailers (one of which is the hull itself).
- Parts are offloaded and assembled in our final assembly facility in Bristol, Rhode Island.

Initial Dealer Network

- Sales are the most important task.
- Maximize regional coverage to provide a running start.



Design Elements

- K.I.S.S.
- Family Fun
- Minimal Maintenance

Hull

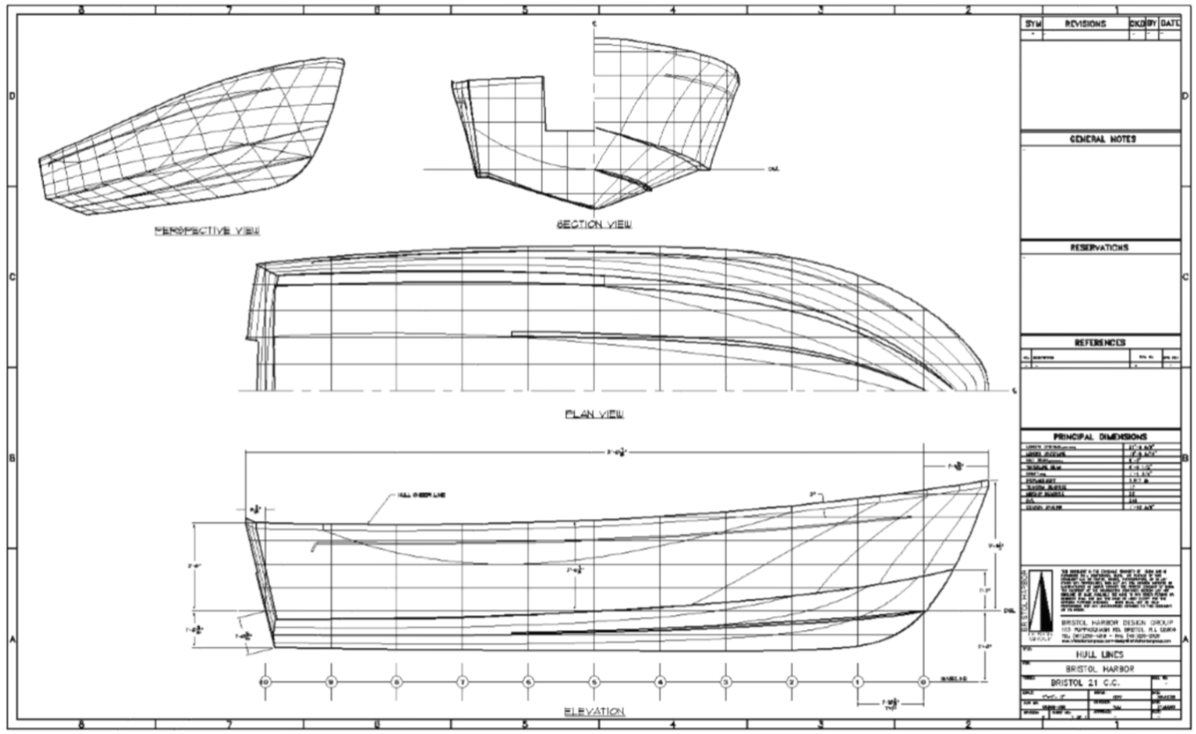
Bristol Harbor Group, Inc. employed its years of experience to design the modified deep-vee hull.

Modified deep-vee hull, 17° dead rise at transom, 21° amidship.

Hard chine

Deep forefoot

High gunnels

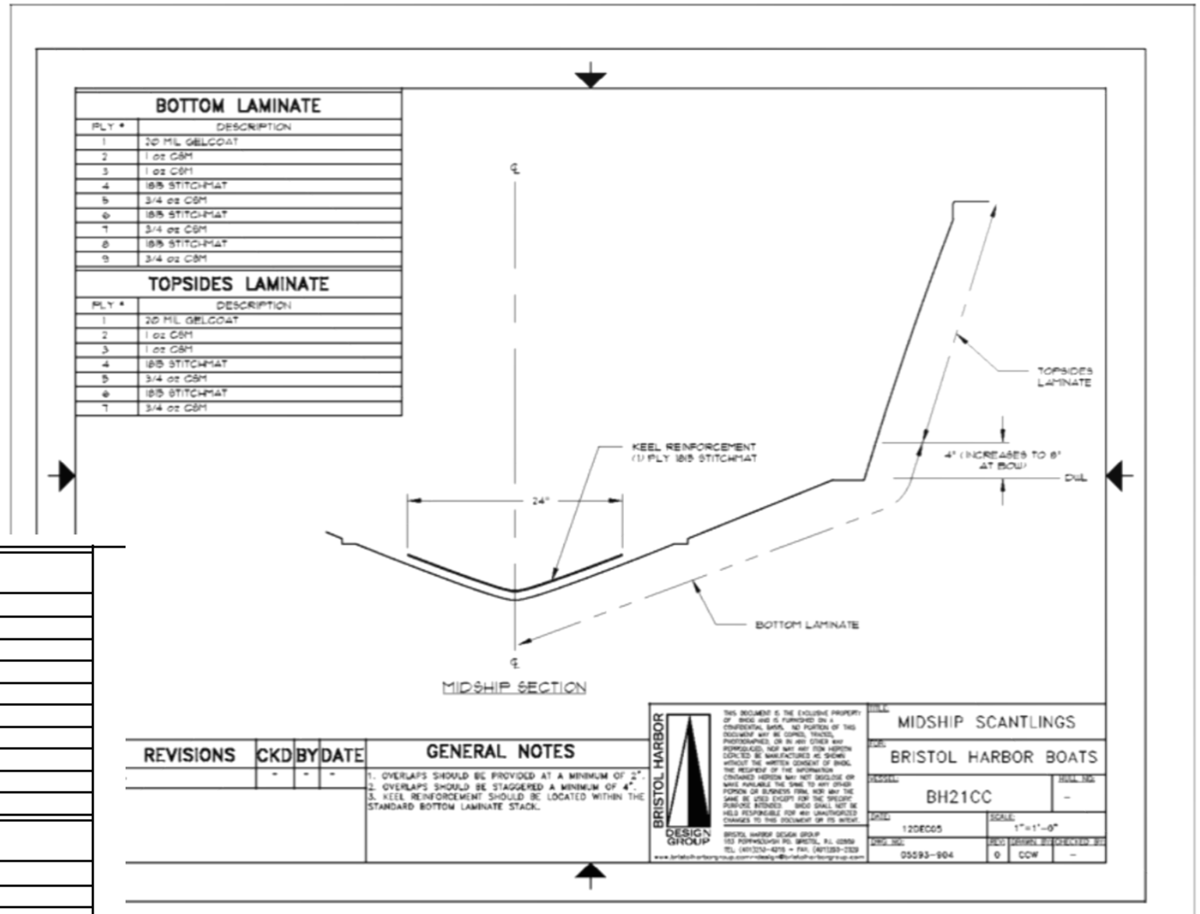


Laminate Schedule

Hull: solid E glass

Transom: 2" high density foam core

Deck / Sole: E glass with Spherecore



BOTTOM LAMINATE	
PLY #	DESCRIPTION
1	20 MIL GELCOAT
2	1 oz CSM
3	1 oz CSM
4	1815 STITCHMAT
5	3/4 oz CSM
6	1815 STITCHMAT
7	3/4 oz CSM
8	1815 STITCHMAT
9	3/4 oz CSM

TOPSIDES LAMINATE	
PLY #	DESCRIPTION
1	20 MIL GELCOAT
2	1 oz CSM
3	1 oz CSM
4	1815 STITCHMAT
5	3/4 oz CSM
6	1815 STITCHMAT
7	3/4 oz CSM

Weight Estimate

Tedious

Brute force effort

Often most junior task

However, it has to float!

Very important for EVERY design

Margin, margin, margin

This one came out within several pounds, which was luck (best +/- 2%), nonetheless, we took this as a good omen.

Preliminary Weight Analysis Date 17-Mar-11

Revision	B
Project Number	05593
Client	Bristol Harbor Boats
Vessel	Bristol 21
By	CCW

Principal Characteristics

Displacement (at DWL)	3,616 lbs	
LWL	18.67 ft	
BWL	6.80 ft	
WP Area	94.83 sq ft	
LCB	11.38 ft	60.9%
LCF	11.08 ft	59.3%
TransRM/Deg	301 ft lbs	
LongRM/Deg	2,173 ft lbs	
PPI	506 lbs/in	

Floatation Calculations with Half Tankage

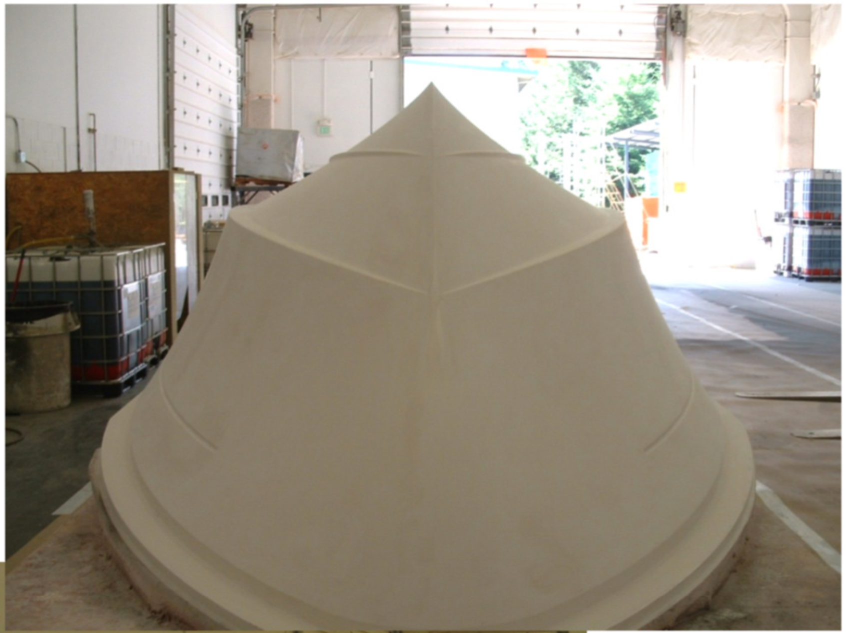
Rise = (Displacement - Weight) / PPI	-0.93 in	(+ = up)
Trim = (LCB - LCG) x Disp/ LongRM/Deg	-0.69 deg	(+ = bow down)
= (LWL x 12) x sin(trim(deg/57.296))	-2.71 in	(+ = bow down)

