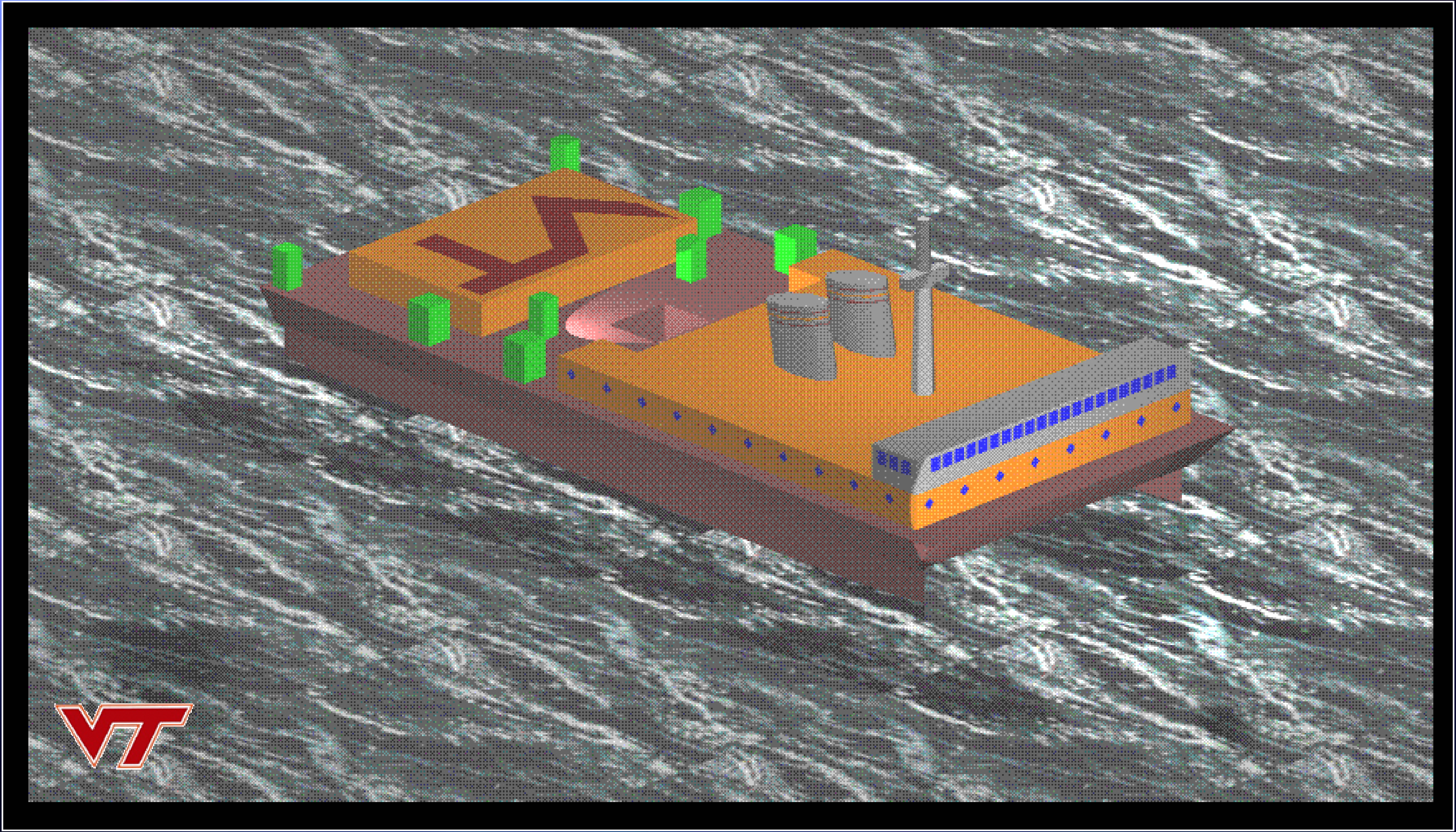
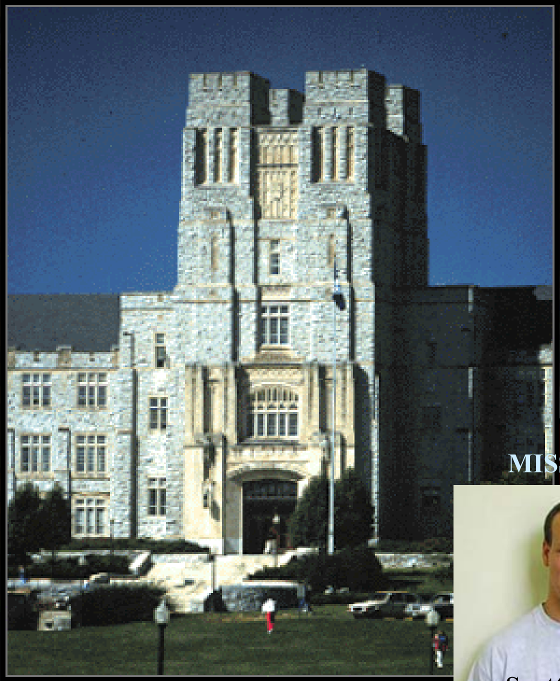
Virginia Tech SWATH AGOR (1998-1999)



SWATH AGOR Team (98-99)

Blacksburg, VA



TEAM LEADER
RESISTANCE

MISSION

HULL FORM

SEAKEEPING

COST

ARRANGEMENTS

Ship Characteristics

Length: 322 ft

Beam: 93 ft 4 in

Draft: 21 ft 6 in

Displacement:

- Light Ship: 2949 ltons
- Full Load: 3757 ltons

Endurance Speed: 10 knots

Sustained Speed: 10.5 knots

Propulsion: Diesel-Electric/IPS

Shaft Horsepower: 1750 hp

Thrusters: (2) 600 hp Omni Directional

Electric Power: (3) PGM 4160 VAC 60 Hz 3 Phase 1000 kW

Operability:

- Unrestricted (all headings): Sea State 6

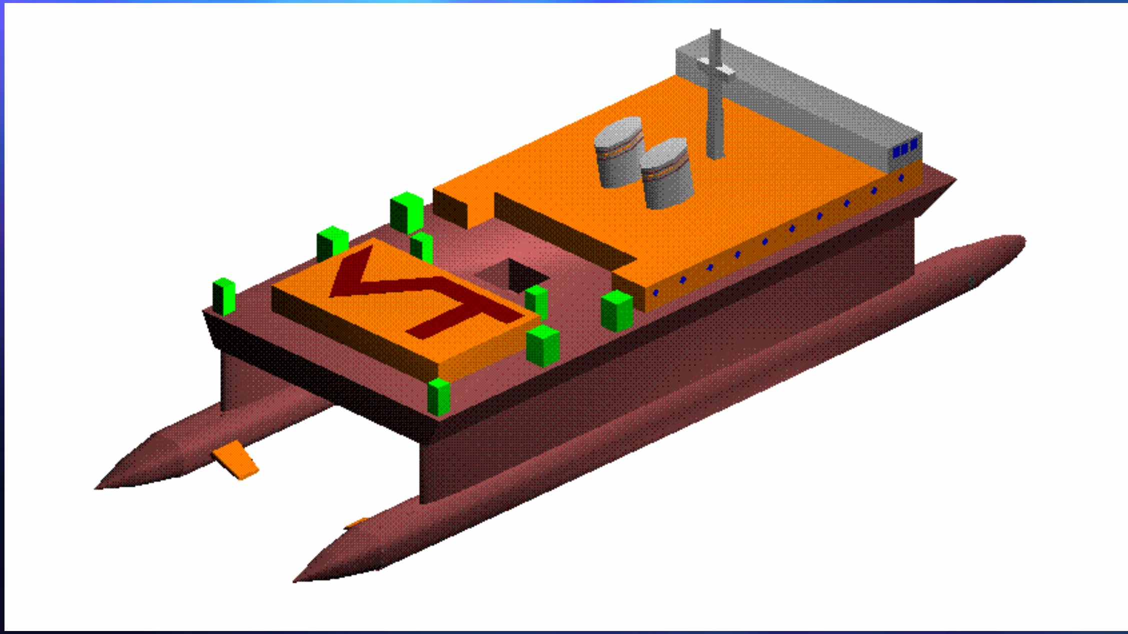
Survivability: Above Sea State 8

Science Payload: 100 ltons

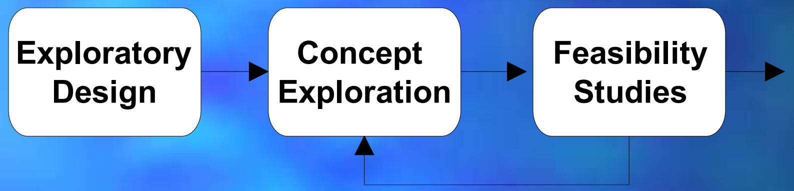
Mission Space Area: 5000 ft^2

Center Well Area: 300 ft^2

Accommodations: 66



Presentation Outline

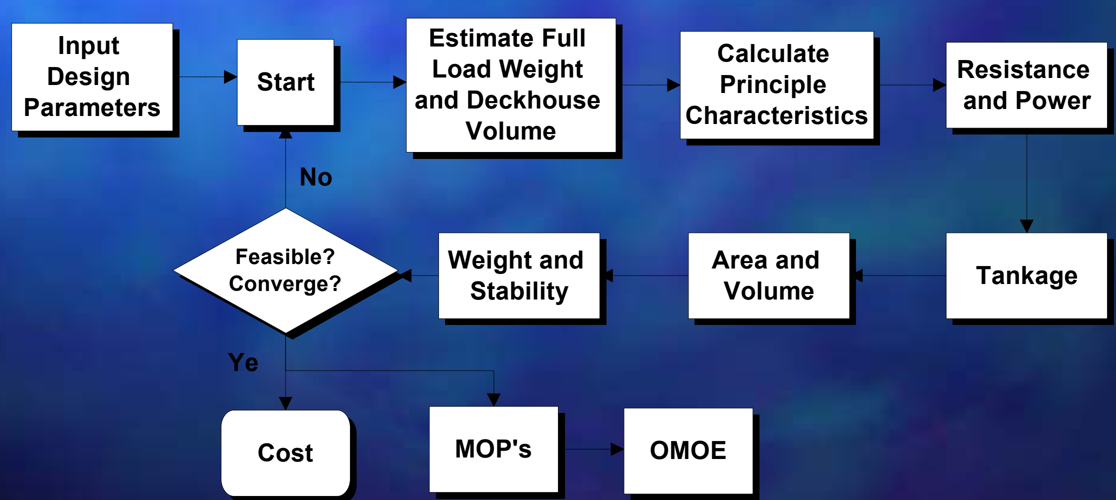


- Exploratory Design
  - Acquire and process information on SWATH technologies
- Concept Exploration
  - Ship Synthesis Model
  - Multi-objective Genetic Algorithm considering cost and effectiveness
  - Selection of design
- Feasibility Study
  - Detailed analyses of ship characteristics
- Summary/Design Critique

Concept Design

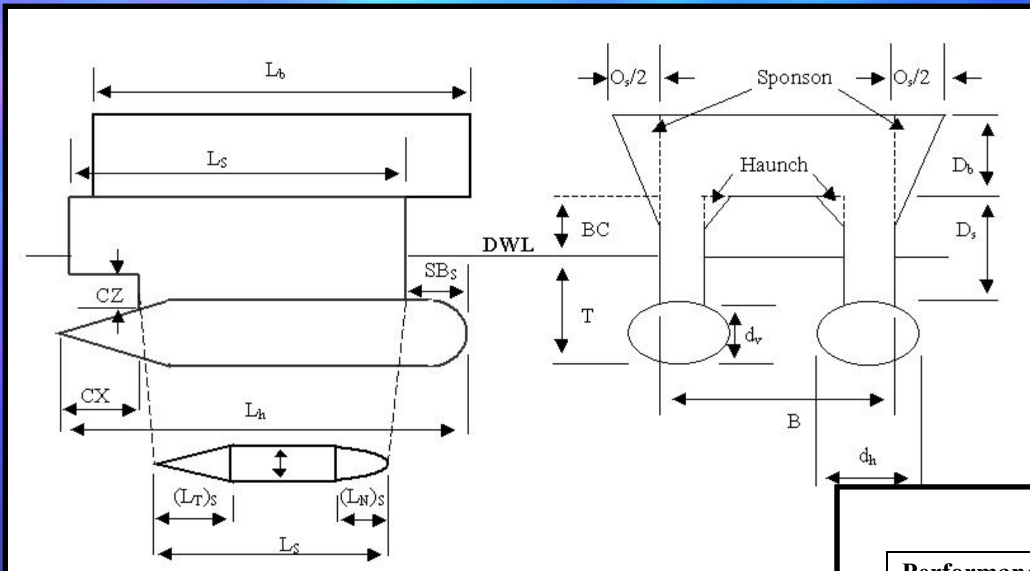
Ship Synthesis Model

- Design Parameters (DP) range of values allow adequate search of design space
- Measures of Performance (MOP) based on Owner's Requirements
- Ship balance, Total Ownership Cost (TOC), and Overall Measure of Effectiveness (OMOE) calculated
- Used in Multi-objective Genetic Algorithm



