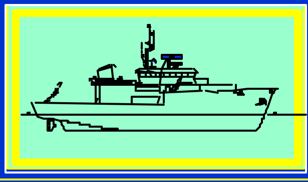
REGIONAL Class AGOR
Concept Definition Task

UNOLS Annual Meeting

17-19 September 2003

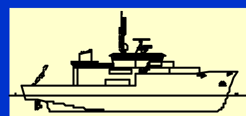
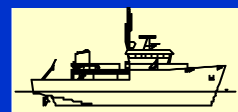
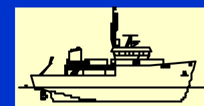
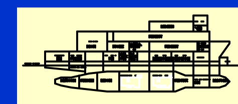
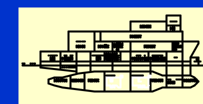
Task Overview

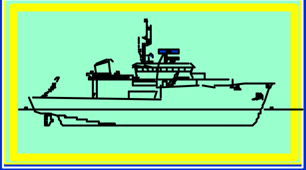
1) <u>Acquisition Process Analysis</u>
   - *What are some possible approaches to procuring the ships ?*
2) <u>Refinement of Concept Design</u>
   - *What kind of ship can we afford for ~$25M ?*
   - *How does it meet the science mission requirements ?*
3) <u>Tonnage Analysis</u>
   - *How will the Regional AGOR to be impacted by tonnage regulations ?*
   - *Can we reduce life cycle cost by limiting tonnage AND meet SMRs ?*
4) <u>Technology Investigation</u>
   - *Operating cost is of paramount importance to the AGOR fleet*
   - *What new technologies might reduce manning, life cycle cost ?*
5) <u>Ship Specification Development</u>
   - *Develop specification and design documentation to support next phase*



REGIONAL Class AGOR
Concept Definition

Concept Design Variants

		← Monohulls →			← SWATHs →	
	SMRs	Desired	Minimum	Under 300t	Desired	Minimum
						
LOA, ft	131-180	176	155	151	149	141
LBP, ft		165	145	141	141	135
Beam, MnDk, ft		36	36	32	61	58
Beam, WL, ft		36	36	32	43	40
Draft, ft	12	12	12	12	19.8	18.5
DISP, Lt		1,150	1,050	900	1,300	1,200
Max. Speed, kts	12	12.5	12.5	12	12	12
Transit Speed, kts	10	10	10	10	10	10
Range, NM	8,000	8,100	8,100	8,100	8,100	8,100
Scientists	16-20	20	16	16	20	16
Lab Area, ft^2	1,000-1,500	1,690	1,015	900	1,510	1,000
Deck Area, ft^2	1,000-1,500	1,800	1,365	1,000	1,900	1,500