* LCG measured as positive aft the origin
* VCG measured as positive above DWL
* TCG measured as positive to STBD

Weight Breakdown				Weight	LCG	L-Mom	VCG	V-Mom	TCG	T-Mom
2.0 Structural				2,001	9.30	18,609	0.83	1,665	0.00	0
3.0 Mechanical				851	19.17	16,317	1.48	1,264	0.07	63
4.0 Electrical				50	17.12	856	-0.14	-7	2.25	113
5.0 Electronics				6	11.04	66	3.10	19	0.00	0
6.0 Auxiliary Systems				30	9.44	283	1.94	58	0.00	0
7.0 Deck Outfitting				508	8.91	4,532	2.62	1,334	0.00	0
8.0 Finishes				29	9.55	272	1.47	42	0.00	0
Tankage										
Gasoline	85	gal	6.14	522	13.87	7,239	-0.21	-110	0.00	0
Captain	1	ea	175	175	13.00	2,275	4.00	700	0.00	0
Crew	1	ea	175	175	6.67	1,167	2.33	408	0.00	0
Full Load Condition				4,347	11.87	51,616	1.24	5,372	0.04	175
Half Load Condition				4,086	11.75	47,997	1.33	5,427	0.04	175
Light Ship Condition				3,475	11.78	40,935	1.26	4,374	0.05	175

Hull Plug

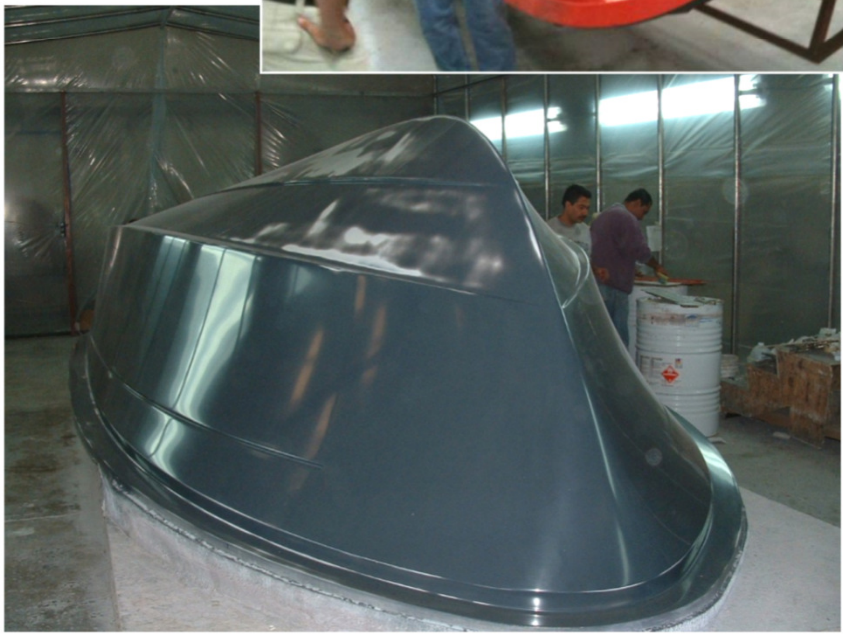
Computer model sent to Boeing subcontractor and plug for tooling was milled out of 22’ block of foam.



Tooling Development

Hull plug sent to laminating subcontractor for finishing.

Laminating subcontractor responsible for building all tooling (ensuring that parts fit together at the end of the project).

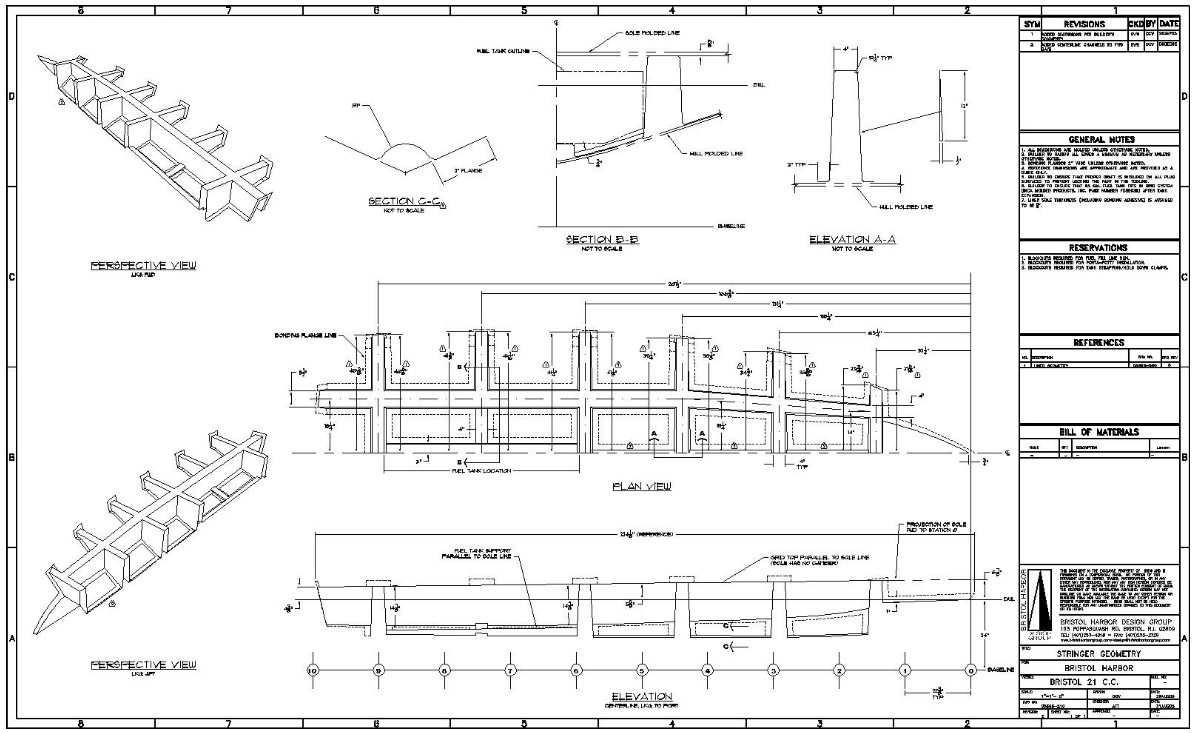


Structural Grid

One piece grid makes up all of the structural components for the boat.

Hollow stringers save weight without losing strength, and hollow longitudinals serve as rigging tubes.

Cavities outboard and forward filled with closed cell floatation foam.



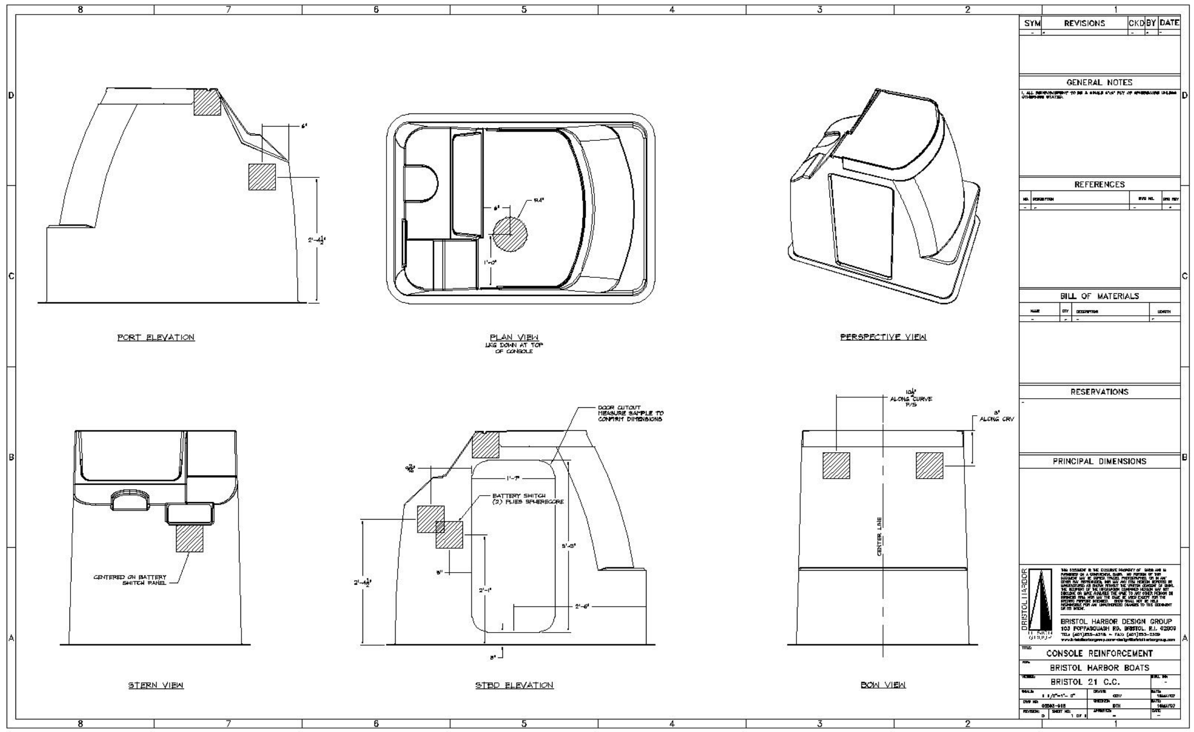
Center Console

Combining modern curves with a traditional hull sheer line.