Concept Design

Design Parameters or Genes



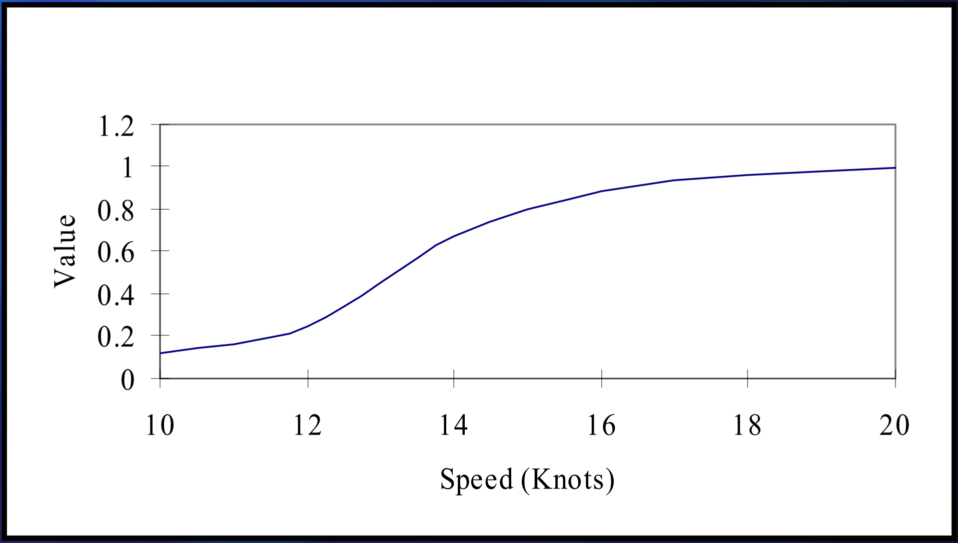
- 36 Design Parameters provide physical description of ship
  - 21 Geometry
  - 15 Performance
  - Set goal and threshold values based on expert feedback

Performance Design Parameter	**Range**
Endurance Speed	*10 – 20 knots*
Endurance Range	*10000 – 15000 nautical miles*
Stores Period	*40 – 80 days*
Science Payload	*50 – 100 long tons*
Science Gear Storage	*10000 – 20000* ft^3
Science Staff	*20 – 30 people*
Center Well Area	*100 – 400* ft^3
Lab Area	*2500 – 5000* ft^3
Deck Machinery Package	3 variations; low, mid, high
C_{dh} (deckhouse area to deck area ratio)	0.1 – 0.5
C_{DHMAT} (deck house material)	1 = aluminum, 2 = steel
BAL_{TYP} (ballast system type)	1 = compensated, 2 = standard
$PSYS_{TYP}$ (propulsion system type)	various
$GSYS_{TYP}$ (generator system type)	various

Concept Design

Evaluation of Effectiveness

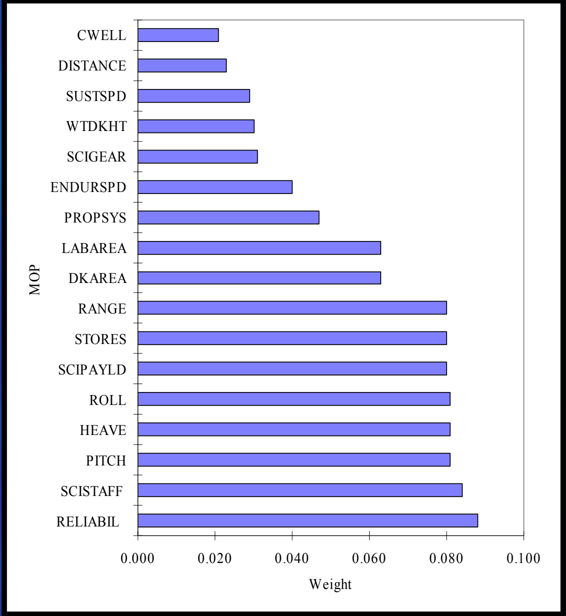
- Measures of Performance (MOP)
  - Used to define performance of ship independent of mission scenarios
  - Goal values set based on mission requirements and expert opinion
  - Threshold represent lower limit at which the ship can still perform mission

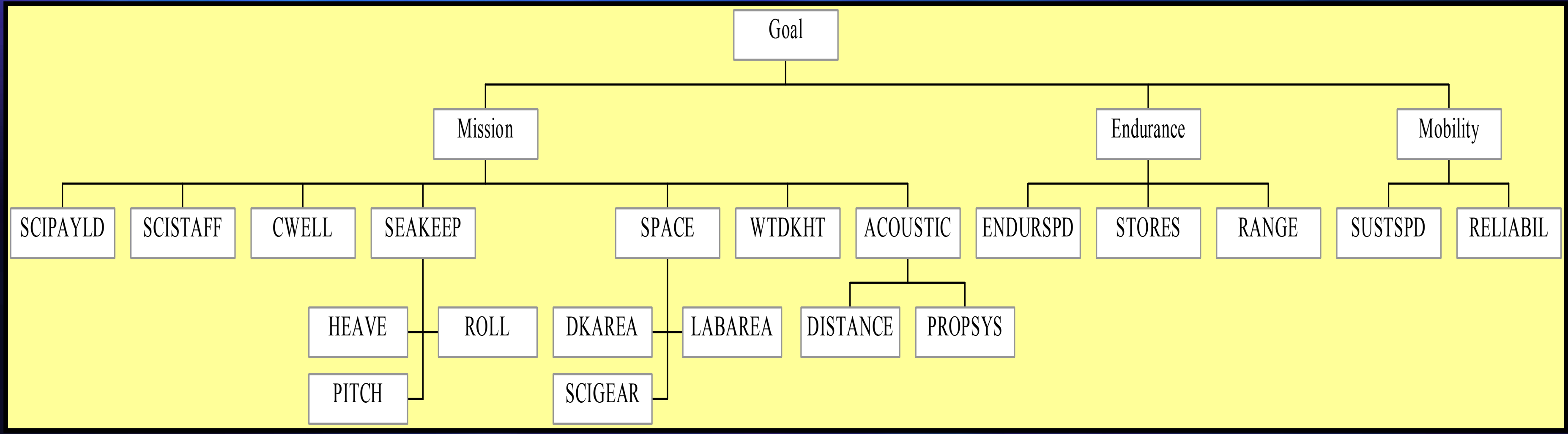


Concept Design

Overall Measure of Effectiveness

- Ship performance requirements are organized and their relationship quantified through Analytical Hierarchy Process
- Weighting based on results of pairwise comparison of MOP's
- One value of effectiveness calculated for each ship





Total Ownership Cost

Weight-based estimate including following components:

- Acquisition cost
- Discounted fuel cost over ship life
- Discounted manning cost over ship life

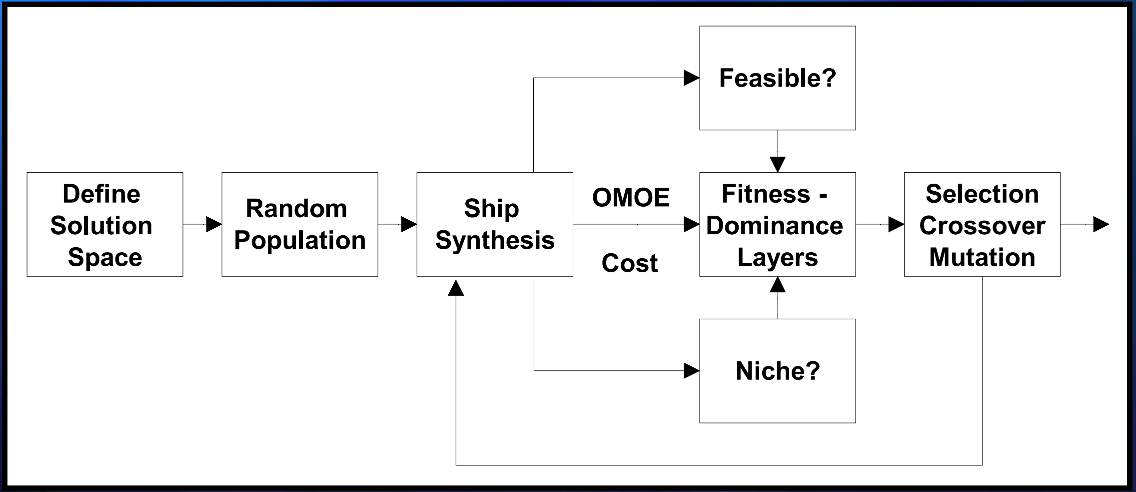
Concept Design
Model Balance

- Ship Balanced For A Given Set of Design Parameters
  - Convergence
    - Weight = Displacement
  - Feasibility
    - Electric power
    - Space
    - Draft
    - Seakeeping/Stability
    - Speed

Concept Design

Multi-objective Genetic Algorithm

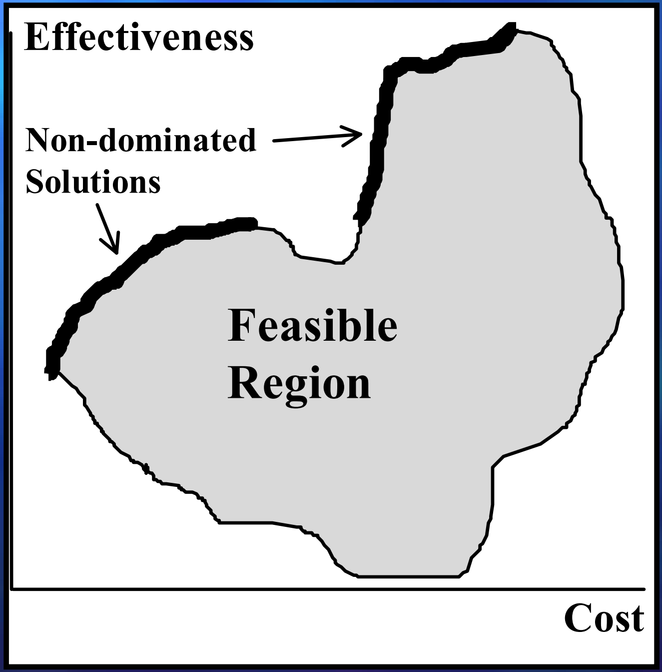
- Uses models of natural selection, reproduction, and mutation to improve a population of individuals or Design Parameters based on the "survival of the fittest"
- Applying Genetic Operators to population
- Creating Generations of increasing effectiveness and decreasing cost ships
- Evaluating feasibility, effectiveness, and cost in synthesis model
- Highly robust solution to non-closed form problem



Results of PGA Search

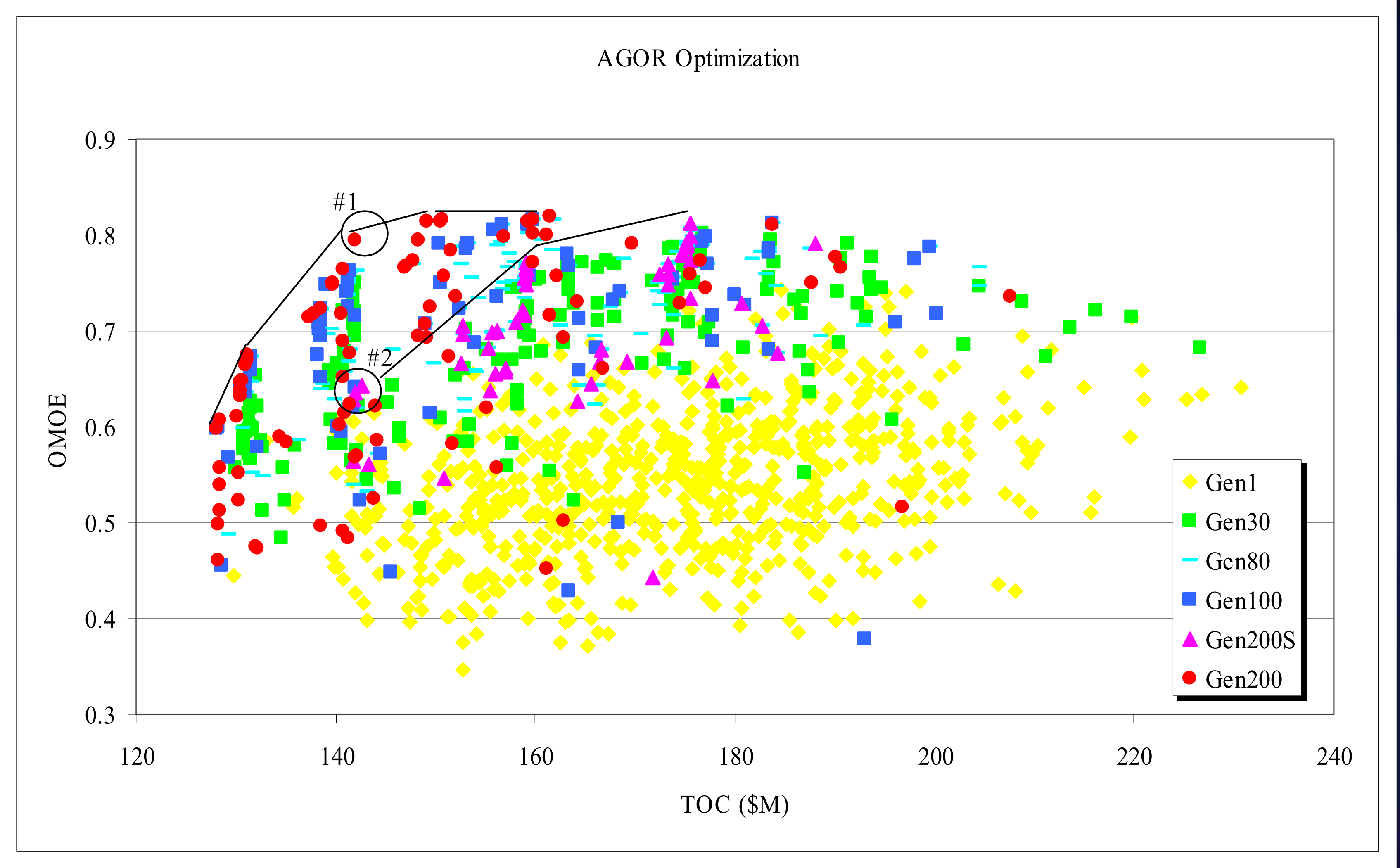
Non-dominated Frontier of Cost Effective Designs