REGIONAL Class AGOR

Concept Definition

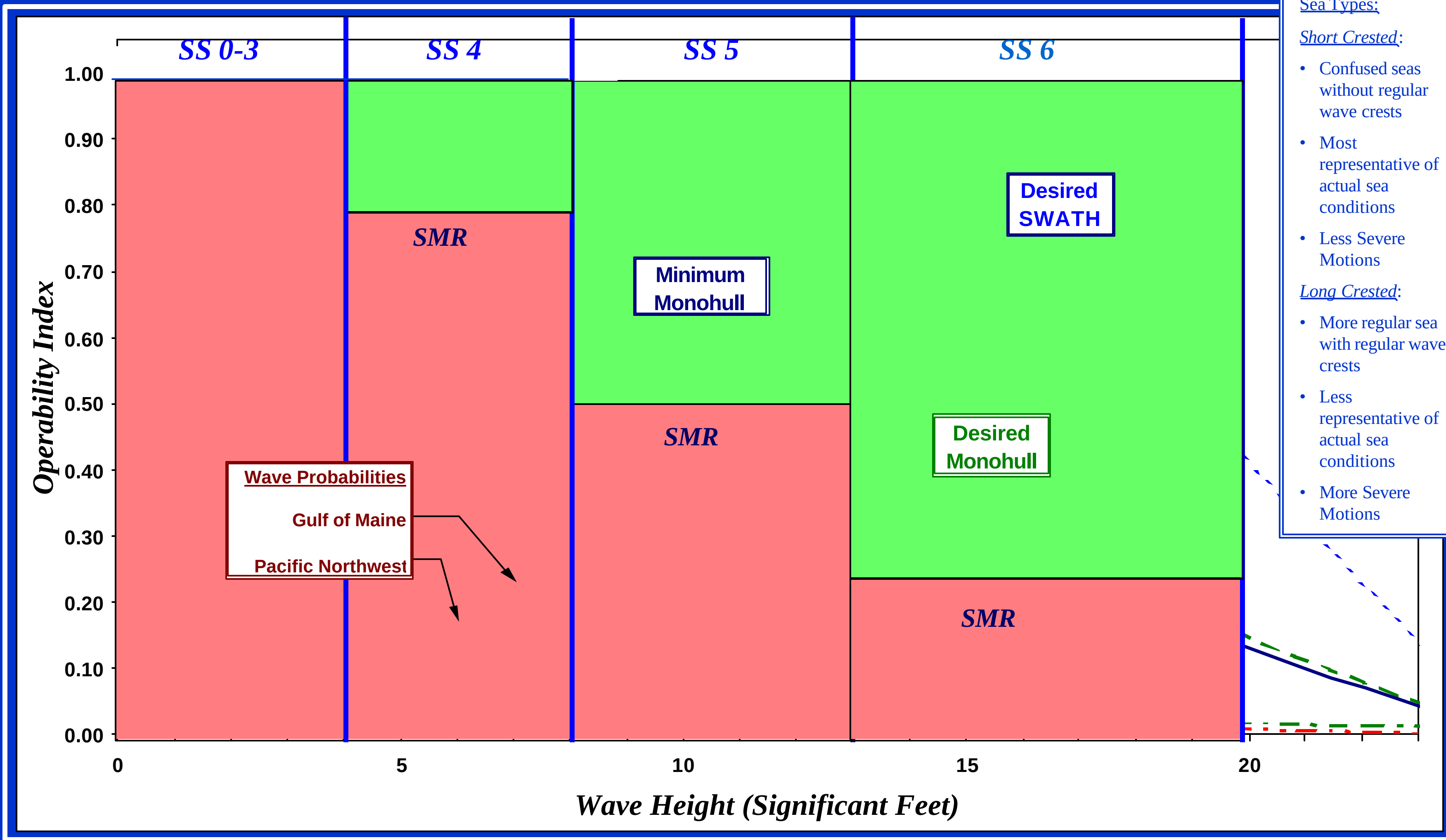
Seakeeping - Table of Operabilities

						Short Crested Seas			Long Crested Seas		
Region	**Season**	**Perf. Index**	**Mission**	**Sea State**	**SMR**	**Minimum Monohull**	**Desired Monohull**	**Desired SWATH**	**Minimum Monohull**	**Desired Monohull**	**Desired SWATH**
Gulf Of Maine	Winter	SPI-1	All	Spectrum	50%	85%	86%	93%	69%	78%	93%
Pacific NW	Winter	SPI-1	All	Spectrum	50%	90%	92%	96%	81%	86%	96%
Gulf Of Maine	Winter	PTO	On Station	SS4	80%	100%	100%	100%	93%	100%	100%
Gulf Of Maine	Winter	PTO	On Station	SS5	50%	70%	80%	97%	45%	60%	98%
Gulf Of Maine	Winter	PTO	On Station	SS6	25%	32%	40%	79%	5%	19%	82%
Gulf Of Maine	Winter	PTO	Transit	SS4	80%	100%	100%	100%	92%	100%	100%
Gulf Of Maine	Winter	PTO	Transit	SS5	50%	73%	81%	95%	51%	64%	93%
Gulf Of Maine	Winter	PTO	Transit	SS6	25%	32%	40%	83%	9%	19%	82%
Pacific NW	Winter	PTO	On Station	SS4	80%	100%	100%	100%	96%	100%	100%
Pacific NW	Winter	PTO	On Station	SS5	50%	70%	80%	97%	45%	60%	98%
Pacific NW	Winter	PTO	On Station	SS6	25%	33%	41%	81%	5%	19%	84%
Pacific NW	Winter	PTO	Transit	SS4	80%	100%	100%	100%	95%	100%	100%
Pacific NW	Winter	PTO	Transit	SS5	50%	73%	81%	95%	51%	64%	93%
Pacific NW	Winter	PTO	Transit	SS6	25%	34%	42%	85%	9%	20%	84%

Notes:

1) PTO = Percent time operability in a given sea state; SPI-1 = Seakeeping performance index (probability weighted across sea spectrum)
2) Analysis accounts for probability of significant wave heights for specific regions in Winter (December-February)
3) Analysis assumes most probable modal wave periods for N. Atlantic and N. Pacific (Bales)