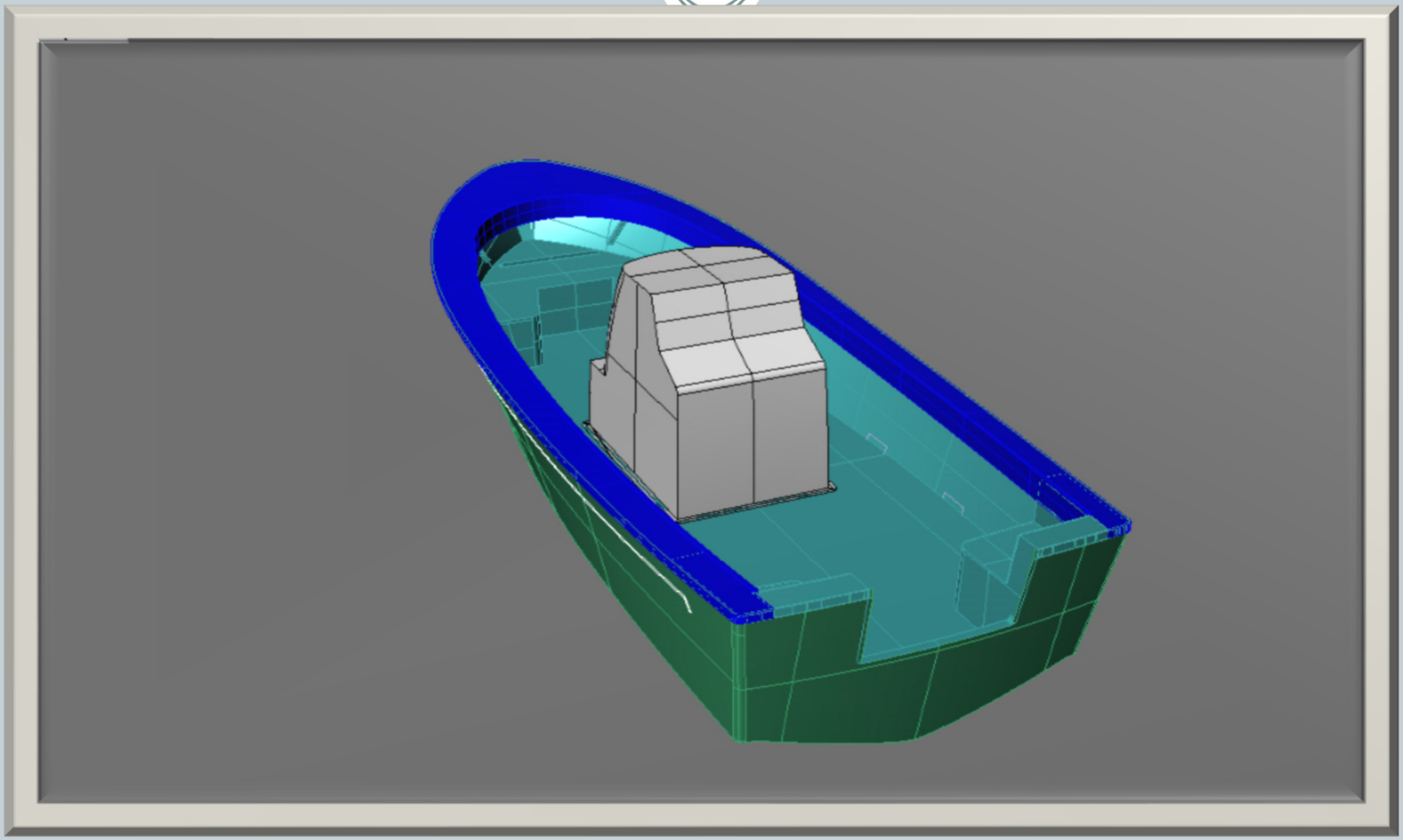
Mock up to determine optimum use of space.

Can accept up to a full 10” integrated display.

Head space also provides excellent access to the batteries and electronics.



Parts



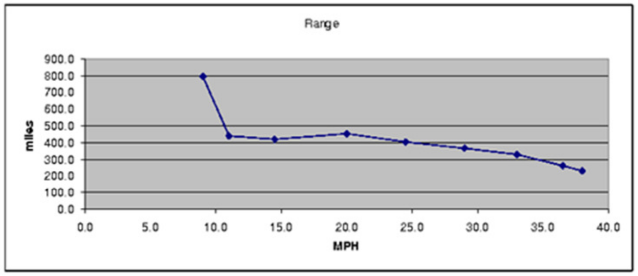
21CC Sea Trial

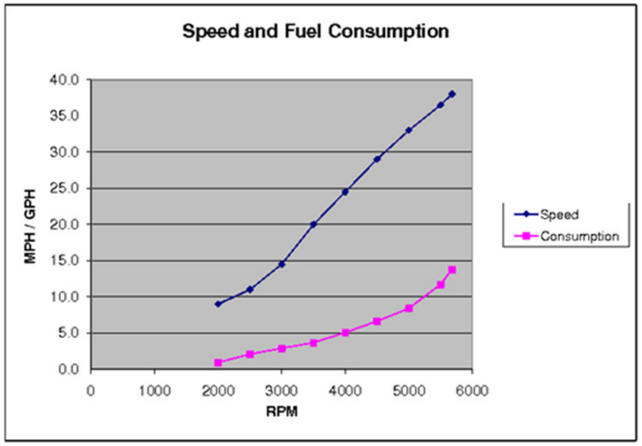
Bristol Habor 21 CC Sea Trial

Date: August 14, 2007
Time: 1100
Weather: flat calm, wind from NNE @ 8 knots
Load: 1 POB, 31.875 gal. fuel (85 gal. tank), safety equipment
Propeller: 14 3/4" x 17"

Heading:	348°		168°		Average		
Revolutions (RPM)	Speed (MPH)	Consumption (GPH)	Speed (MPH)	Consumption (GPH)	Speed (MPH)	Consumption (GPH)	Range (miles)[1]
2000	9.0	0.6	9.0	1.3	9.0	1.0	795.8
2500	11.0	2.1	11.0	2.1	11.0	2.1	440.0
3000	14.0	2.9	15.0	2.9	14.5	2.9	420.0
3500	20.0	3.7	20.0	3.7	20.0	3.7	454.1
4000	24.0	5.1	25.0	5.1	24.5	5.1	403.5
4500	29.0	6.8	29.0	6.5	29.0	6.7	366.3
5000	33.0	8.5	33.0	8.3	33.0	8.4	330.0
5500	36.0	11.7	37.0	11.7	36.5	11.7	262.1
5680	38.0	13.8	38.0	13.8	38.0	13.8	231.3

1. based on 84 gal.