- A Non-dominated solution is a feasible solution for which no other feasible solution exists which is better in one objective attribute and at least as good as all others
- "Best Buy Ships" lie at 'knees' on the NDF
- Design selection depends of customers preference for cost and effectiveness



VT SWATH AGOR

Design Selection



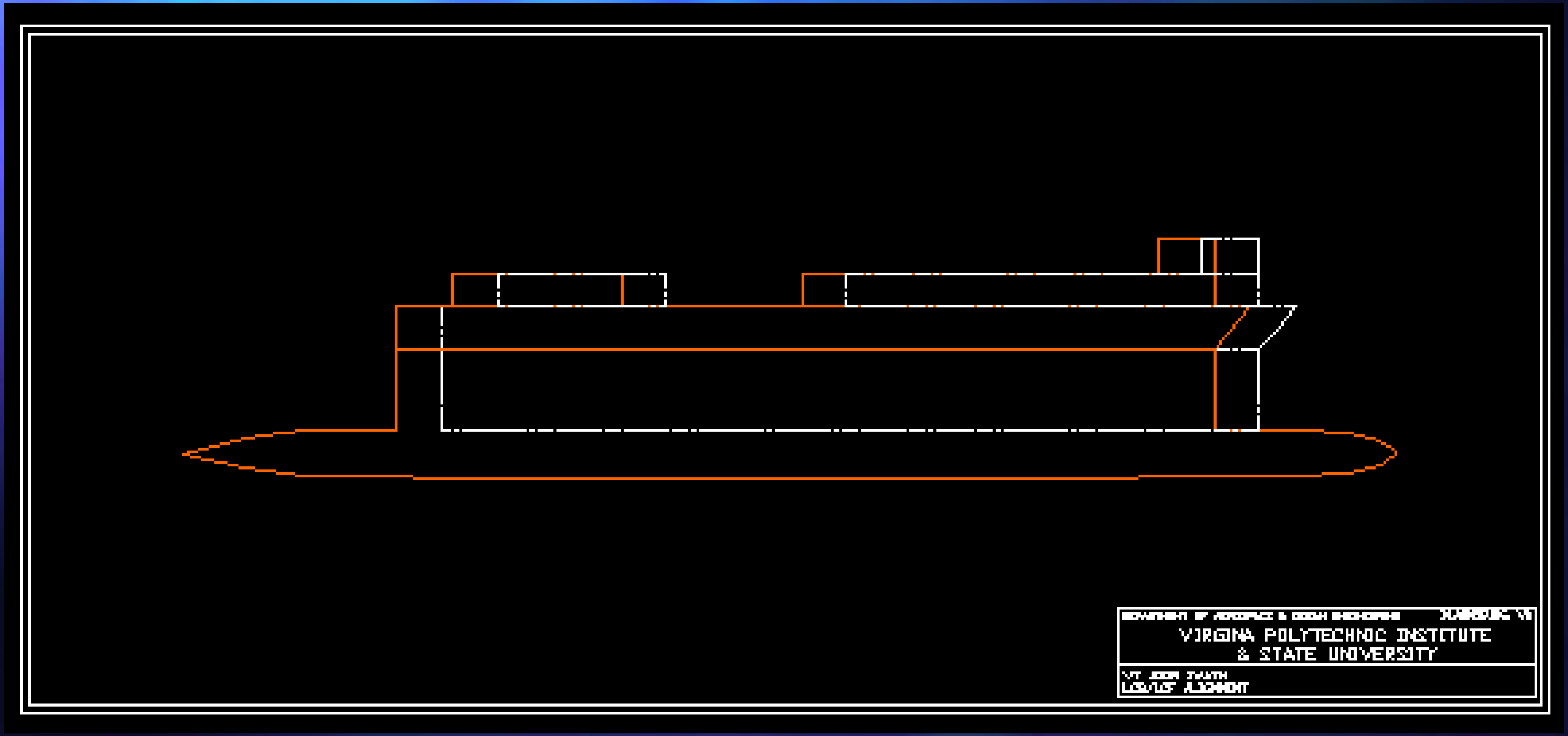
Design Parameter and Cost Comparison

Design Parameter	Best Buy (#1)	SNAME Best Buy (#2)	T-AGOS 19	Monohull Atlantis	Owner's Requirements
Length (ft)	322	326	234.5	274	N/A
Beam (ft)	93.333	93.143	93.5	52.5	N/A
Draft (ft)	21.467	22.102	24.75	17	24
Weight (ltons)	3720	3561	3397	3510	N/A
Sustained Speed (kts)	10.5	13	9.6	15.0	12
Endurance Speed (kts)	10	12	3.0	12.0	N/A
Range (nm)	13000	10000	N/A	17280	10000
Stores (days)	80	80	N/A	60	50
Science Payload (lton)	100	100	130	N/A	65
Scientific Gear Storage (ft^3)	15000	15000	N/A	N/A	15000
Science Staff	35	29	34	24	25
Centerwell (ft^2)	300	300	N/A	N/A	100
Lab Area (ft^2)	5000	3500	1400	3710	3000
Deck Machinery	(2) Boom Crane (2) Knuckle Crane (4) Hydro Winch (1) Traction Winch	(1) Boom Crane (1) Knuckle Crane (2) Hydro Winch (1) Traction Winch	Array Winch	Traction Hydro 2 Cranes 2 HIAB	N/A
Propulsion System	D/E (3-1175 hp/eng)	D/E (3-1700 hp/eng)	D/E (1600 hp)	D/E	N/A
Generator System	(3) 1Mw Gen's	(3) 1.25Mw Gen's	4 x 830kw	3 x 715kw	N/A
OMOE	0.79	0.64	N/A	N/A	N/A
Total Overall Cost (M$)	143.146	142.77	N/A	N/A	N/A

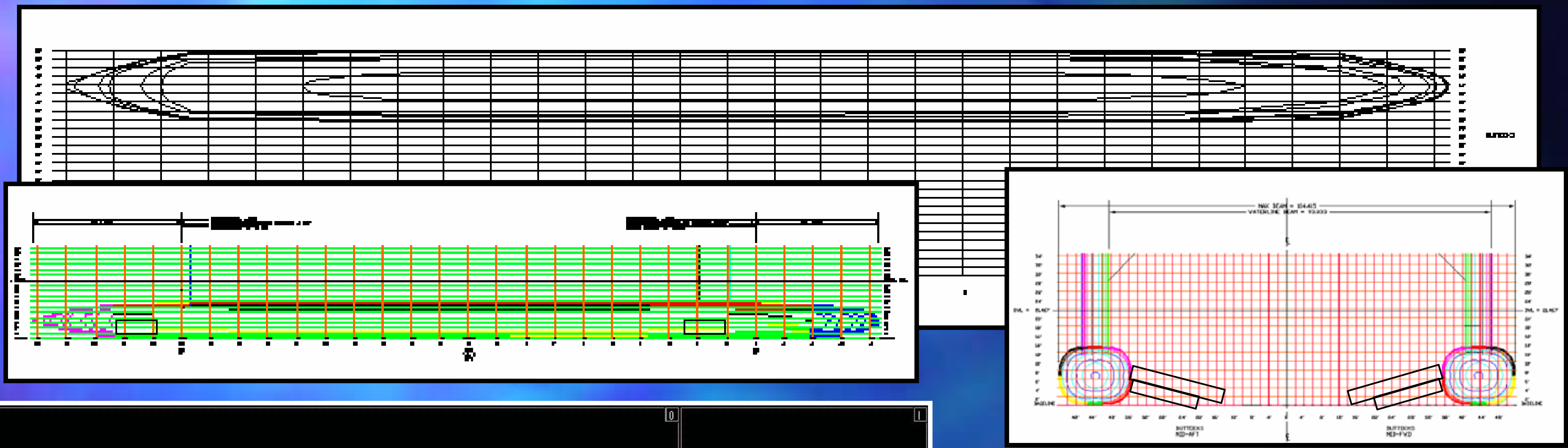
Feasibility Study

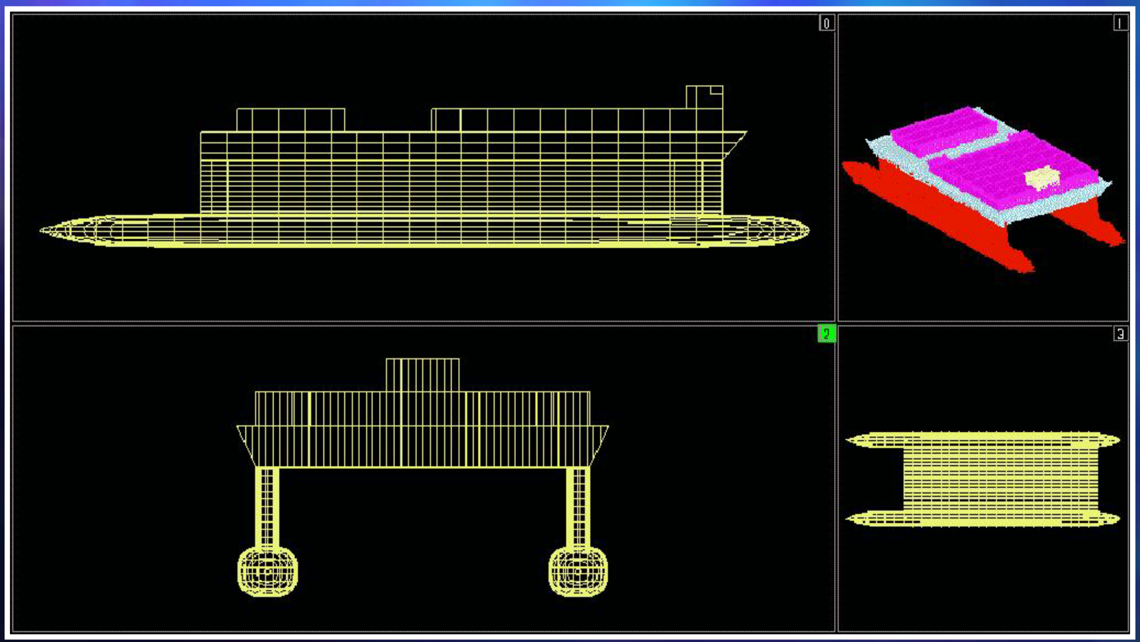
Preliminary Analysis

- Initial Hydrostatics
  - Misalignment between LCB and LCF
  - Resulting in adverse seakeeping effects
  - Decision made to move strut and box 12 ft aft to align LCB/LCF



Hull Form





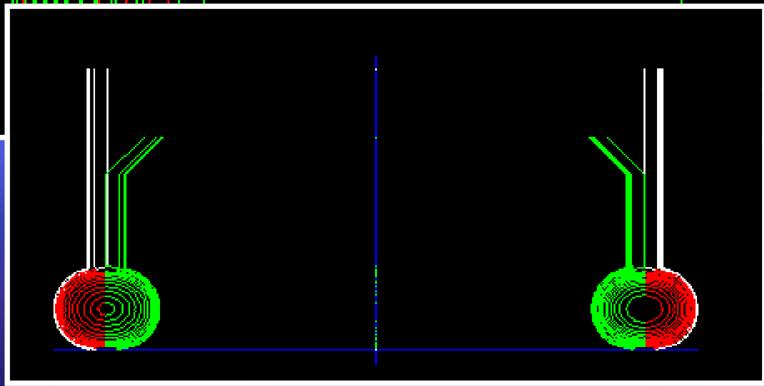
TOOLS:

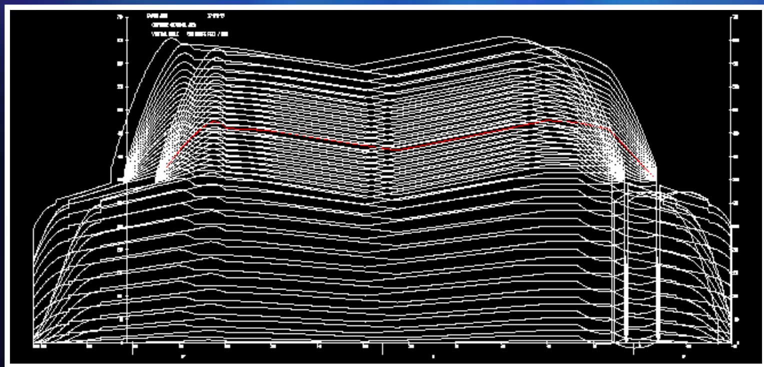
•Hull Geometry Modeled and Faired with **FastShip** software

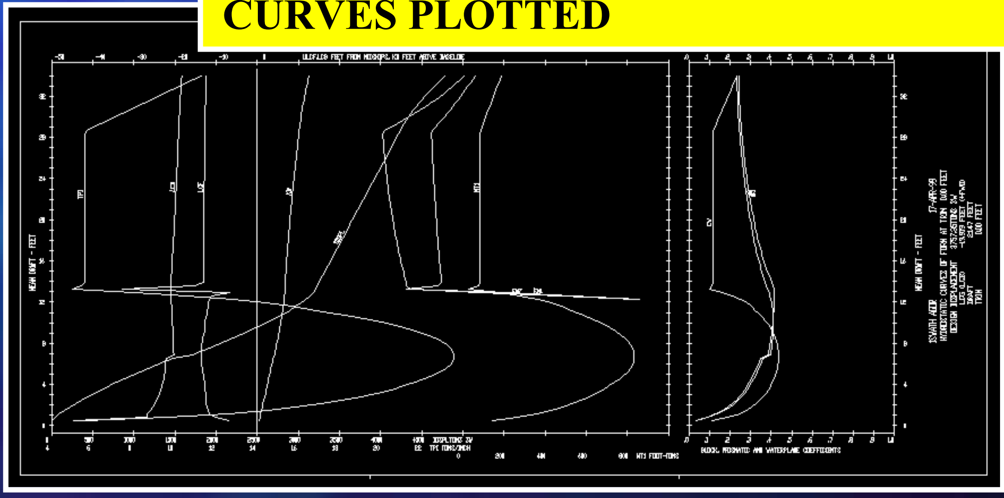
•Lines Drawings drafted using **AutoCAD** software