Operability vs. Wave Height
Short Crested Seas



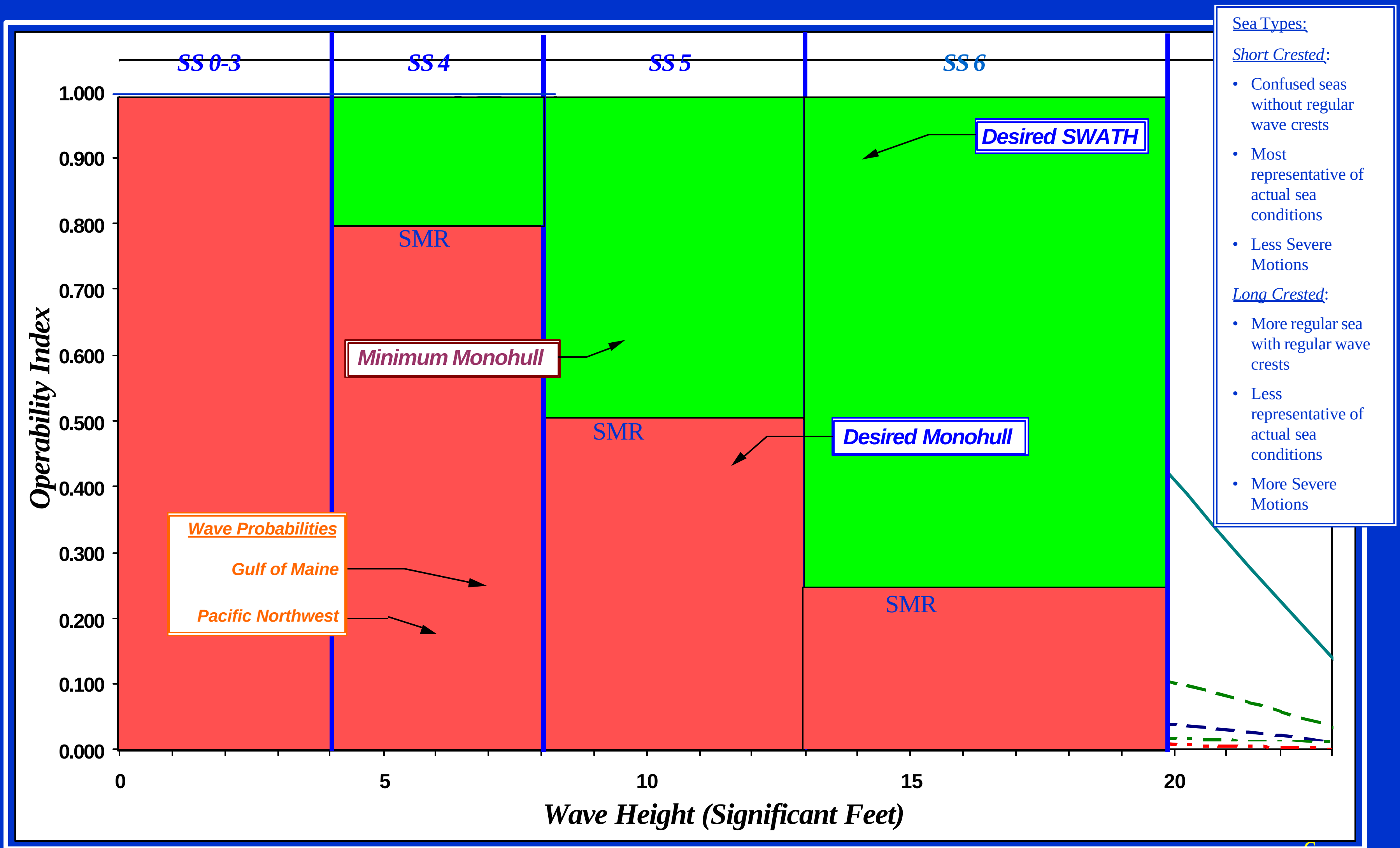
Sea Types:

Short Crested:
- Confused seas without regular wave crests
- Most representative of actual sea conditions
- Less Severe Motions

Long Crested:
- More regular sea with regular wave crests
- Less representative of actual sea conditions
- More Severe Motions

REGIONAL Class AGOR Concept Definition

Operability vs. Wave Height
Long Crested Seas



REGIONAL Class AGOR

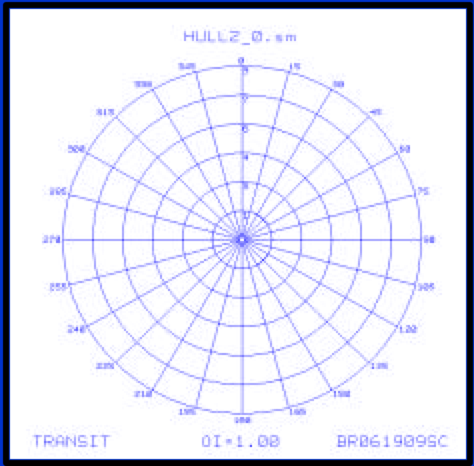
Concept Definition

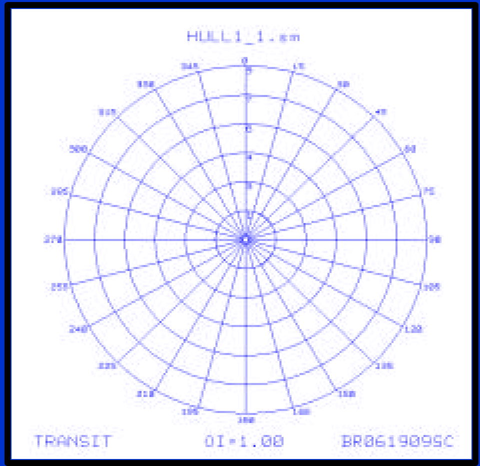
Seakeeping - Sea State 4

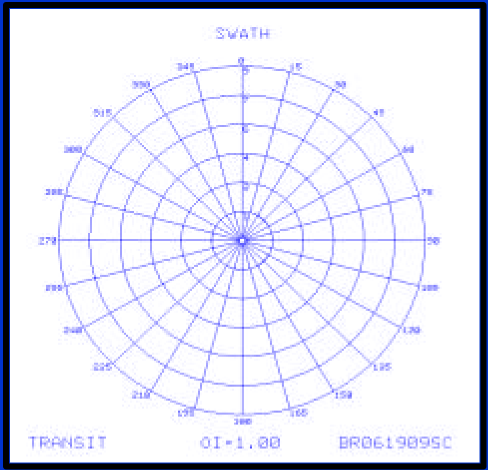
Transit, MID SS4, Tm=9s, With Roll Stabilization (for monohull)