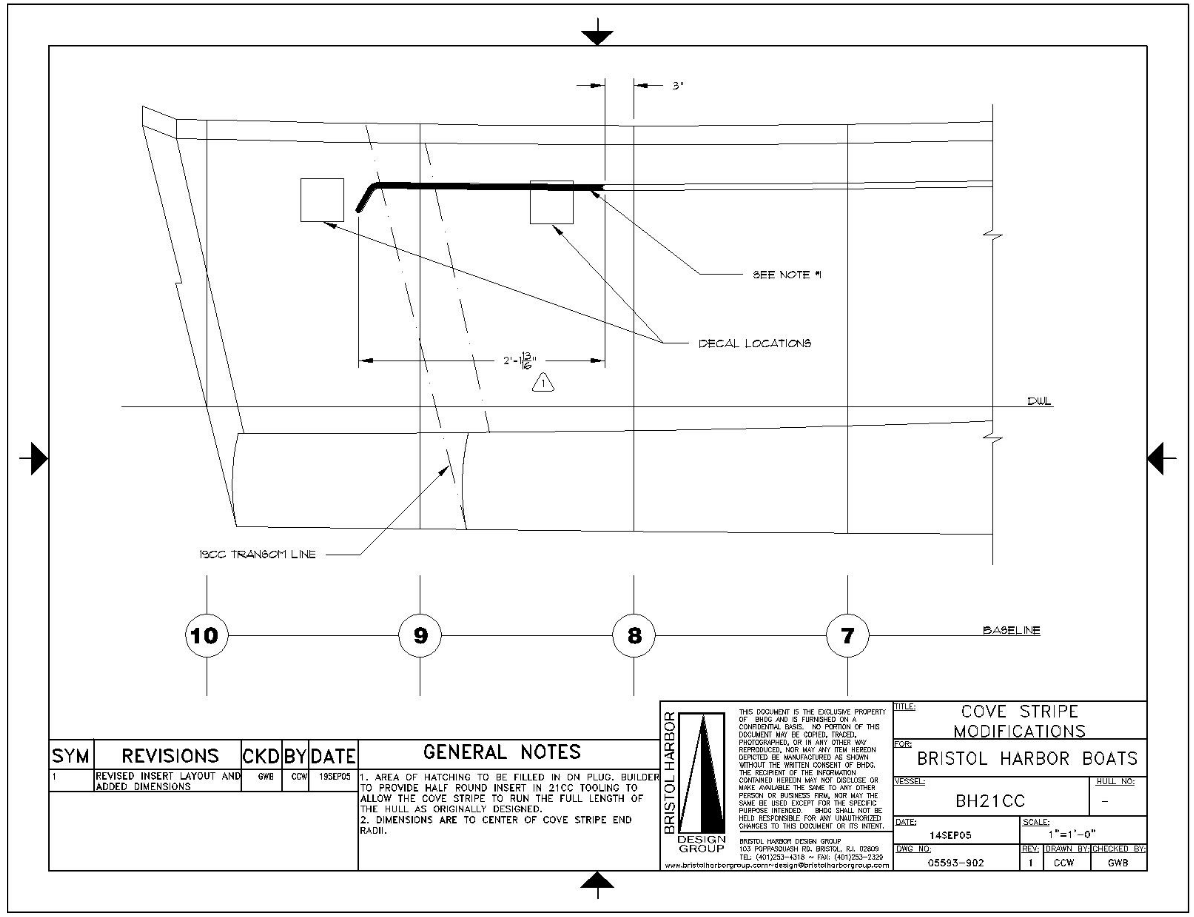


Common Tooling

Hull mold for 21CC is also used for the 19CC

A "block out" is inserted in the mold prior to laying up the 19CC hull part

Liner, deck ring and stringer grid molds are also used for both models



19CC and 21CC Models

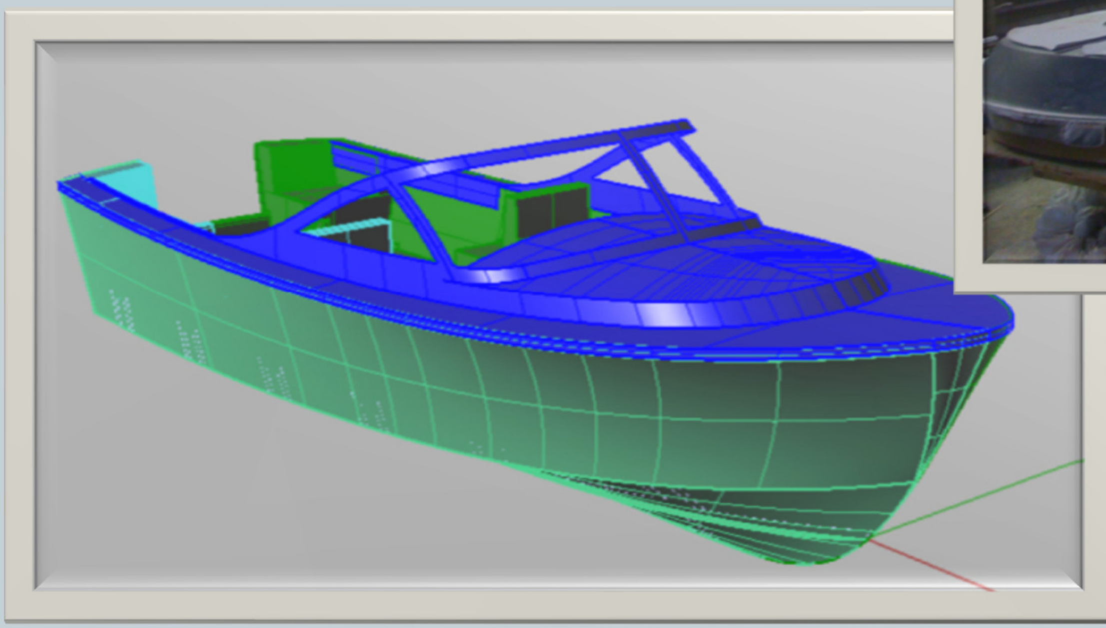
USCG TESTING

Vanquish Boats

- 23' Bristol Harbor Series Center Console
- 23' Bristol Harbor Series Cuddy Cabin

Bristol Harbor 23' Cuddy Cabin

- Began new model development in 2011.



23’ Cuddy Cabin

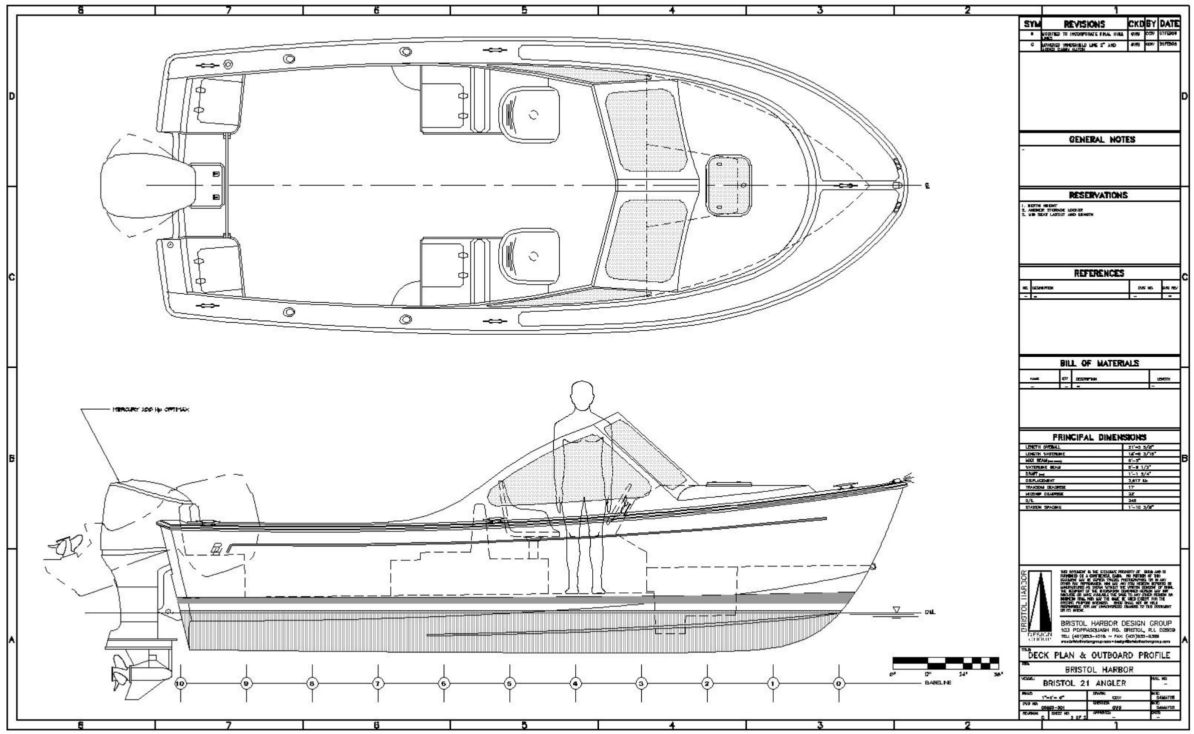
Bass boat style

21CC hull

New liner

New deck ring and foredeck

Addition of an engine well or transom bracket



Bristol Harbor 23' Cuddy Cabin

Advanced Technologies in Commercial Naval Architecture and Marine Engineering

GREG BEERS, P.E., PRESIDENT
CORY WOOD, VICE PRESIDENT

BRISTOL HARBOR GROUP, INC.
THE SHEARER GROUP, INC.

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Also Commercial Naval Architects

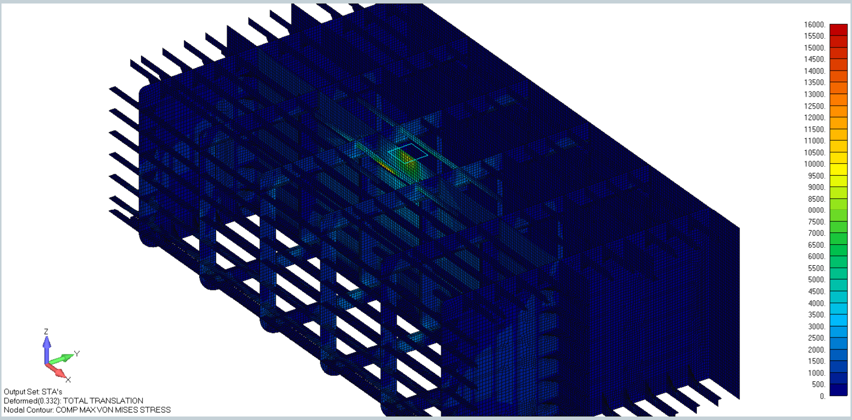
- Full service naval architecture, marine engineering and marine surveying companies; Bristol Harbor Group, Inc. in Rhode Island; and The Shearer Group, Inc. in Texas.
- Technical team includes naval architects, designers and marine surveyors who have graduated from some of the top engineering schools in the country:
  - U.S. Coast Guard Academy
  - University of Michigan
  - Webb Institute
  - Texas A&M University
  - Virginia Polytechnic Institute and State University
  - University of New Orleans
- The Core Purpose of our companies is: **To Create**. This purpose, combined with a passion for boats, serves as a motivation for our talented staff.

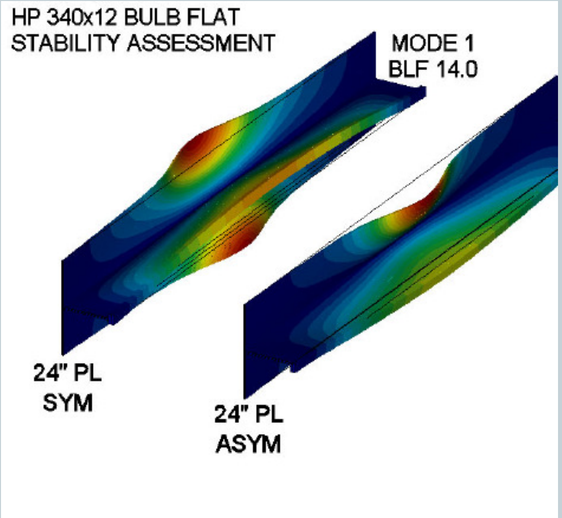
Advanced Technologies

- Techniques
  - Finite Element Analysis (FEA)
  - Computational Fluid Dynamics (CFD) Analysis
  - Operational Modelling (hybrid or energy storage)
- Examples
  - Alternative Fuels
    - LNG
    - Biodiesel
  - Electrical Propulsion
  - Robotics and Automation
  - Unique Cargo (NASA, etc.)
- Future

Techniques - FEA

- Finite Element Analysis
  - Models range from global to detailed submodels
  - Analysis also spans a large range, from crude beam element models for load determinations to detailed solid models with nonlinear gap elements for thorough understanding of contact between structures
- FEMAP and Nastran