Hydrostatics

- SHCP SWATH HULL MODELED BY CREATING NEGATIVE APPENDAGES
- HYDROSTATICS ANALYSIS ACHIEVED USING SHCP MODULES
- CURVES OF FORM PLOTTED
- COMPOSITE SECTIONAL AREA CURVES PLOTTED

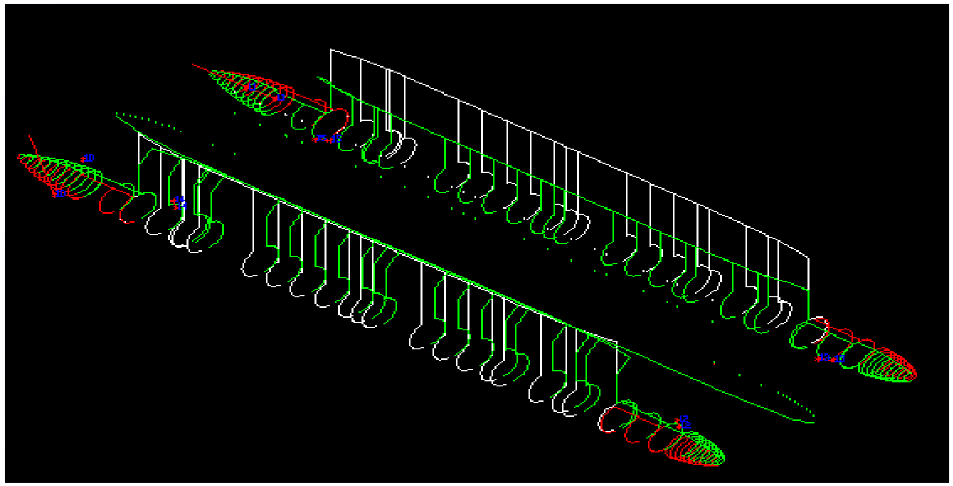






Stability Analysis

- Intact and Damaged Stability Assessed using SHCP Stability modules
- Extreme Operating Conditions:
  - Departure
  - Arrival
  - Ballasted Up



Beam Wind Heeling Arm Calculated by:

$$HA = \frac{.004 * V^2 * A * L * Cos^2\theta}{2240 * \Delta}$$

where:

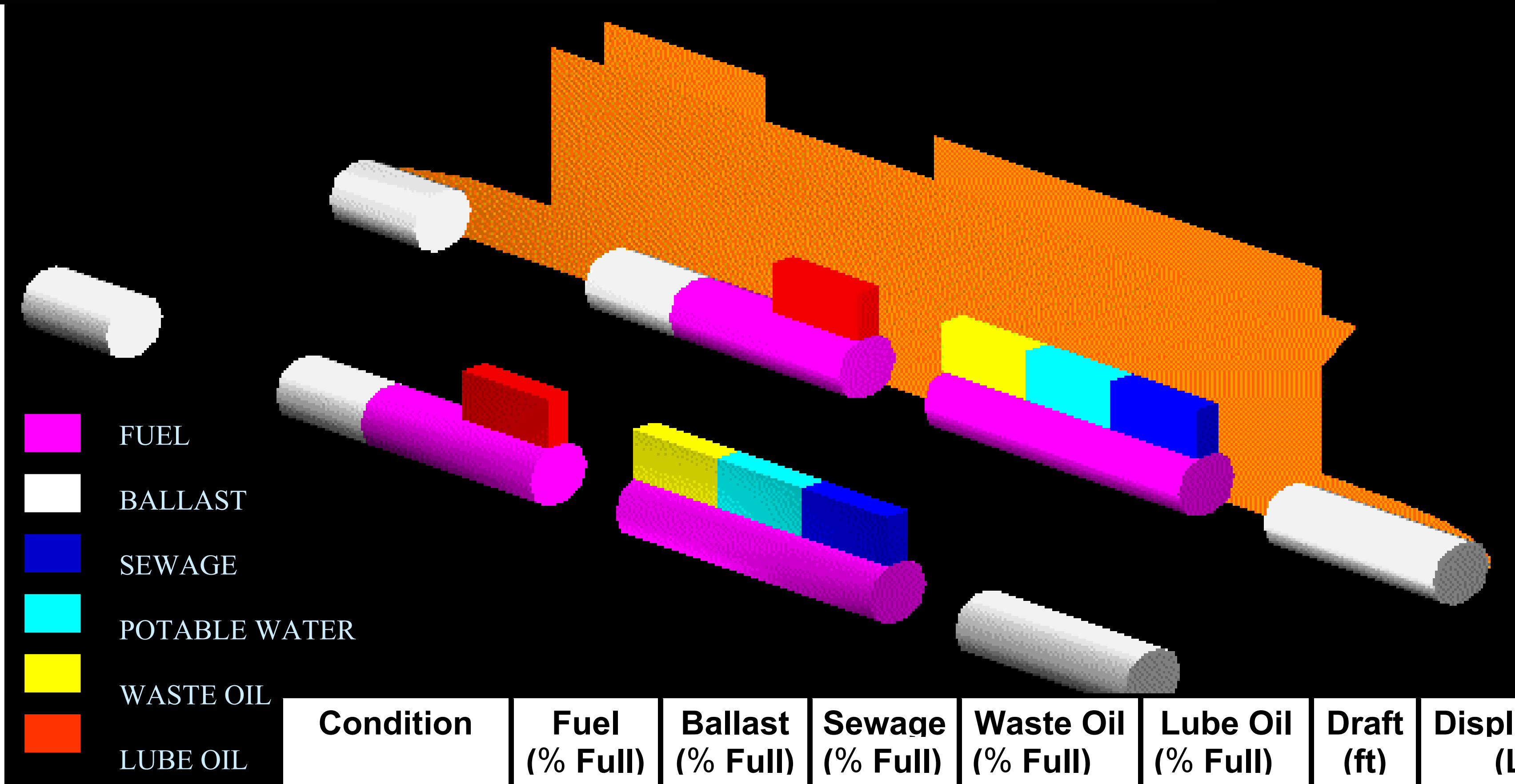
V= wind velocity in knots

A=hull sail area in ft^2

L=distance between the centroid of the sail area and the line of underwater resistance in ft

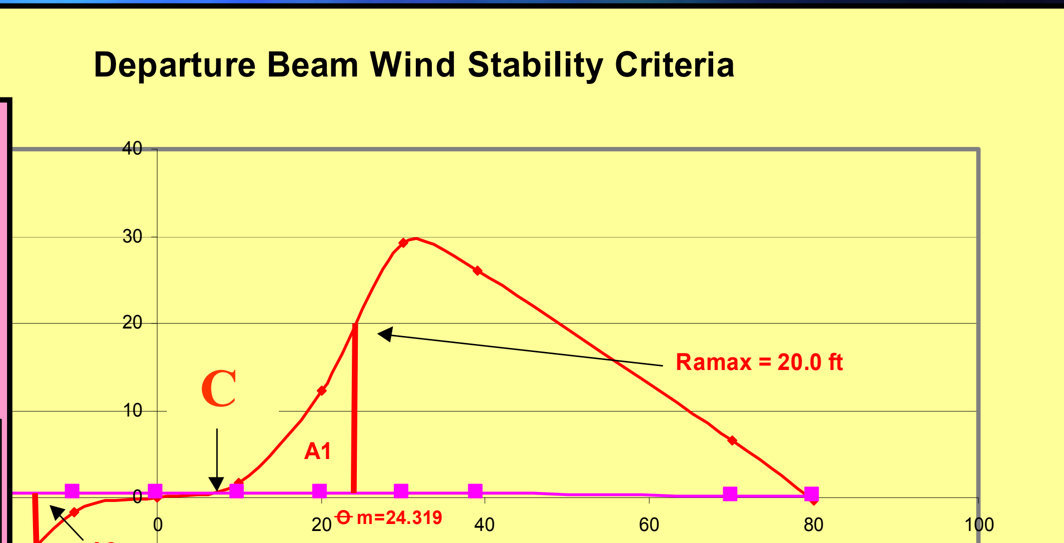
Loading Conditions

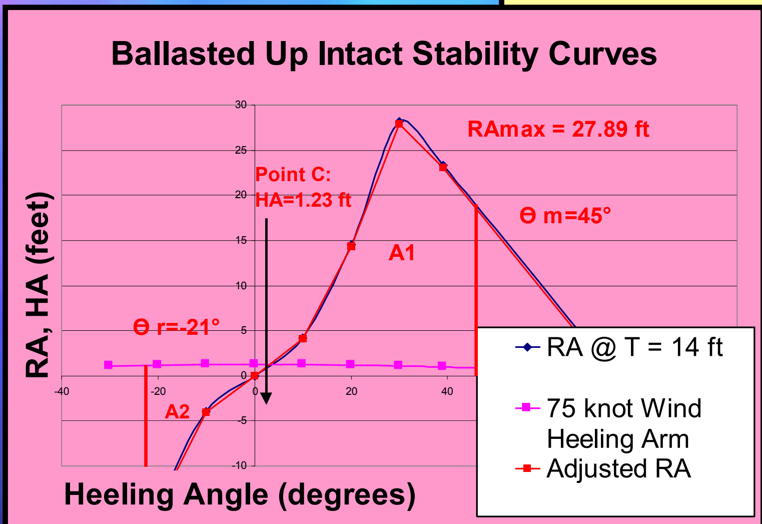
FREE SURFACE EFFECTS ON R.A. CALCULATED AS REQUIRED DURING BOTH ARRIVAL AND BALLASTED UP CONDITIONS

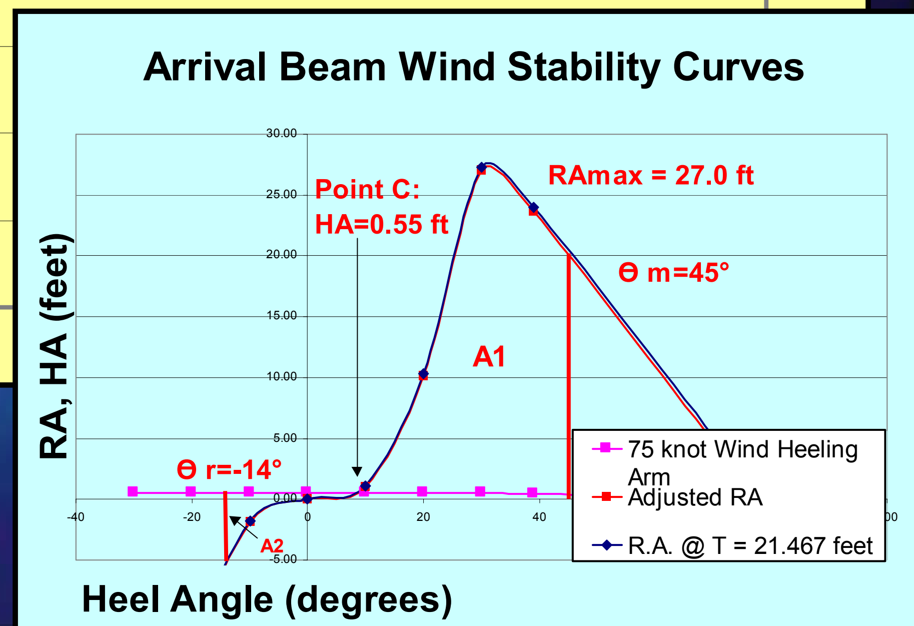


Condition	Fuel (% Full)	Ballast (% Full)	Sewage (% Full)	Waste Oil (% Full)	Lube Oil (% Full)	Draft (ft)	Displacement (Lton)
Departure	100.0	0.0	0.0	0.0	100.0	21.5	3757
Arrival	10.0	90.0	100.0	90.0	10.0	21.5	3757
Ballasted Up	20.0	0.0	100.0	90.0	10.0	12.0	3252

AGOR Stability in Wind







EXCEEDS ABS REQUIREMENTS

- RA @ POINT C < 0.6 R.A. MAX.
- EQUIL. HEEL < 12 DEGREES
- A1 > 1.4 A2 FOR θ rollback > 25°

Stability in Damage

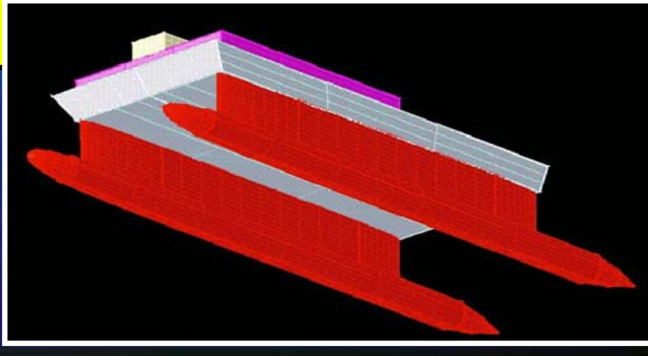
DAMAGE CONDITONS

- LONGITUDINAL AND TRANSVERSE DAMAGE MODULES PERFORMED IN SHCP
- 28 DAMAGE CONDITIONS ASSUMED PROBABLE
- FLOODING IN BOW AND STERN COMPARTMENTS CONSIDERED OCCURING BOTH SYMMETRICALLY AND ASYMMETRICALLY
- ASYMMETRIC FLOODING CONSIDERED IN REMAINING LOWER HULL COMPARTMENTS
- LONGITUDINAL LENGTH OF DAMAGE MANDATED BY ABS CRITERIA EQUATES TO FLOODING IN TWO COMPARTMENTS