Desired SMR Monohull | Minimum SMR Monohull | Desired SMR SWATH

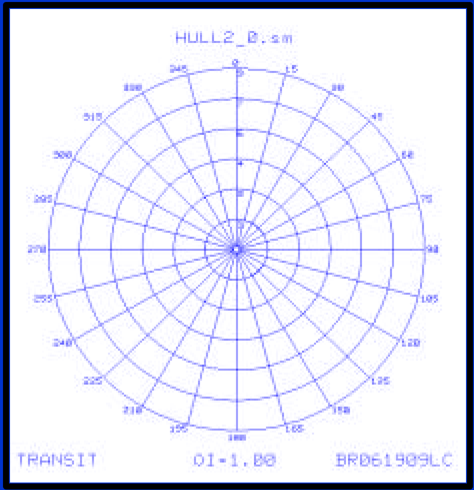
Short Crested Seas

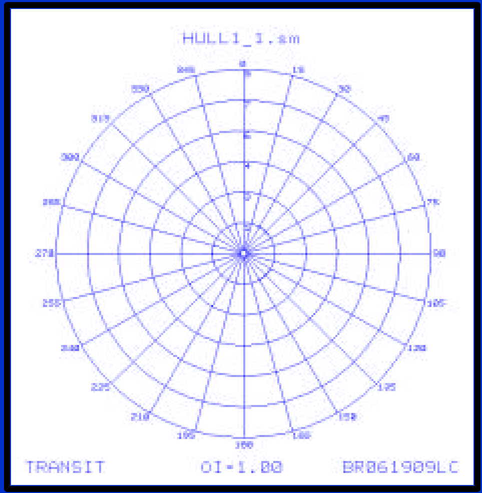


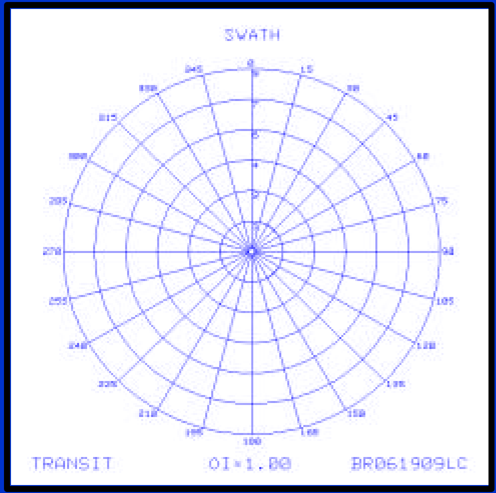




Long Crested Seas







Shaded Areas Exceed Motion Criteria

REGIONAL Class AGOR
Concept Definition

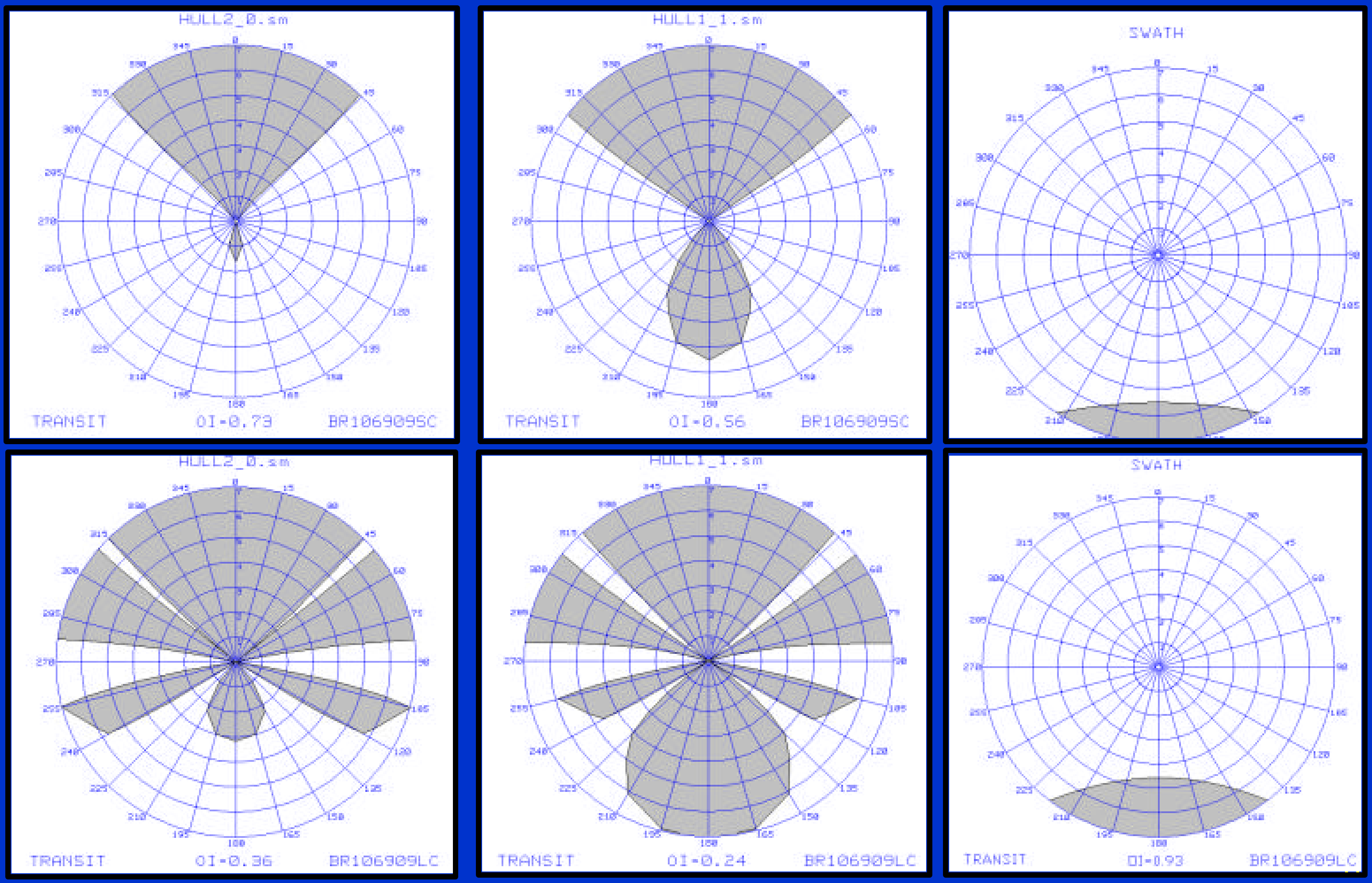
Seakeeping - Sea State 5

Transit, MID SS5, Tm=11s, With Roll Stabilization Tank (for monohull)