FEA - Stern Coupling

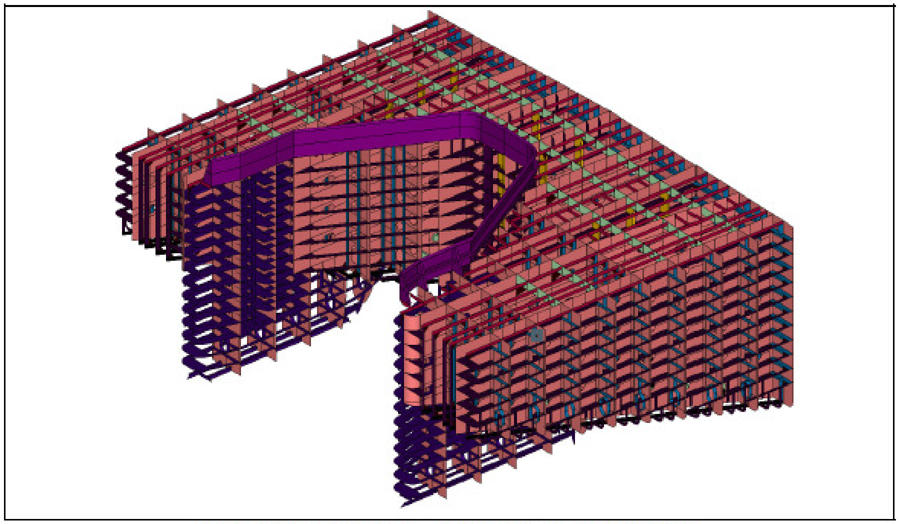


FIGURE 02: GEOMETRY - IMAGE 02 - Isometric View 2

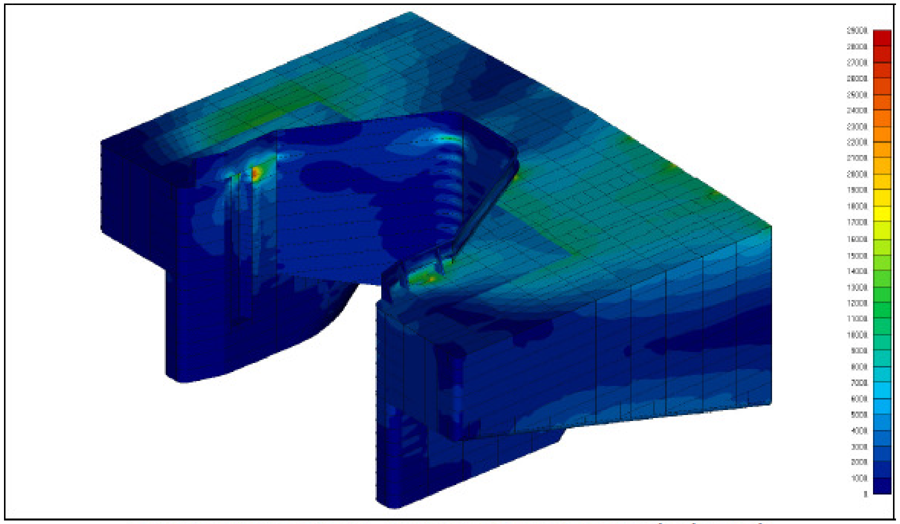
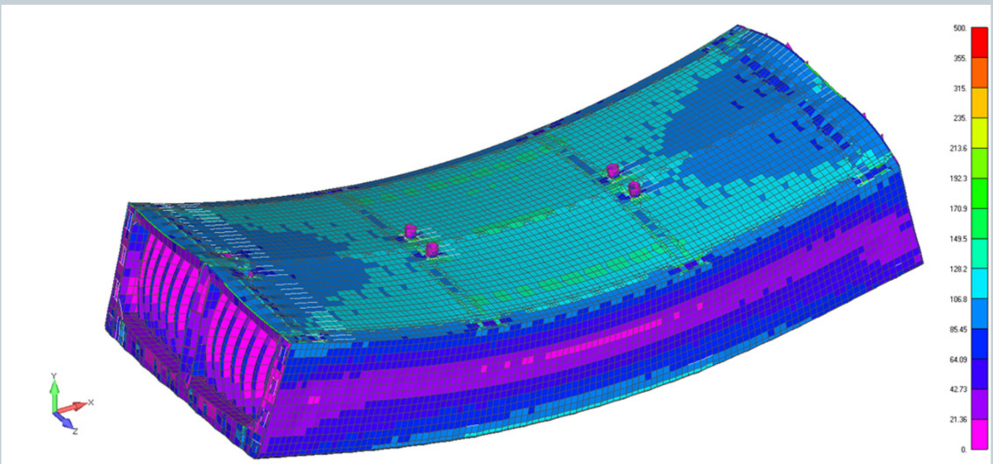
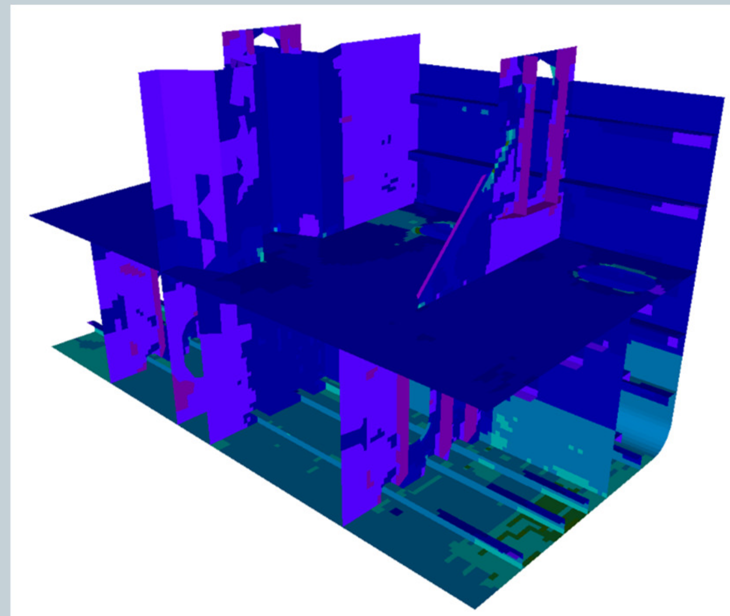


FIGURE 63: LOAD CASE 2 - STRESS - IMAGE 01 - Isometric View (psi)

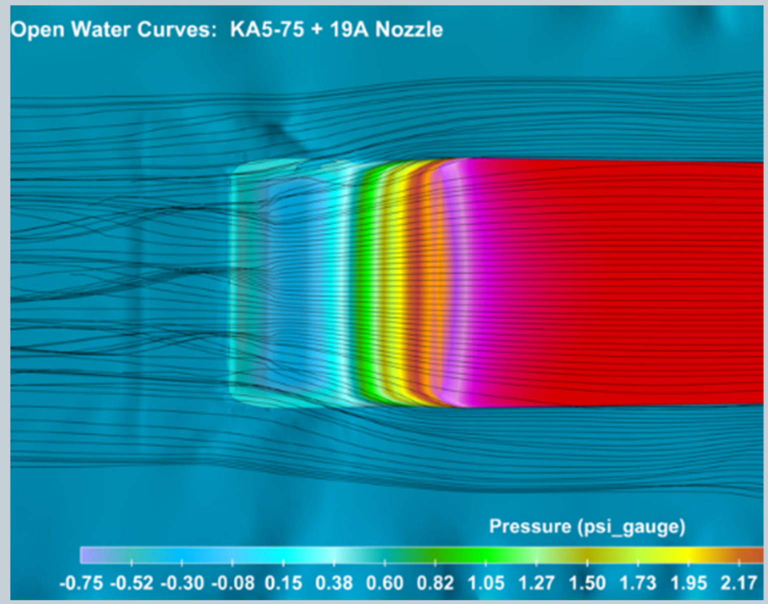
FEA - Thermal Stress Analysis



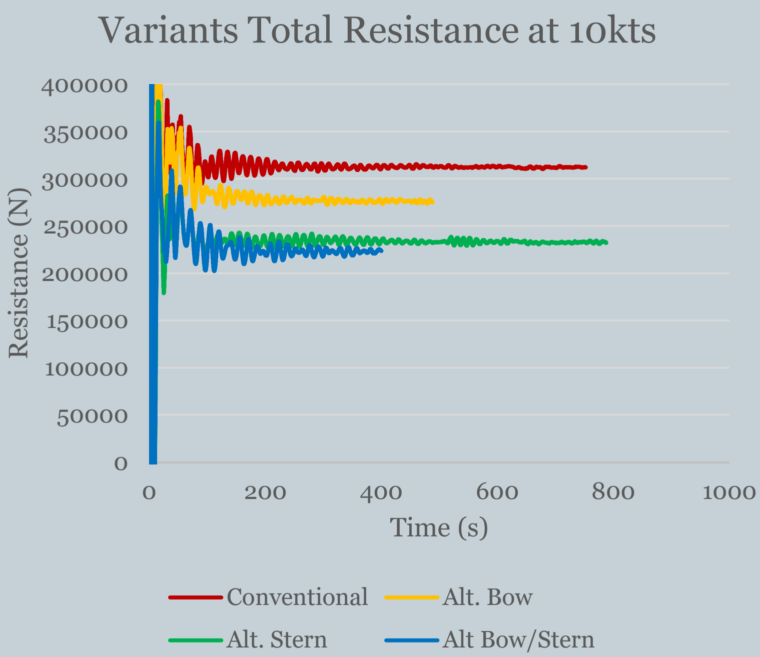


Techniques - CFD

- Computational Fluid Dynamics
- Reynolds -averaged Navier-Stoke (RANS) based code
  - Simerics
  - Star-CCM+
- Resistance and flow optimization as well as detailed seakeeping analyses



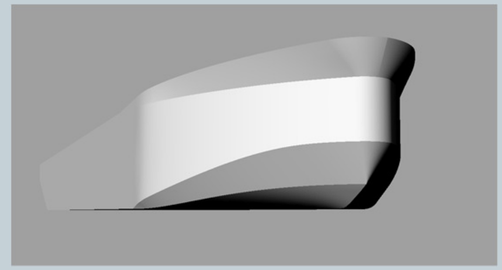
CFD - Results



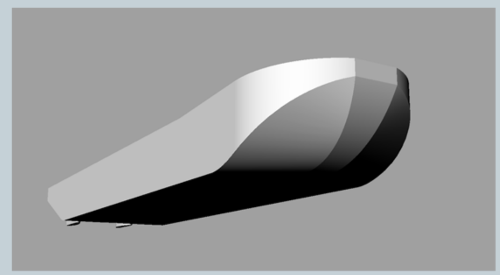
Variant	Speed (kts)	Resistance (N)
Conventional	10	312,351
Alt. Bow	10	276,341
Alt. Stern	10	232,945
Alt. Bow/Stern	10	223,162

CFD - Results

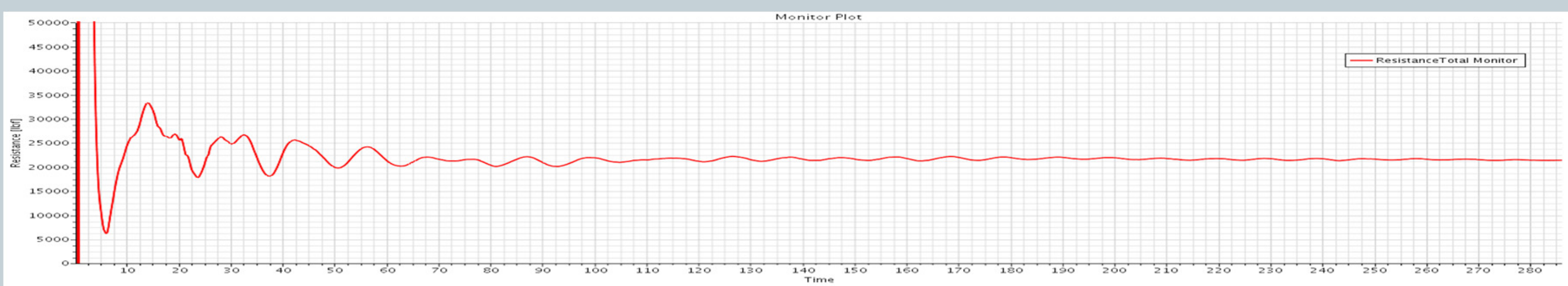
- Ship Shape vs. Spoon
  - + 5% @ 8kts
  - + 8% @ 10kts