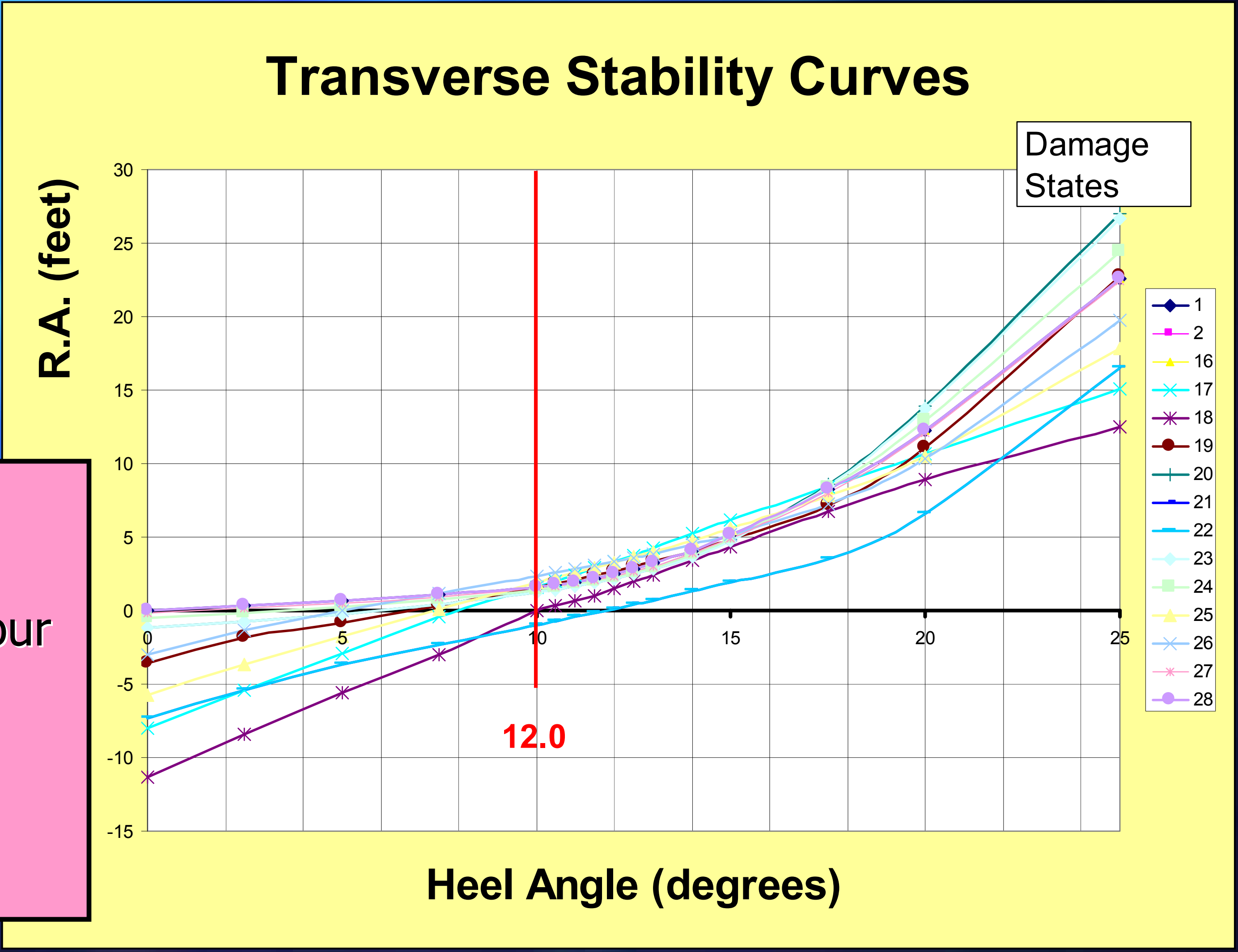
DAMAGE SURVIVAL

DAMAGE STABILITY IS SATISFACTORY IF IN THE FINAL CONDITION OF DAMAGE:

- EQUILIBRIUM HEEL $< 12^{\circ}$
- THE POSITIVE RESIDUAL R.A. CURVE HAS A MINIMUM RANGE OF 15 DEGREES BEYOND EQUILIBRIUM
- THE AREA UNDER THE R.A. CURVE IS $\geq$ 2.82 ft-degrees
- THE MAXIMUM POSITIVE R.A. IS $\geq$0.328′ WITHIN THE 15 DEGREE RANGE



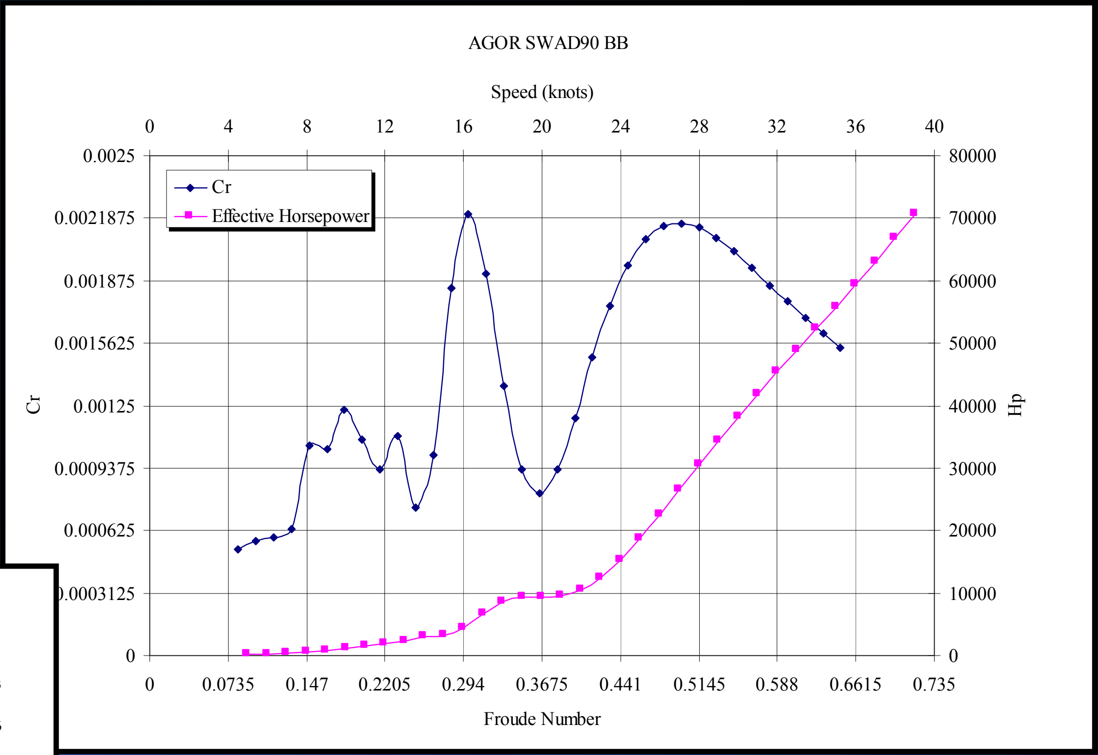
Damaged Stability

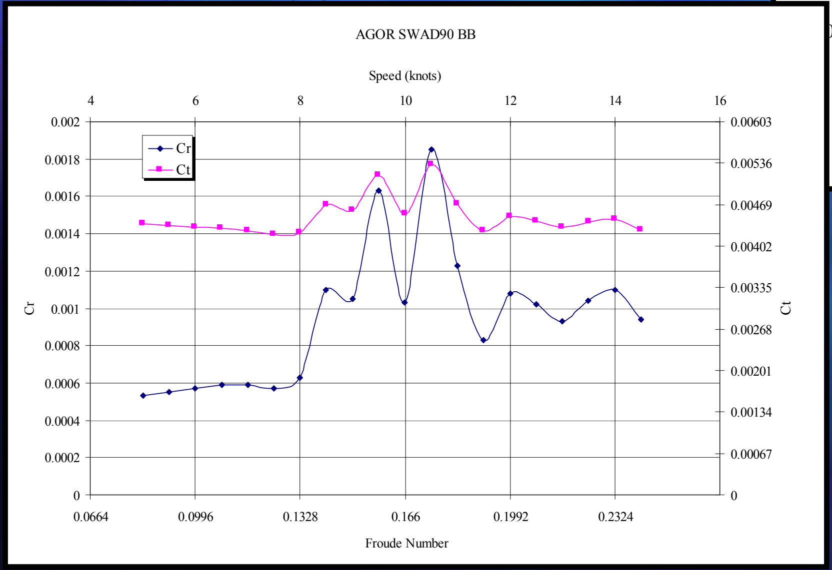


- 28 Damage Cases
- Survives All Four Damage Conditions for Every Loading Condition

Resistance

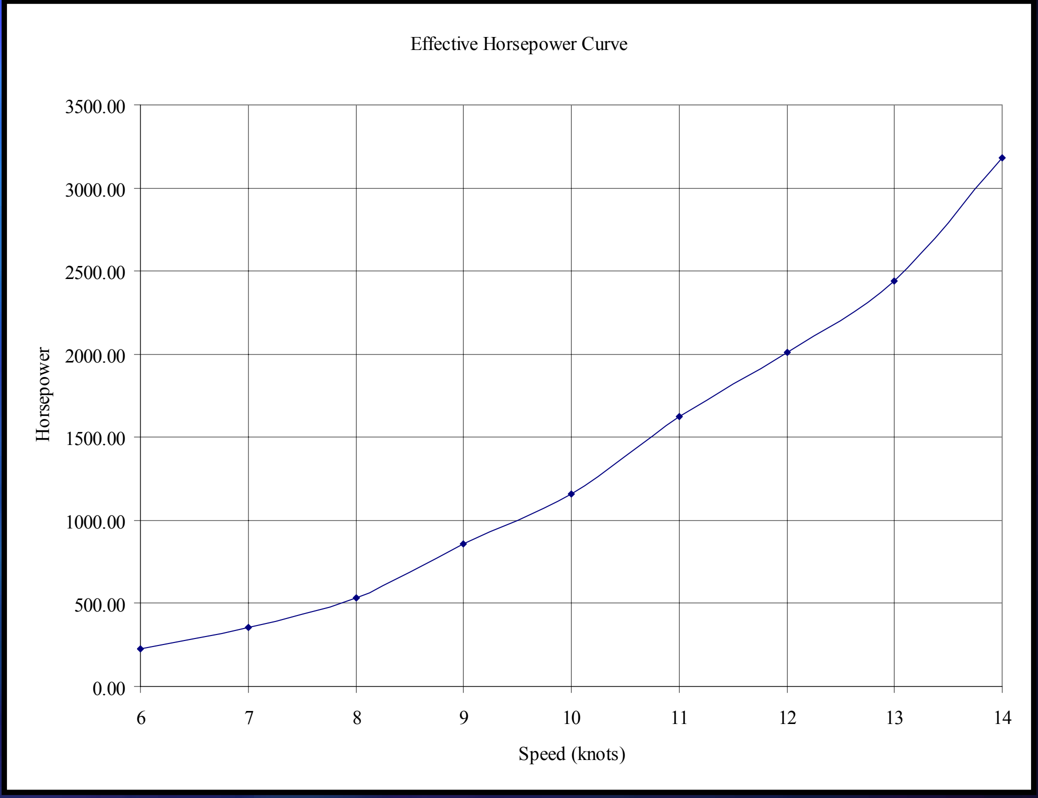
- Synthesis Model
  - Wave Making
    - Chapman Integral Method
  - Viscous
    - 1957 ITTC Line
  - Eddy, Pressure Effects
    - Form Allowance
- Feasibility Study
  - SWAD90