Desired SMR Monohull | *Minimum SMR Monohull* | *Desired SMR SWATH*

Short Crested Seas

Long Crested Seas



Shaded Areas Exceed Motion Criteria

REGIONAL Class AGOR

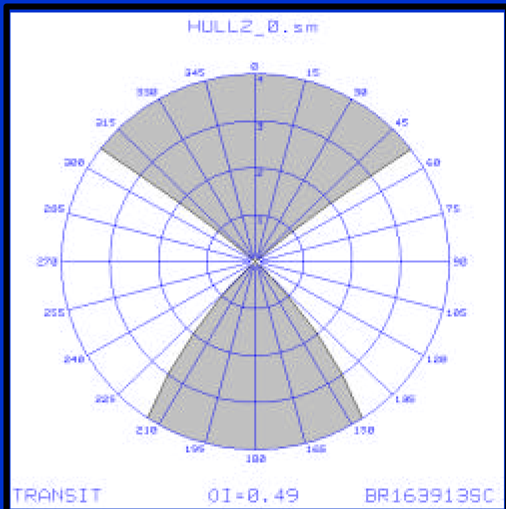
Concept Definition

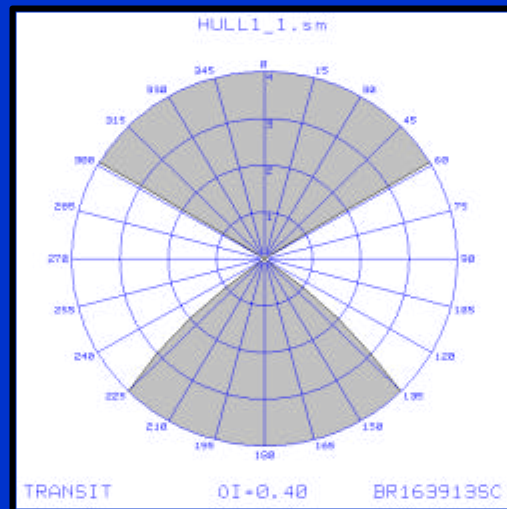
Seakeeping - Sea State 6

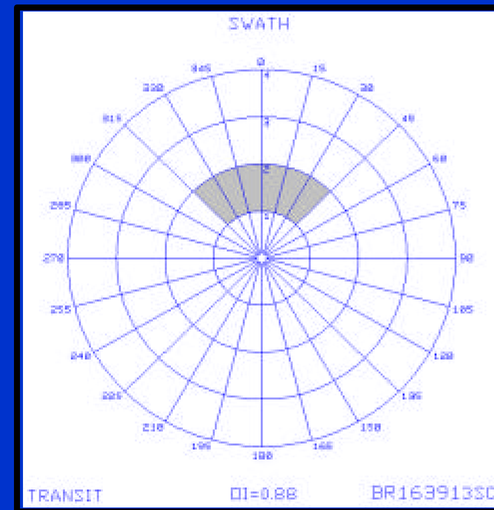
Transit, Mid SS6, Tm=13s, With Roll Stabilization Tank (for monohull)