Ship Shape Bow “Type A” (alternate)

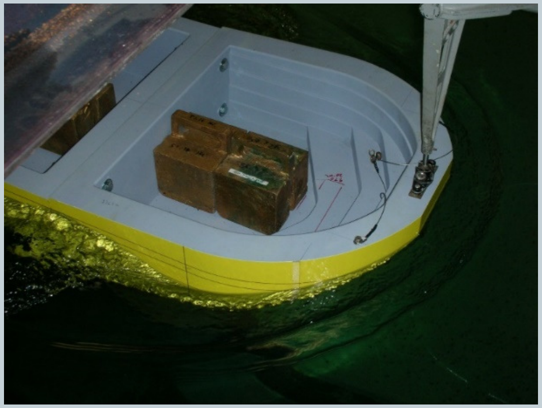


Spoon Bow “Type S”



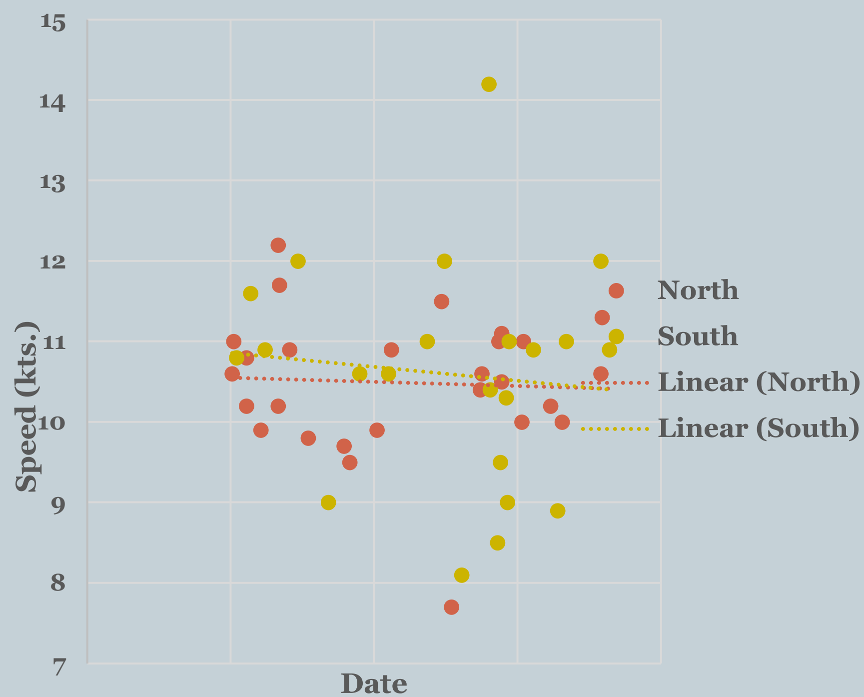
CFD - Validation

- BHGI understands the need to ground-truth CFD results
- Therefore, tank test with alternate bows
- One model with two bows, one ship shape and the other a spoon bow
- Tested at University of Michigan Marine Hydrodynamics Laboratory
- Data matches CFD delta approximation +/-1 %



CFD - Validation

- Track actual units on Marine Traffic to understand full scale (real life) transit speeds versus calculated
- This example shows that over 10 months, loaded transit speed on average matches our calculated speed for 80% MCR
- Interestingly, when light, this vessel only picks up about ½ knot at less than 80% MCR
- Point being we “trust but verify” our computational results



Operational Modeling

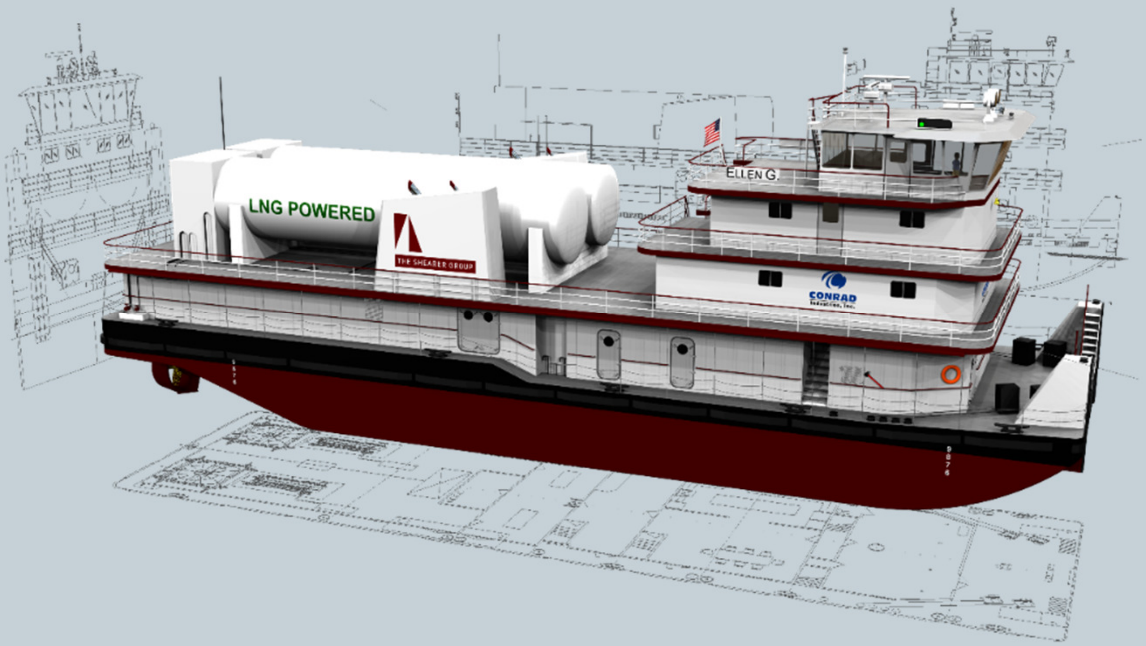
- Marine Electrical Propulsion Simulation Lab (MEPS)
  - Vision Excerpt
    - MEPS provides a high-impact research capability for hybrid and all-electric marine vessels through collaboration with naval and commercial industries along with other universities

Examples - Alternative Fuels

- LNG
  - Clean Jacksonville
  - First LNG bunker barge built in North America
  - Delivered in 2018
  - GTT Membrane Technology
  - Capacity of 2,200m^3

Examples - Alternative Fuels

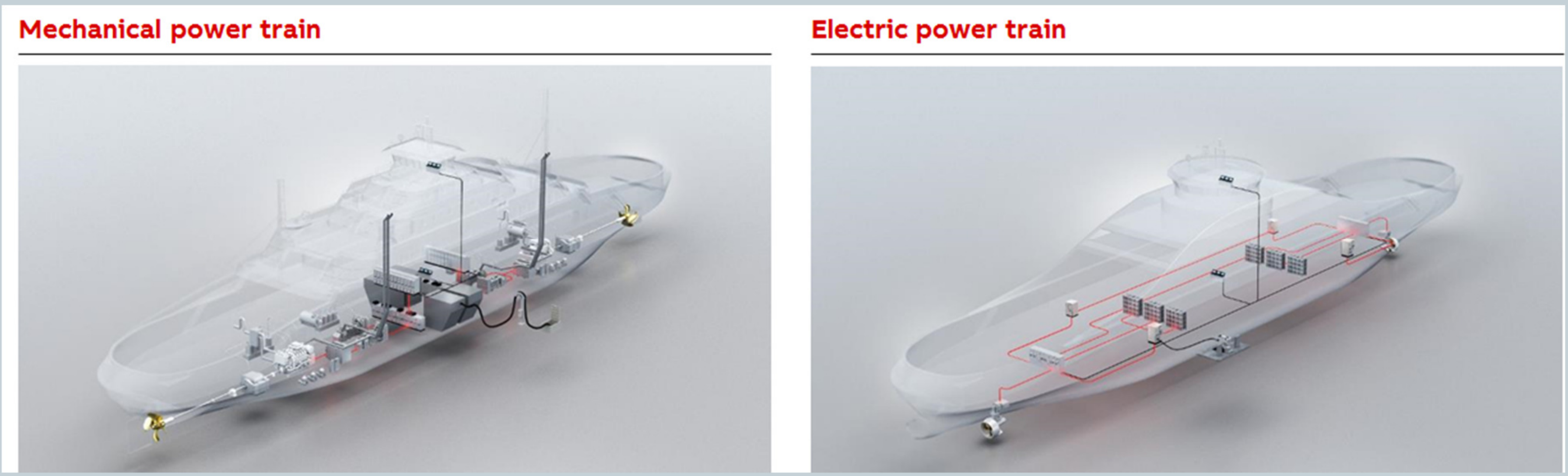
- LNG
  - Towboats
    - Retrofits
      - Dual-Fuel via Air Fumigation
    - Ellen-G
      - AiP from ABS



Examples – Alternative Fuels

- Biodiesel
  - In 2013, USACE had BHGI investigate the viability of using various types of biodiesel on a variety of vessels
  - Focused on power output and environmental and emissions effects
  - Physically inspected and assessed nine candidate vessels including installing monitoring equipment and conducting extended trials
  - Culminated in a paper entitled: *Measurement of Criteria Pollutant Emissions from Vessels Operated by the US Army Corps of Engineers and using Advanced Fuels*; Gysel, Miller, Welch &; Cocker; Final Report (Amended), April 2014

Examples – Electrical Propulsion



Examples – Electrical Propulsion

- Electric motor provides shaft power to propeller or thruster
- Several generators instead of main engines + generator
- Generators provide energy for propulsion system as well as house loads – no extra house generator needed
- Ability to shed prime movers when less power is needed
- Redundancy in the event of a prime mover failure, while failure of any part of a direct drive system means loss of propulsion