Propeller Selection

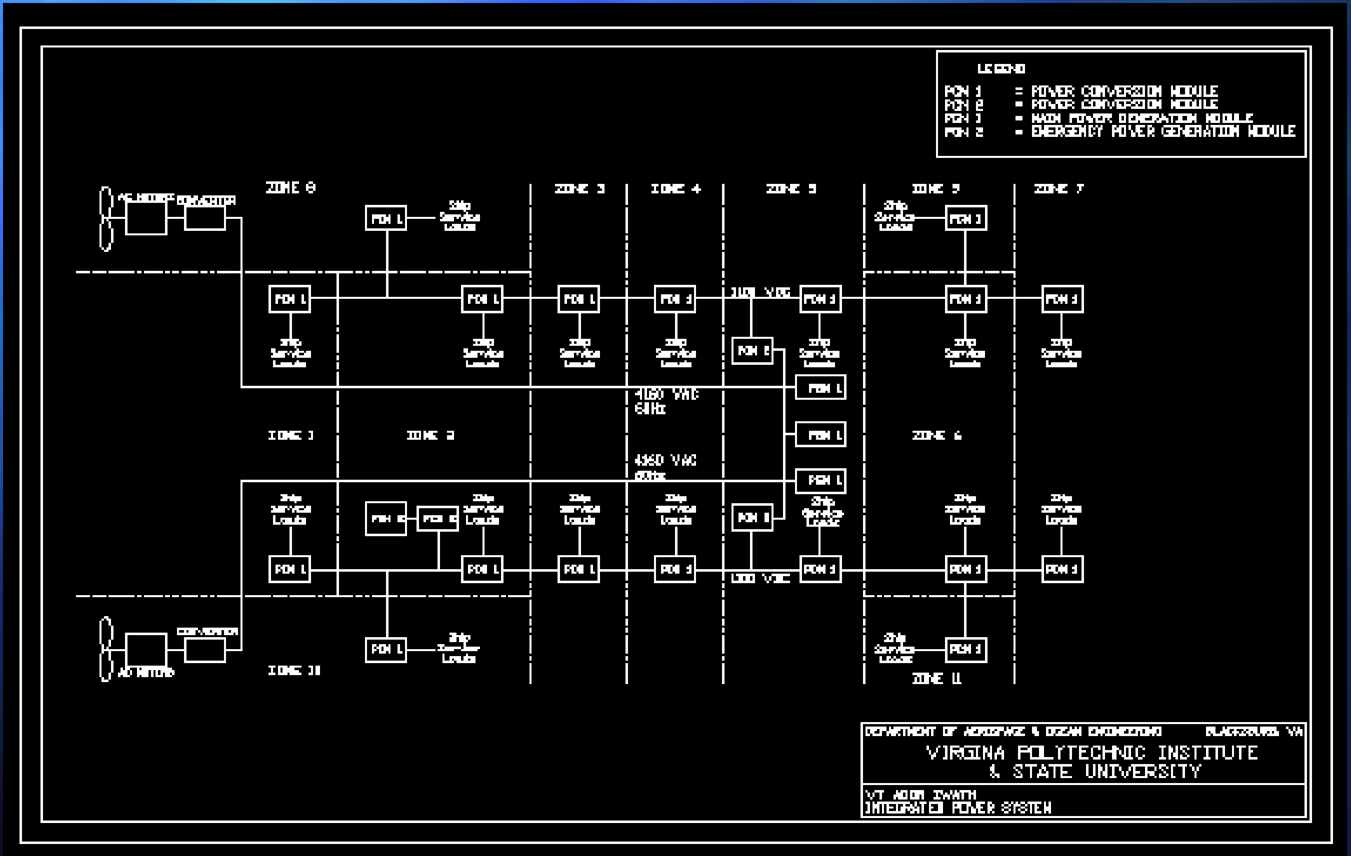
- Feasibility Study
  - Propeller Selection Optimization Program (PSOP)
    - Diameter taken to be 90% of max vertical hull diameter
    - Wake fraction, Thrust deduction taken as 0.1
    - Relative rotative efficiency taken as 1
    - Analysis based on EHP curve developed in SWAD90
  - Results of PSOP
    - B-Series, 5 Blades
    - Blade Area Ratio = 0.355
    - P/D = 1.486
    - Open water efficiency at endurance speed = 0.67
    - 80 RPM



INTEGRATED POWER SYSTEM

- Power Generation Modules (PGM 1)
  - Produce 4160 VAC 60 Hz 3 Phase Power, 1MW
  - Distributed to the Propulsion Motors
- Ship Service Distribution System
  - Power Conversion Modules (PCM 2) Convert 4160 VAC to 1100 VDC Using Solid Sate Electronics
  - In Zone Electrical Distribution Power is Converted to a more usable form, Dependent on Zone Requirements, by Power Conversion Modules (PCM 1)

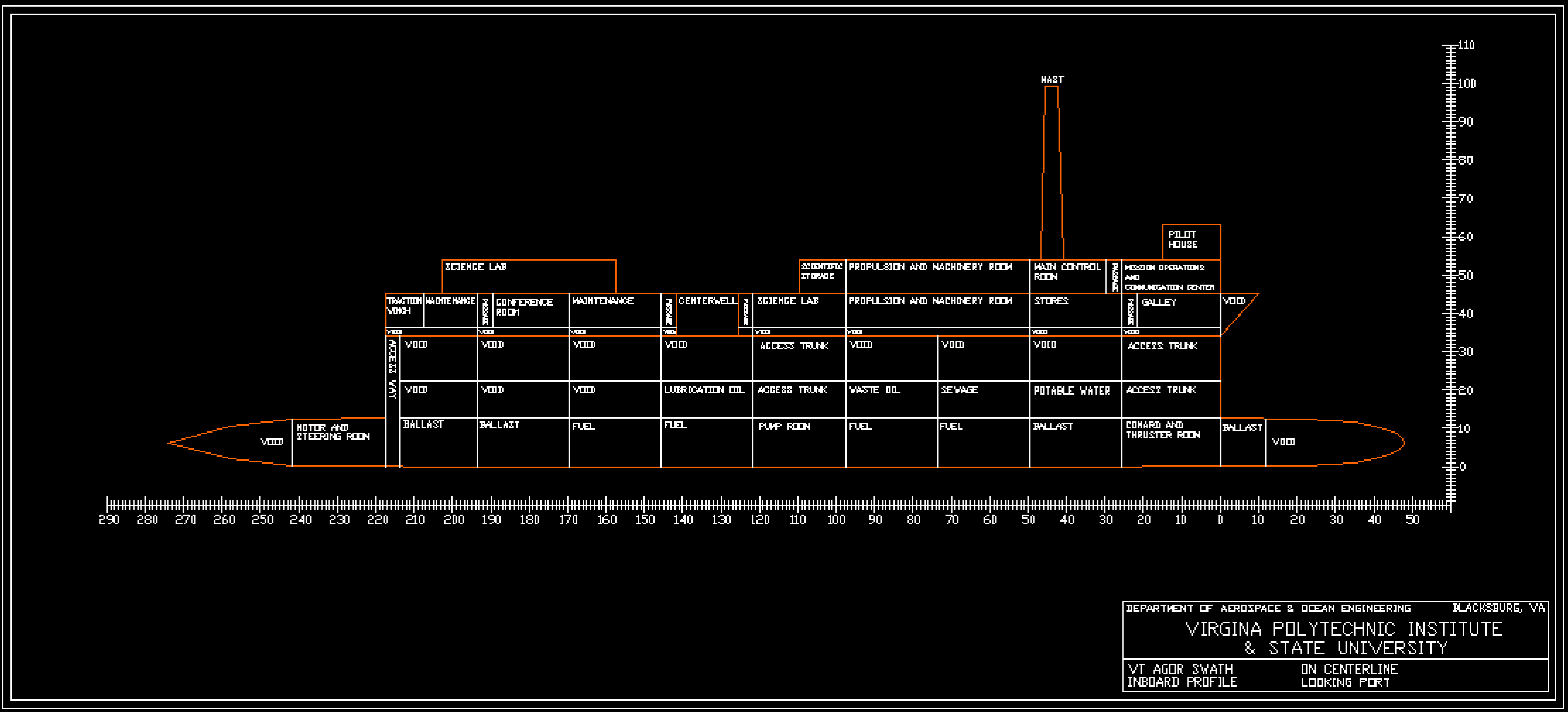
- Main Engines
  - (3) CAT 3512V12
    - 1175 BHP
- Emergency Engines
  - (1) DD 16V92T
    - 720 BHP



ARRANGEMENTS

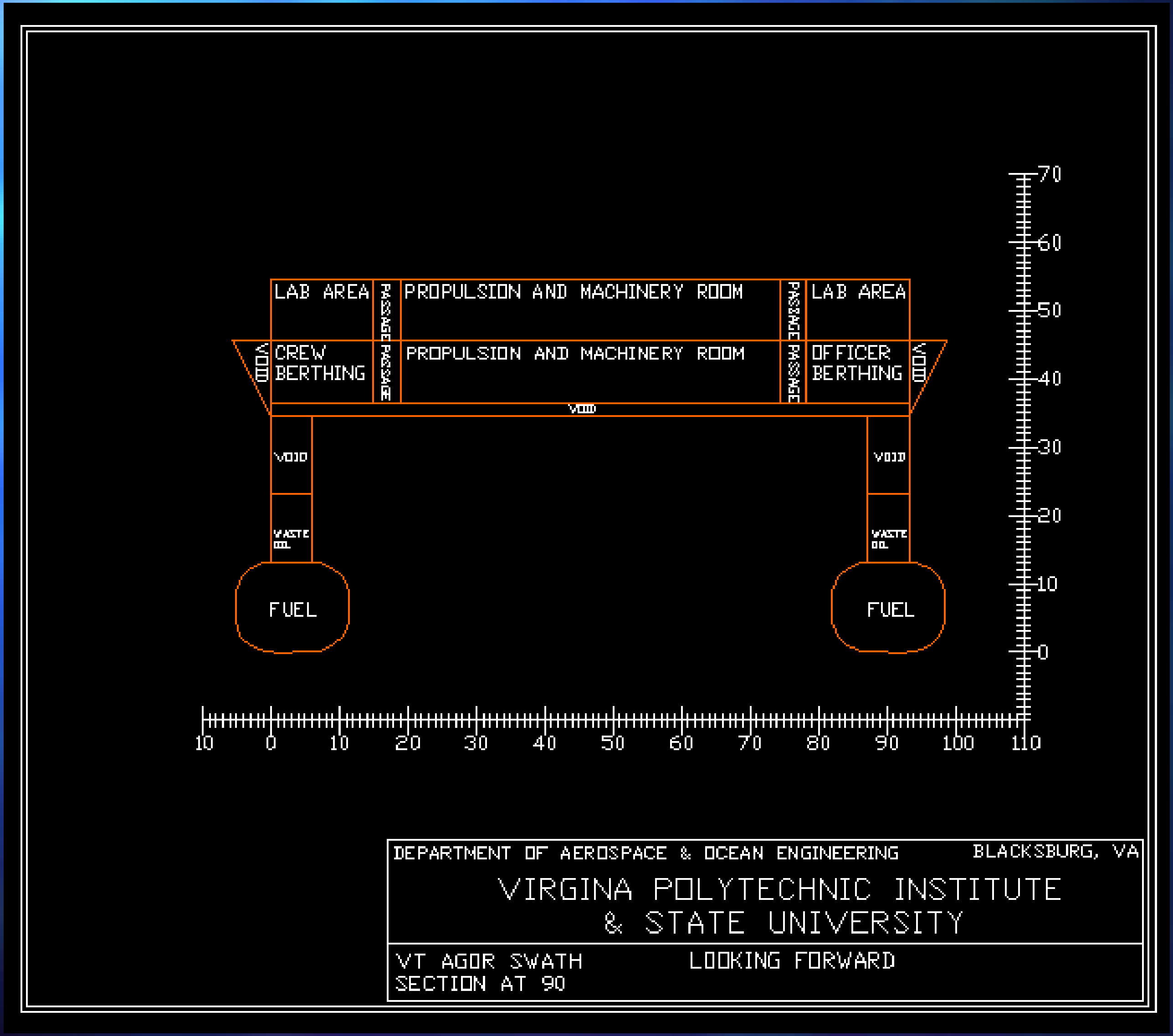
- Profile View

- Arrangement design Based on
  - Scientific Needs
  - LCG
  - Bulkhead Arrangement