Desired SMR Monohull | *Minimum SMR Monohull* | *Desired SMR SWATH*

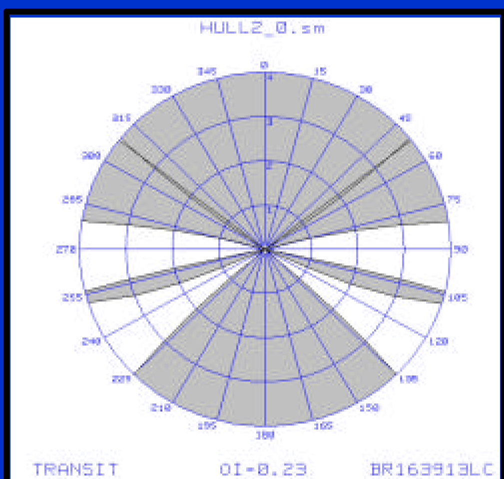
Short Crested Seas

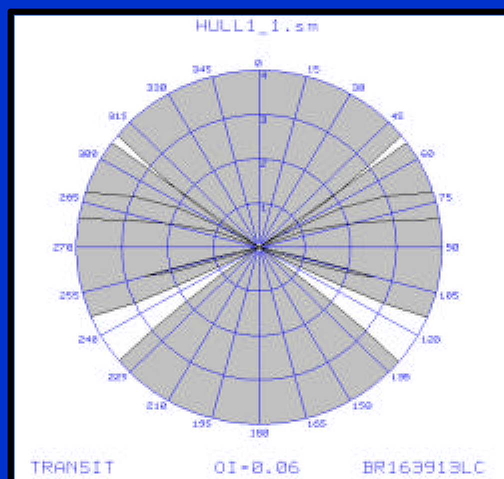


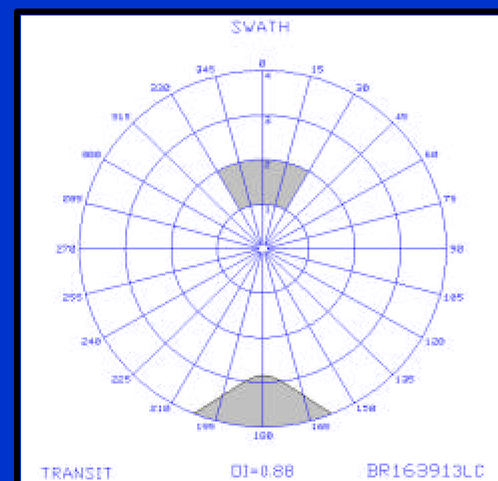




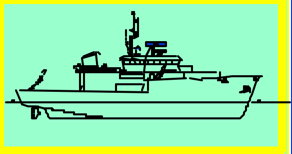
Long Crested Seas







Shaded Areas Exceed Motion Criteria



REGIONAL Class AGOR

Concept Definition

Program Cost Estimate

Concept Variant	Program Cost, Lead Ship ('04$)
Desired SMR Monohull	$25-28M
Minimum SMR Monohull	$23-26M
Desired SMR SWATH	$30-37M
Minimum SMR SWATH	$27-33M

- *Can Achieve Economy With Multiple Ship Contract, So Follow Ships Cheaper*
  - *Multiple Equipment Purchases*
  - *Non-recurring Design Cost*

REGIONAL Class AGOR
Concept Definition

Fuel Cost Analysis

Desired Monohull:

	Cruise	Transit			Towing/Survey			On Station		Total Days	Avg Daily Fuel Cost	Cruise Fuel Cost	Yearly Fuel & Lube Cost
		Speed	Days	$/day fuel	Speed	Days	$/day fuel	Days	$/day fuel				
1	2D,3D High Res Sonar	10	2	$1,809	5	18	$867	2	$776	22	$944	$20,776	FOY =
2	Piston Coring	10	4	$1,809				10	$776	14	$1,071	$14,996	200
3	Observatory Servicing	10	2	$1,809				2	$776	4	$1,293	$5,170	days
4	Current Meter Moorings, etc.	10	3	$1,809	8	5	$1,205	7	$776	15	$1,126	$16,884	
5	Demo Oceanographic Tech	10	0.2	$1,809	1.4	0.2	$795	0.25	$776	0.65	$1,100	$715	
6	Towed Magnetometer Study	10	8	$1,809	4	6	$825	11	$776	25	$1,118	$27,958	
7	Carbon Cycling	12	2	$2,948	6	10	$939	4	$776	16	$1,149	$18,390	
8	Shelfbreak Front Upwelling	12	2	$2,948	3.5	8	$820	2	$776	12	$1,167	$14,008	
9	Mixing by Solutions	12	0	$2,948	6	14	$939	0	$776	14	$939	$13,146	
			23.2			61.2		38.25		122.65	$1,101		$225,163

Minimum Monohull:

	Cruise	Transit			Towing/Survey			On Station		Total Days	Avg Daily Fuel Cost	Cruise Fuel Cost	Yearly Fuel & Lube Cost
		Speed	Days	$/day fuel	Speed	Days	$/day fuel	Days	$/day fuel				
1	2D,3D High Res Sonar	10	2	$1,545	5	18	$707	2	$629	22	$776	$17,074	FOY =
2	Piston Coring	10	4	$1,545				10	$629	14	$891	$12,470	200
3	Observatory Servicing	10	2	$1,545				2	$629	4	$1,087	$4,348	days
4	Current Meter Moorings, etc.	10	3	$1,545	8	5	$994	7	$629	15	$934	$14,008	x Avg Daily
5	Demo Oceanographic Tech	10	0.2	$1,545	1.4	0.2	$645	0.25	$629	0.65	$916	$595	Fuel Cost
6	Towed Magnetometer Study	10	8	$1,545	4	6	$670	11	$629	25	$932	$23,299	
7	Carbon Cycling	12	2	$2,794	6	10	$771	4	$629	16	$988	$15,814	
8	Shelfbreak Front Upwelling	12	2	$2,794	3.5	8	$665	2	$629	12	$1,014	$12,166	
9	Mixing by Solutions	12	0	$2,794	6	14	$771	0	$629	14	$771	$10,794	
			23.2			61.2		38.25		122.65	$923		$189,636

Fuel Cost Assumed = $1/gal

REGIONAL Class AGOR
Concept Definition

Fuel Cost Analysis

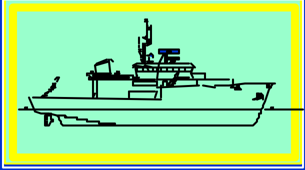
Desired SWATH:

	Cruise	Transit			Towing/Survey			On Station		Total Days	Avg Daily Fuel Cost	Cruise Fuel Cost	Yearly Fuel & Lube Cost
		Speed	Days	$/day fuel	Speed	Days	$/day fuel	Days	$/day fuel				
1	2D,3D High Res Sonar	10	2	$2,386	5	18	$915	2	$776	22	$1,036	$22,794	FOY =
2	Piston Coring	10	4	$2,386				10	$776	14	$1,236	$17,304	200
3	Observatory Servicing	10	2	$2,386				2	$776	4	$1,581	$6,324	days
4	Current Meter Moorings, etc.	10	3	$2,386	8	5	$1,499	7	$776	15	$1,339	$20,085	x Avg Daily
5	Demo Oceanographic Tech	10	0.2	$2,386	1.4	0.2	$788	0.25	$776	0.65	$1,275	$829	Fuel Cost
6	Towed Magnetometer Study	10	8	$2,386	4	6	$849	11	$776	25	$1,309	$32,718	
7	Carbon Cycling	12	2	$3,436	6	10	$1,014	4	$776	16	$1,257	$20,116	
8	Shelfbreak Front Upwelling	12	2	$3,436	3.5	8	$825	2	$776	12	$1,252	$15,024	
9	Mixing by Solutions	12	0	$3,436	6	14	$1,014	0	$776	14	$1,014	$14,196	
			23.2			61.2		38.25		122.65	$1,255		$256,092

Minimum SWATH:

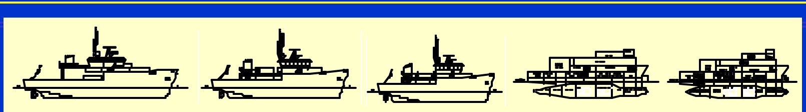
	Cruise	Transit			Towing/Survey			On Station		Total Days	Avg Daily Fuel Cost	Cruise Fuel Cost	Yearly Fuel & Lube Cost
		Speed	Days	$/day fuel	Speed	Days	$/day fuel	Days	$/day fuel				
1	2D,3D High Res Sonar	10	2	$2,297	5	18	$911	2	$776	22	$1,025	$22,544	FOY =
2	Piston Coring	10	4	$2,297				10	$776	14	$1,211	$16,948	200
3	Observatory Servicing	10	2	$2,297				2	$776	4	$1,537	$6,146	days
4	Current Meter Moorings, etc.	10	3	$2,297	8	5	$1,463	7	$776	15	$1,309	$19,638	x Avg Daily
5	Demo Oceanographic Tech	10	0.2	$2,297	1.4	0.2	$787	0.25	$776	0.65	$1,247	$811	Fuel Cost
6	Towed Magnetometer Study	10	8	$2,297	4	6	$846	11	$776	25	$1,280	$31,988	
7	Carbon Cycling	12	2	$3,210	6	10	$1,005	4	$776	16	$1,223	$19,574	
8	Shelfbreak Front Upwelling	12	2	$3,210	3.5	8	$826	2	$776	12	$1,215	$14,580	
9	Mixing by Solutions	12	0	$3,210	6	14	$1,005	0	$776	14	$1,005	$14,070	
			23.2			61.2		38.25		122.65	$1,228		$250,584