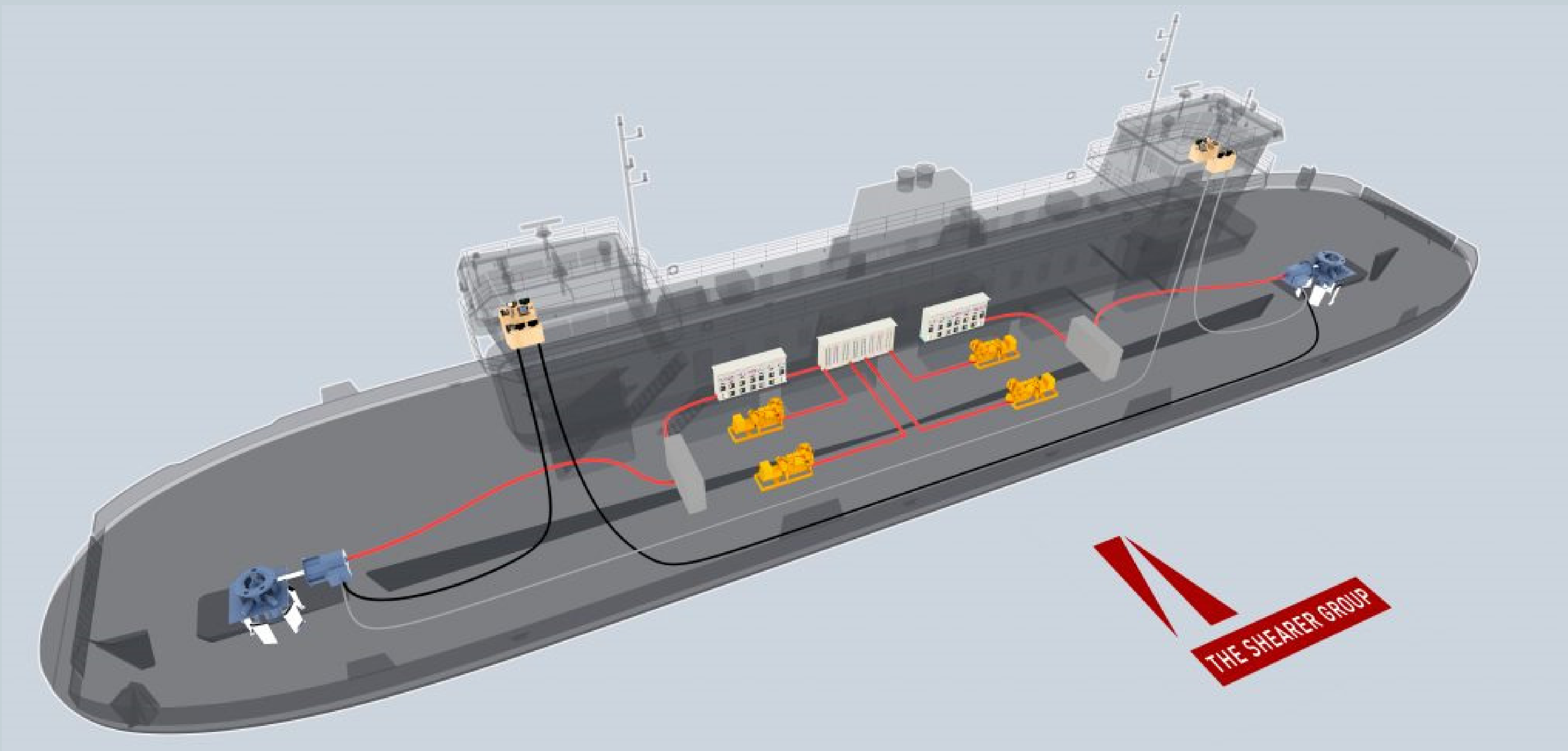
Examples – Electrical Propulsion

- Diesel electric systems do require additional considerations such as climate controlled area for electronics
- Recent studies indicate that capital expense of diesel electric system very similar to Tier 4 w/ EGR direct drive system
- Diesel electric system generators have shorter maintenance intervals than typical low speed diesels, but ability to make speed with less than the total # of generators available reduces time on each engine and extends maintenance intervals
  - More flexibility for maintenance
  - Out-of-service time minimized

Examples – Electrical Propulsion

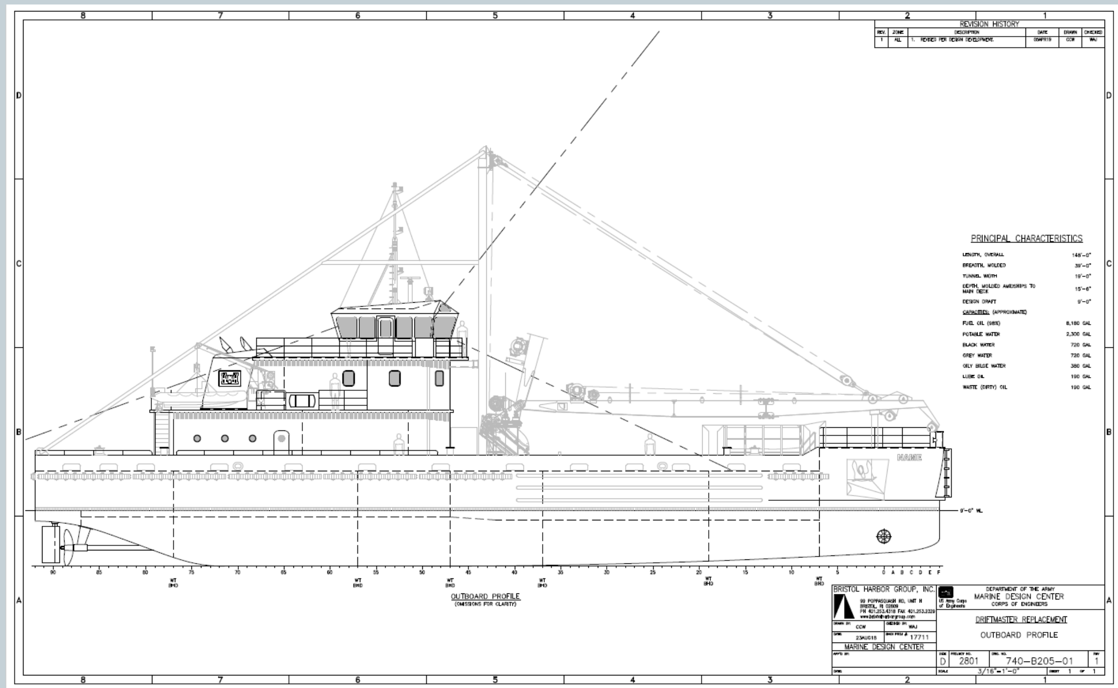
- Texas DOT Galveston to Bolivar Peninsula
- 293’ x 66’ Car Ferry
- 70 Cars and 495 Passengers
- Voith Schneider Propulsion
- 1.4MWHr Energy Storage

Examples – Electrical Propulsion



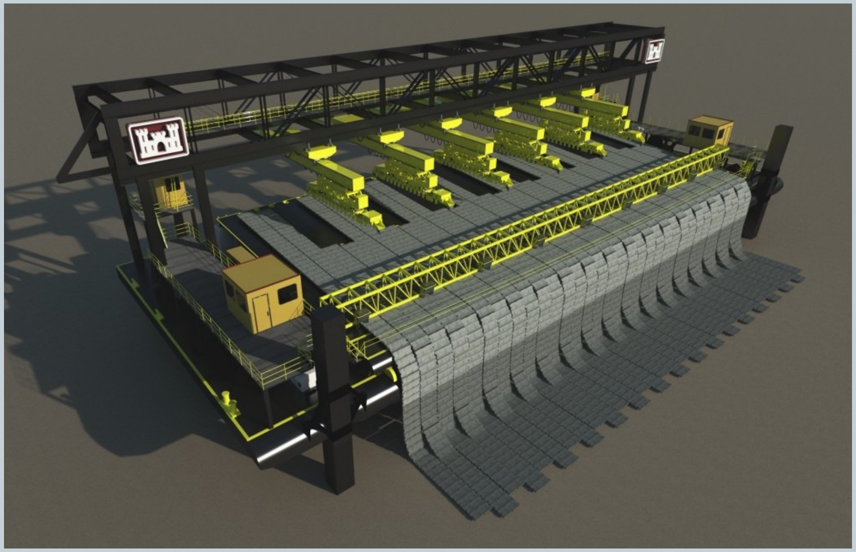
Examples – Electrical Propulsion

- *DRIFTMASTER II*
- 148’ x 39’ Debris Collection Vessel
- Operates in N.Y.C. Harbor
- 3 MWh Energy Storage