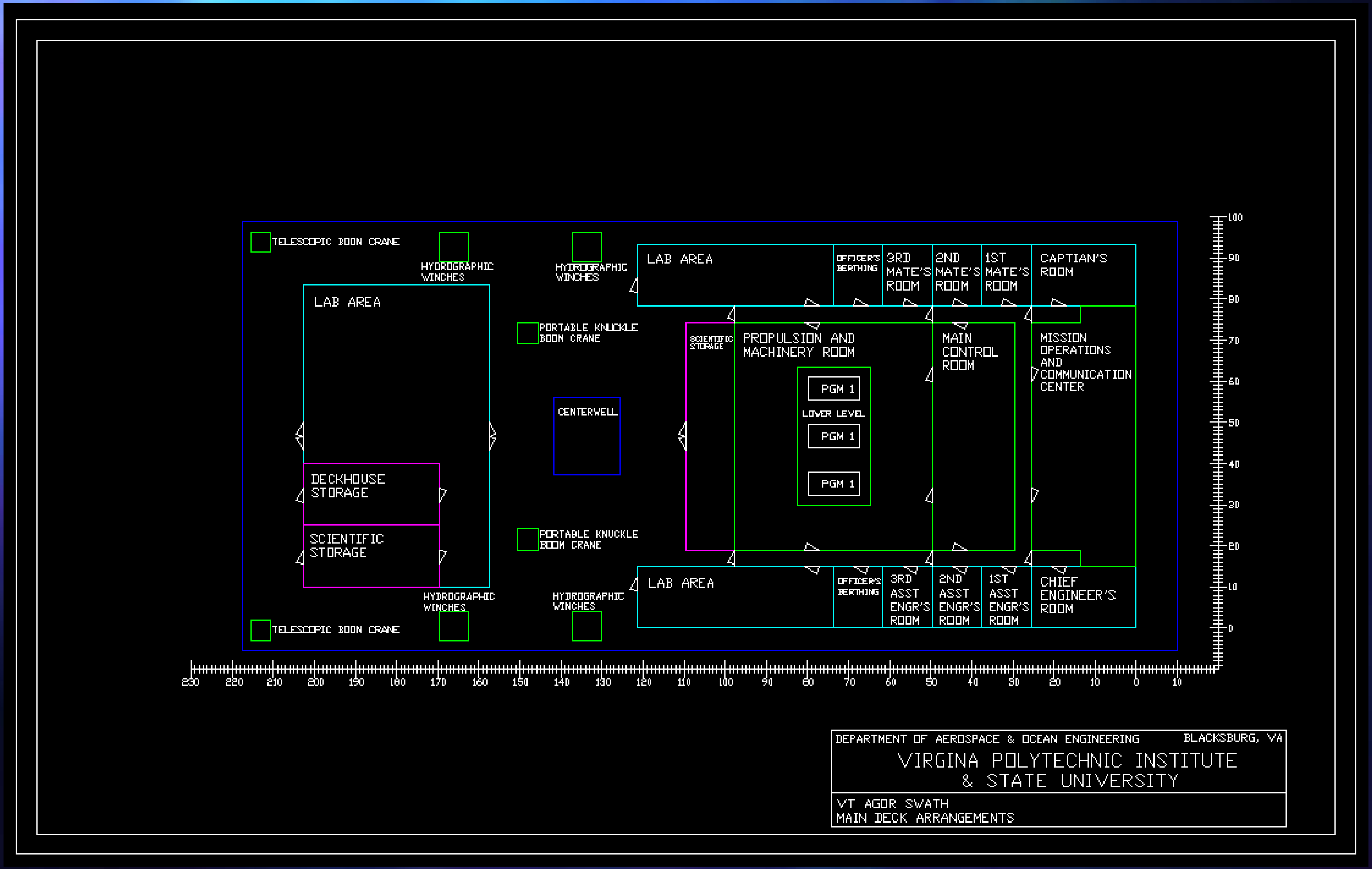
ARRANGEMENTS

- FRONT VIEW



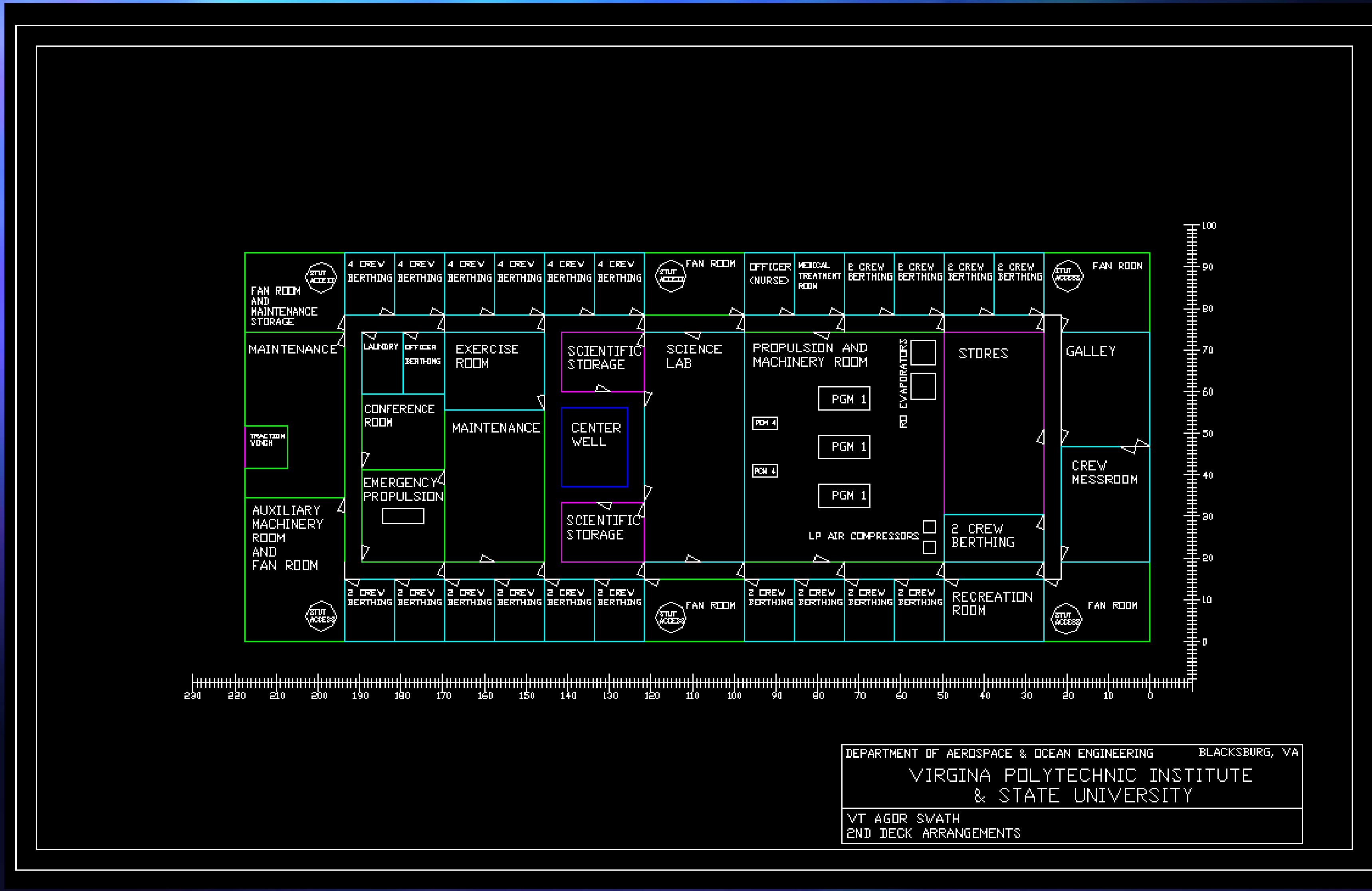
ARRANGEMENTS

- MAIN DECK

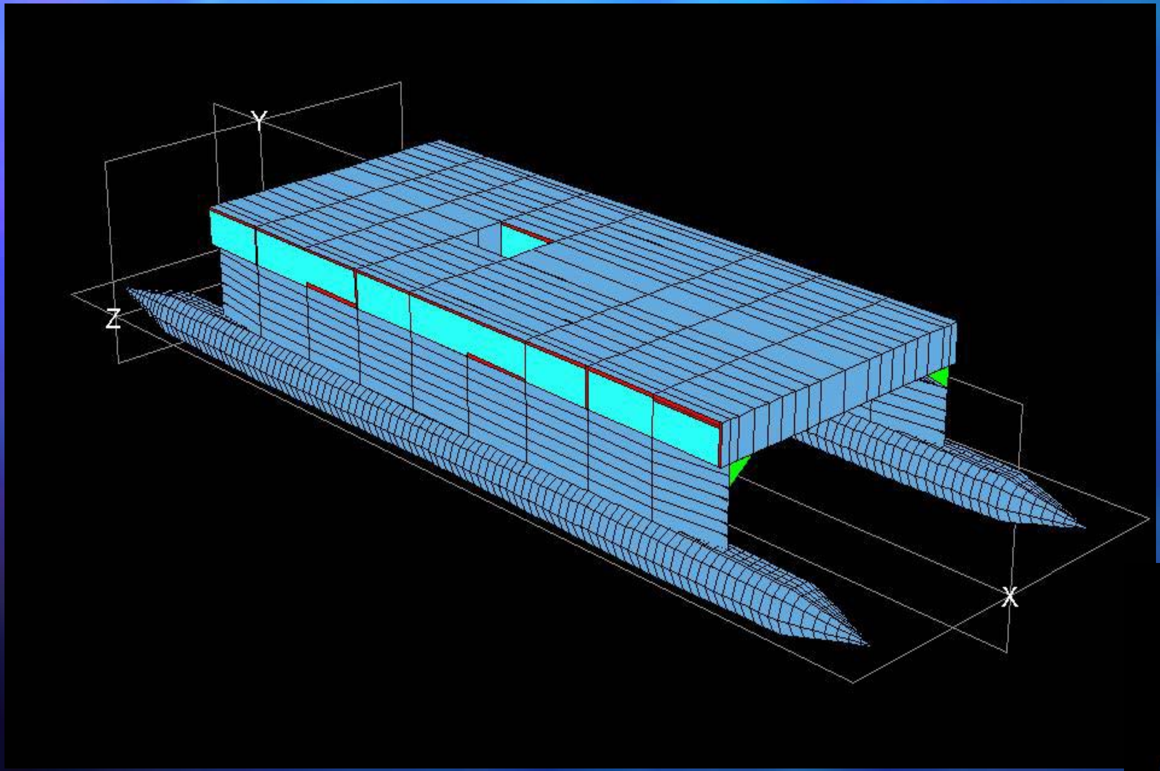


ARRANGEMENTS

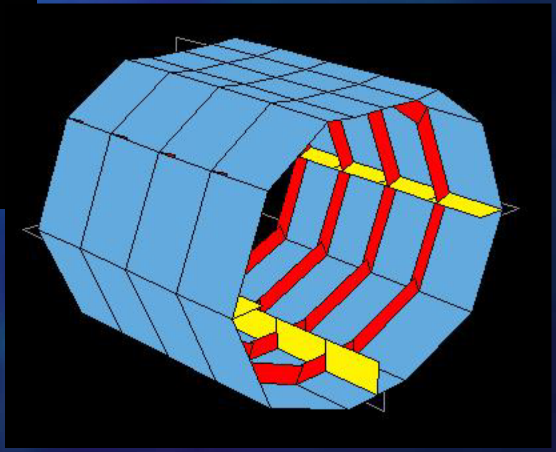
- 2ND DECK



Structures
Developed in MAESTRO



- Substructures:
  - hull
  - strut
  - box
  - haunch
- Transverse Framing
  - Frame spacing: 3 ft
  - Bulkhead spacing: 24 ft
- Preliminary scantlings are modeled after TAGOS-19, information provided by NAVSEA.



Load Forces
Work in Progress

- Load Cases
  - Three Main Cases (From the paper "SWATH Structures" by Jerry Sikora and Alfred L. Dinsenbacher)
    - Side Load
    - Torsional Load
    - Wave Slamming Loads

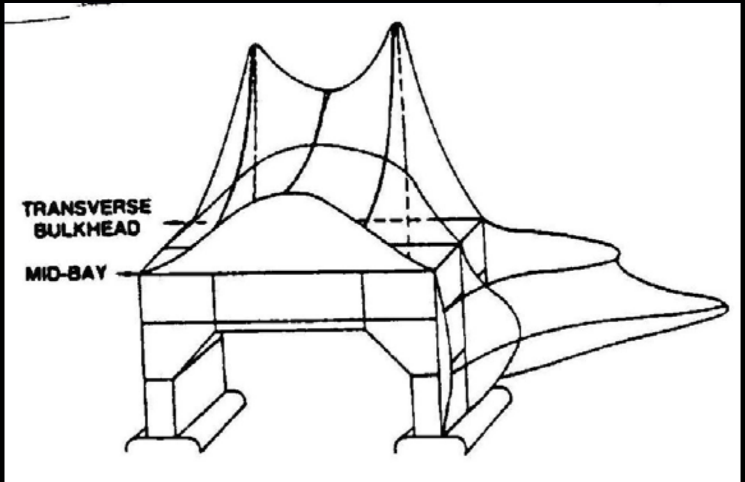
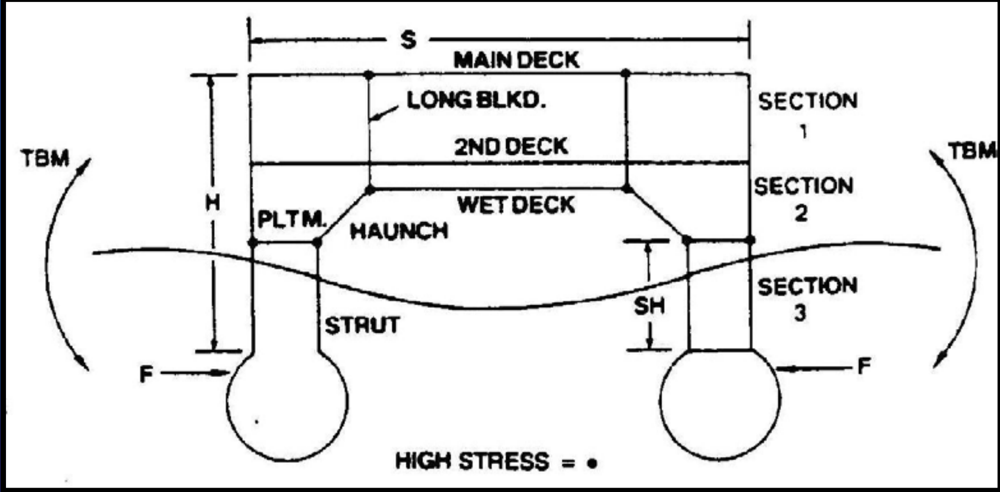
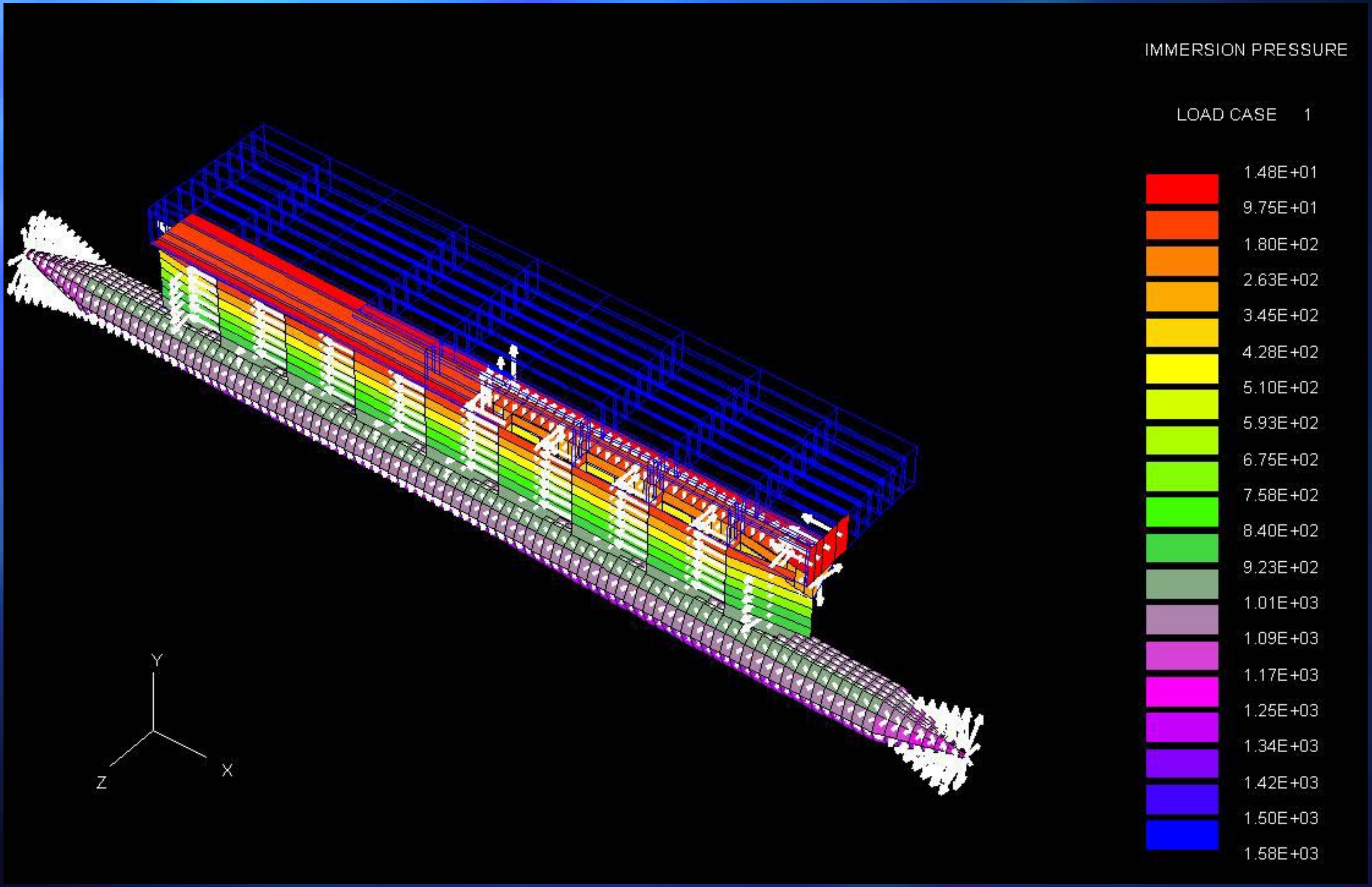


Fig. 9 Transverse stress distribution



Wave Pressure Distribution



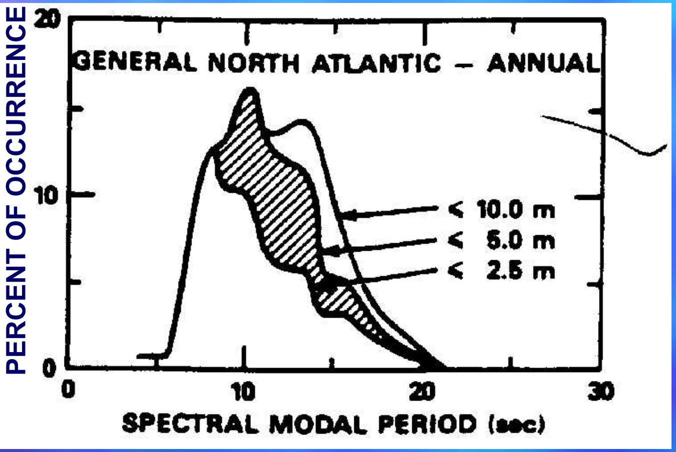
Weights and Centers

- Developed based on
  - Arrangements
  - LCG/LCB alignment

SWBS	COMPONENT	WT (lton)	LCG (ft)	VCG (ft)
100	HULL STRUCTURES	1728.94	117.35	28.13
200	PROPULSION PLANT	166.05	187.94	35.42
300	ELECTRIC PLANT, GENERAL	82.70	76.82	40.12
400	COMMAND+SURVEILLANCE	48.05	7.50	45.00
500	AUXILIARY SYSTEMS, GENERAL	518.53	176.03	42.58
600	OUTFIT+FURNISHING,GENERAL	266.23	108.50	28.44
Light Ship		2949.36	128.44	35.18
F00	LOADS	804.67	111.39	8.70
Full Load Departure		3754.03	121.69	29.72
Full Load Arrival		3754.03	121.55	29.72

Seakeeping

Preliminary Calculations



- North Atlantic year round conditions
- 3 Seakeeping MOP's based on natural periods

Motion	Goal (sec)	Threshold (sec)
Heave	10	12
Pitch	19	17
Roll	21	19

Seakeeping

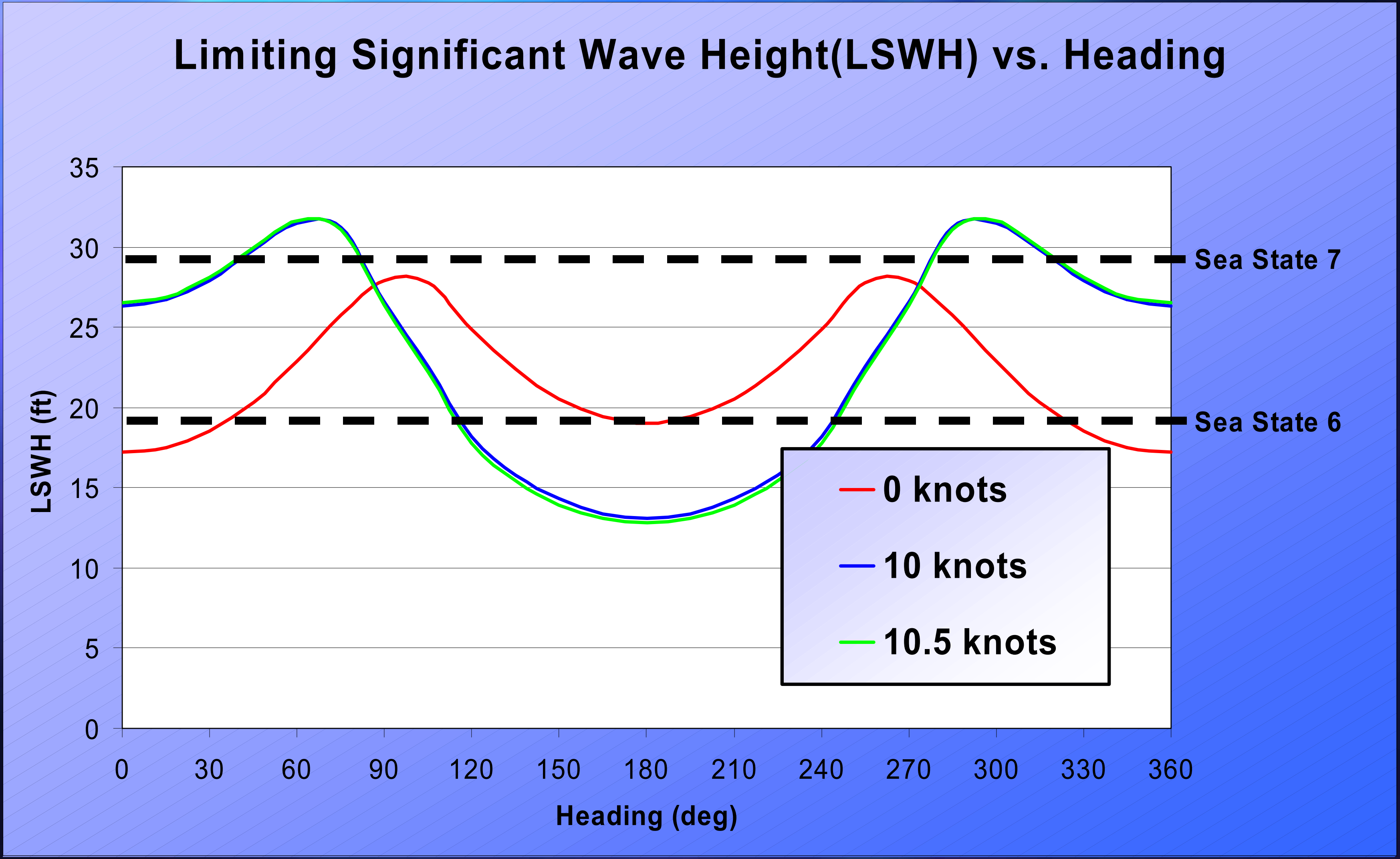
Detailed Analysis

- SWATH Motions Program (SWMP)
  - Fins
  - Natural periods
  - Response RMS values

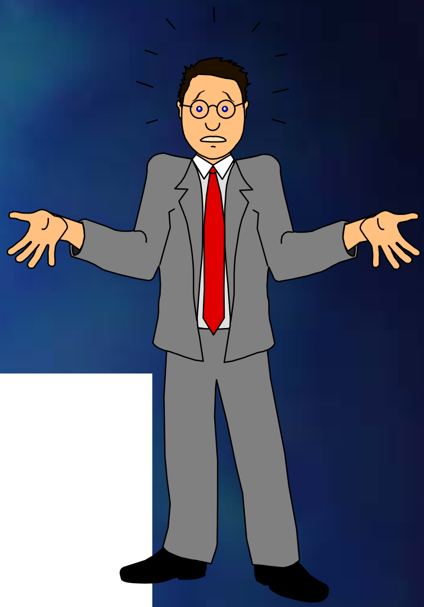
Motion	Natural Period (sec)
Heave	12.020
Pitch	19.203
Roll	21.409

Condition	Speed	Roll (deg)	Pitch (deg)	Lateral Acceleration at Pilot House	Vertical Acceleration at Pilot House	Vertical Acceleration at Transom	Vertical Acceleration at Midship
Operating	12	8	3	0.2g	0.4g	0.4g	-
On Station	0	5	3	0.2g	0.4g	0.4g	0.4g

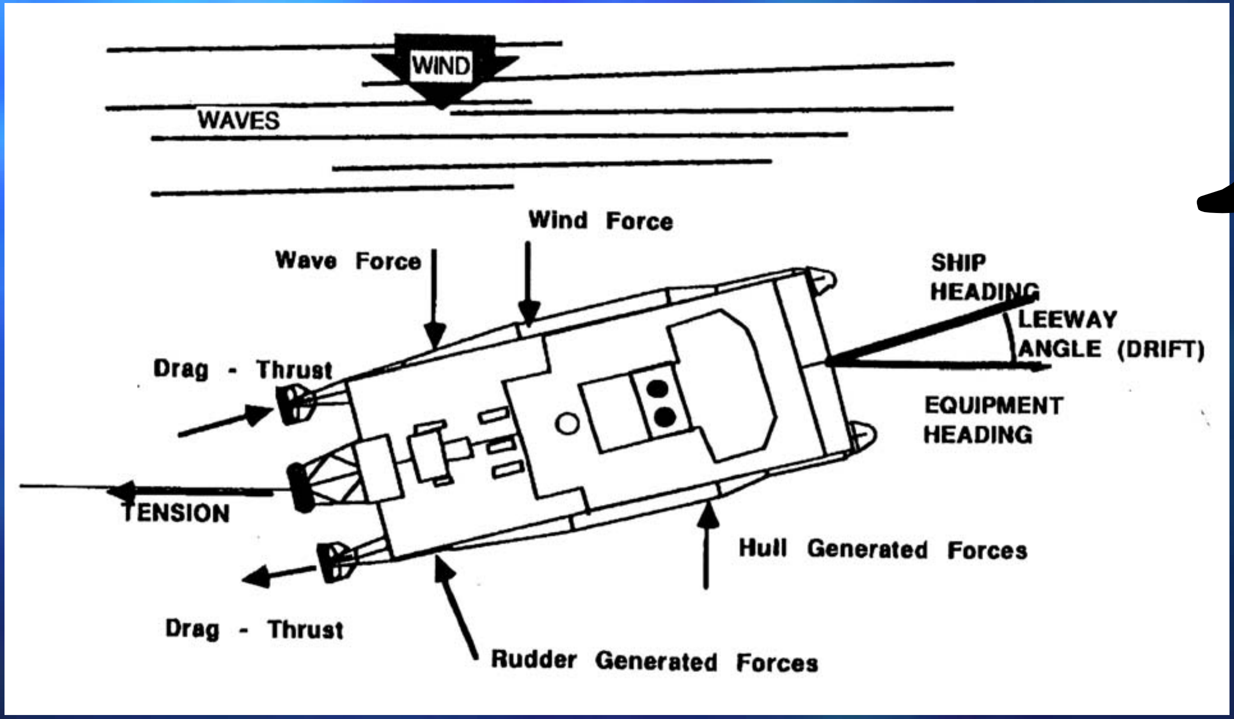
Seakeeping
Detailed Analysis



Stationkeeping



- Analysis is currently underway



Cost Distribution

- **Acquisition Cost(FY 2000): $102.9 Million**
  - Hull Structure - $22.6 Million
  - Propulsion - $4.3 Million
  - Electric - $5.5Million
  - Command, Control and Surveillance - $2.1 Million
  - Auxiliary - $22.5 Million
  - Outfit - $14.1 Million
  - Margin Costs - $3.6 Million
  - Integration/Engineering - $3.9 Million
  - Ship Assembly and Support - $5.0 Million
  - Basic cost of construction - $83.5 Million

  - Rough Order Magnitude Lead Ship Construction Cost = (0.0167 $M/LT) ($W_{LS}$) + $15M for W_{LS} = 3,757.352 LT => $77.75 Million

  - Builder Profits: $8.4 Million
  - Change Order Costs: $11.0 Million

- **Discounted fuel Cost Over Ship Life: $6.3 Million**
- **Discounted manning Cost Over Ship Life: $40.5 Million**
- **TOC = $143.3 Million**

Manning

- Crewmembers - 31
  - Estimated using weight based equations
  - Dependent on automation
- Science staff - 35
- Total accommodations - 66

Summary and Critique

- Flexible Arrangements
  - Adequate volume and area to allow variation in layout
  - Overhangs provide simplified overboard operations
  - Open and uncluttered deck space
- Commercial Standards
  - Meets all ABS/CFR requirements
  - Highly producible hullform
- Maintenance and Reliability
  - Reliability heavily weighted
  - Low Maintenance systems
  - Inherent redundancy within power system
- Recognized Problems
  - LCF/LCB Misalignment
  - Towing - Consider overhanging strut
  - Increased crew cost with decreased speed
  - Overhanging nose and tail potential structure difficulty
- Continuing Around the Design Spiral
  - Return to optimization