Examples – Robotics and Automation

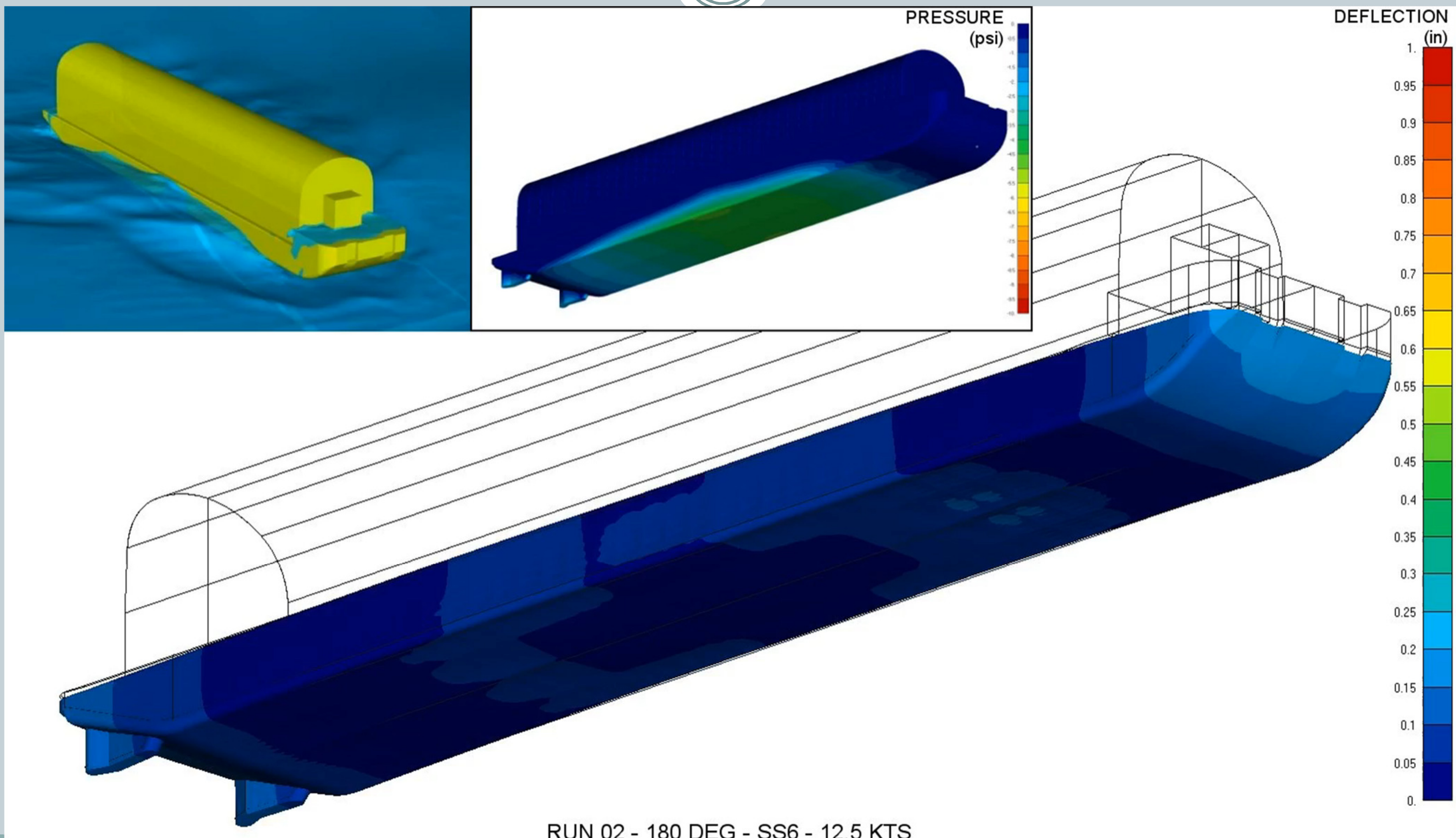
- ARMOR 1
- 188’ x 74’ Mat Boat
- Floating concrete mat factory for armoring the bends of the Mississippi
- Carnegie Mellon University’s National Robotics and Engineering Center



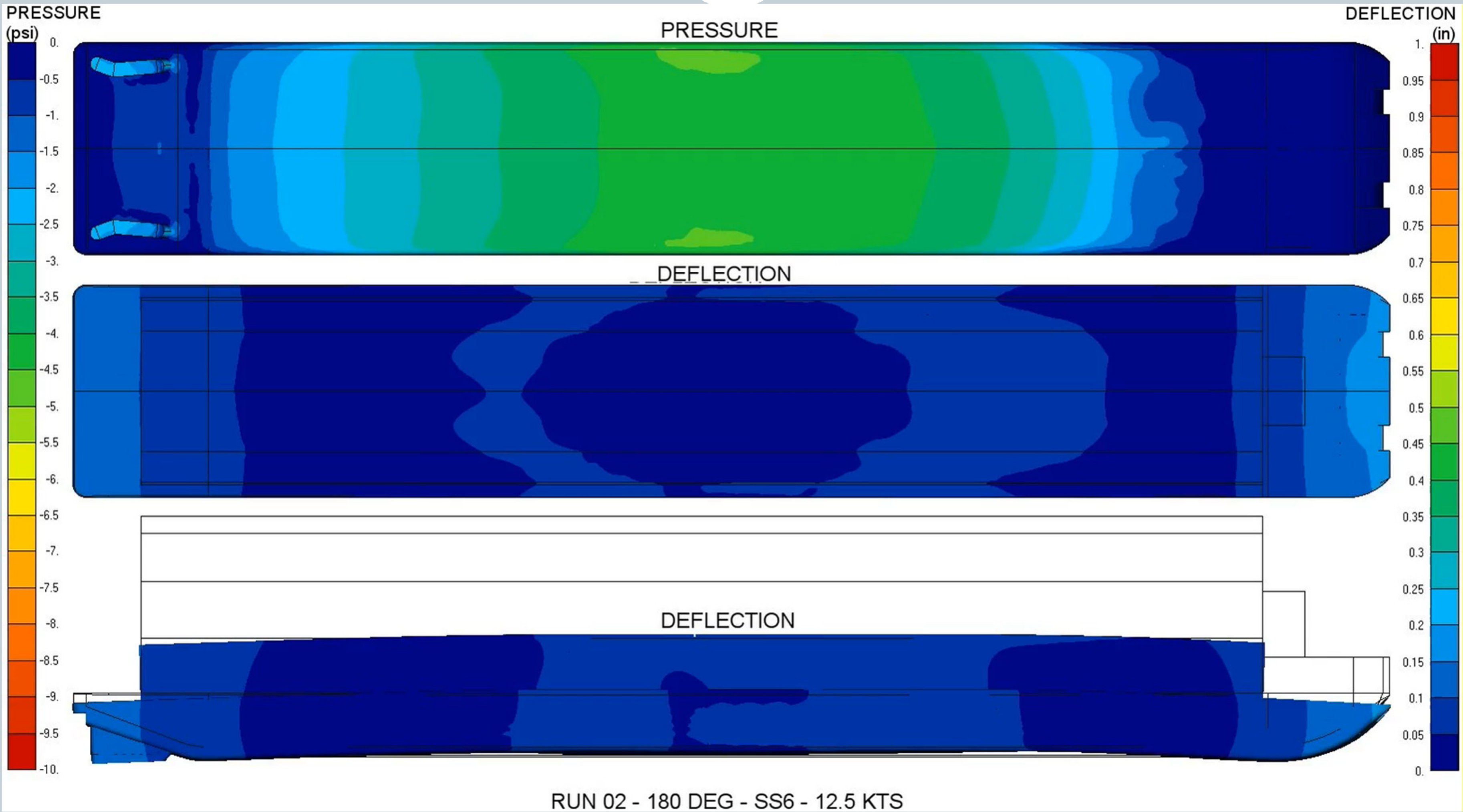
Examples – Unique Cargo - NASA

- NASA – RoRo – Flight Article (i.e. very light)
- First Space Launch System (SLS) rocket core stage for Artemis program
- En route from Michoud (NOLA) to Stennis (Mississippi)
- Preparation for the Green Run test series, final test campaign
- Larger than Saturn V rocket stages built at Michoud

Examples – Unique Cargo - NASA

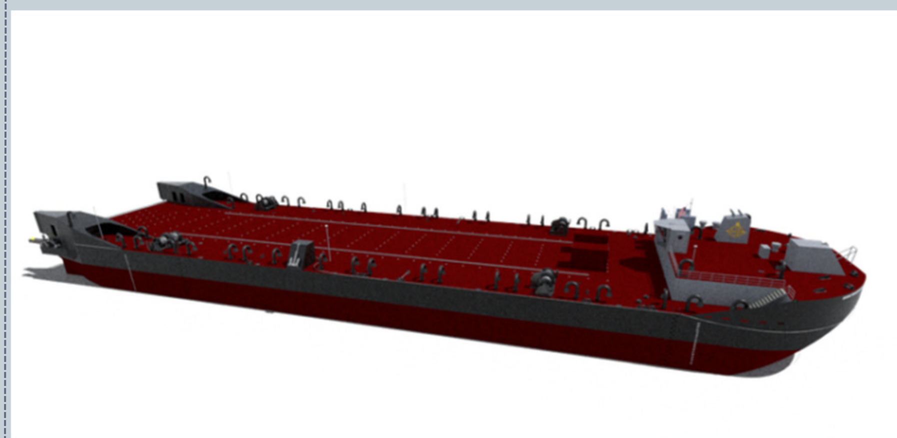


Examples – Unique Cargo - NASA



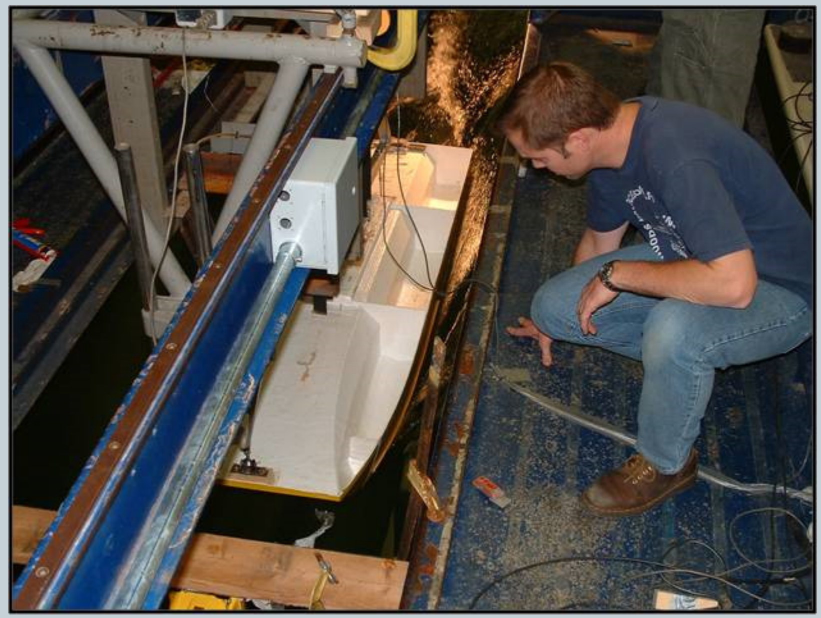
Examples – Unique Cargo - OTB

- OTB – RoRo – HEAVY
- 395' x 100' ocean transport barge for General Dynamics Electric Boat
- Under construction at Bollinger Marine Fabrication, Amelia, LA
- Simple answers to complex problems – simple rule for human ops in an emergency



Future

- Committed to the use of advanced techniques and automation for efficiency
- Actively promoting and exploring opportunities for the advancement of alternative fuel AND electric propulsion for tugs and towboats (already doing this for ferries)
- Exploring other opportunities from LNG Dredges to all electric barges
- Exciting time to be a naval architect!



Thank You

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