Fuel Cost Assumed = $1/gal



REGIONAL Class AGOR
Concept Definition

Operating Costs in '03$

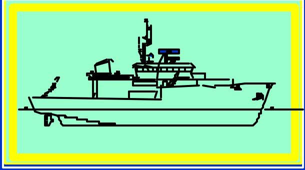


	Avg Expenses Interm. Class 98/99 $	Interm. Class Escalated to '03$	Ratio By	Monohull Desired	Monohull Min	Monohull <300GT	SWATH Desired	SWATH Min
Year $	1998.5	2003		2003	2003	2003	2003	2003
Payroll								
Salaries, ship	$846,548	$966,984	Crew Size	$1,128,148	$1,128,148	$966,984	$1,128,148	$1,128,148
Salaries, shore	$193,834	$221,410	Unity	$221,410	$221,410	$221,410	$221,410	$221,410
Payroll Subtotal	***$1,040,382***	***$1,188,393***		***$1,349,557***	***$1,349,557***	***$1,188,393***	***$1,349,557***	***$1,349,557***
Maintenance								
Repairs & Maintenance	$143,603	$164,033	Vessel Displ [1]	$179,655	$164,033	$140,599	$213,242	$196,839
Major Overhaul	$153,713	$175,582	Vessel Displ [2]	$192,304	$175,582	$150,498	$239,125	$220,731
Maint Subtotal	***$297,316***	***$339,614***		***$371,958***	***$339,614***	***$291,098***	***$452,368***	***$417,570***
Other Costs								
Fuel, lube	$132,811	$151,706	Calculated	$225,163	$189,636	$170,672	$256,092	$250,584
Food	$73,375	$83,814	Complement	$98,264	$86,704	$75,143	$98,264	$86,704
Insurance	$7,600	$8,681	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000
Stores	$43,002	$49,119	Complement	$57,588	$50,813	$44,038	$57,588	$50,813
Travel	$8,318	$9,501	Crew Size	$11,084	$11,084	$9,501	$11,084	$11,084
Shore Facility	$57,317	$65,471	Vessel Displ	$71,706	$65,471	$56,118	$81,059	$74,824
Misc	$128,216	$146,457	Vessel Displ	$160,405	$146,457	$125,534	$181,327	$167,379
Indirect Costs	$233,427	$266,636	Vessel Displ	$292,030	$266,636	$228,545	$330,121	$304,727
Other Subtotal	***$684,064***	***$781,384***		***$956,241***	***$856,800***	***$749,552***	***$1,055,536***	***$986,115***
Total Ship Cost	***$2,021,762***	***$2,309,391***		***$2,677,756***	***$2,545,972***	***$2,229,043***	***$2,857,461***	***$2,753,242***
Operating Days	215.75	215.75		200	200	200	200	200
Day Rate (200 days)	***$10,109***	***$11,547***		***$13,389***	***$12,730***	***$11,145***	***$14,287***	***$13,766***
Tech Support Costs	$2,000	$2,285	Unity	$2,285	$2,285	$2,285	$2,285	$2,285
Total per day Cost	$12,109	$13,831		$15,673	$15,014	$13,430	$16,572	$16,051
Displacement	1050	1050		1150	1050	900	1300	1200
Crew Size	12	12		14	14	12	14	14
Scientific Complement	17	17		20	16	14	20	16

Acquisition Goals

Goals of a Successful AGOR Program:

- *Satisfy Owner’s (NSF) Requirements For Oversight and Management of Program and Funds*
- *Remain Below Cost Ceiling*
- *Maximize Mission Capability*
  - *Maximize Funds Applied Directly To Ship*
  - *Optimize Design*
- *Achieve Effective University Community Input*
  - *Begin Early and Maintain Throughout Program*
  - *Ensure Resulting Ship Meets Research Needs*
  - *Minimize Costly Change Orders During Construction*



REGIONAL Class AGOR Concept Definition

Acquisition Approaches

Contract Design

1. Develop Specification
2. Solicit Proposals for Concept Designs
3. Teams Develop Concept Designs
4. Select Best Concept
5. Develop Preliminary Design
6. Develop Contract Design and Detailed Specification
7. Solicit Bids for Detail Design and Construction
8. Select Bid That Meets Cost Cap and Requirements
9. Detail Design and Construction

Circular of Requirements

1. Develop Specification
2. Solicit Proposals for Concept Designs
3. Teams Develop Concept Designs
4. Select Best Concept
5. Develop Preliminary Design and Circular of Requirements
6. Solicit Bids for Cont./Detail Design and Construction
7. Select Bid That Meets Cost Cap and Requirements
8. Detail Design and Construction

(AGOR 23, 24, 25)

Integrated Product Team

1 Team

1. Develop P-Spec or Desired Operational Capabilities
2. Solicit Proposals For Industry Teams
3. Form IPT Consisting of Gov't, Industry, UNOLS
4. IPT Develop Concept/Prel Design To Cost Ceiling
5. Detail Design and Construction

(AGOR 26)

2 Team

1. Develop P-Spec or Desired Operational Capabilities
2. Solicit Proposals For Industry Teams
3. Form IPTs Consisting of Gov't, Industry, UNOLS
4. IPT #1 Develop Concept/Prel Design To Cost Ceiling / IPT #2 Develop Concept/Prel Design To Cost Ceiling
5. Select Best Design
6. Detail Design and Construction

Contract Design Approach:

Pros:

- *Community Opportunity for Input at Design Reviews*
- *Design Defined in Detail*
- *Greatest Control Over Design Process*

Cons:

- *No Shipbuilder Input to Design Process or Cost Estimate*
  - *Limits Innovation by Yard and Designer*
  - *Risk of Exceeding Budget Ceiling Because of Unknown Costs*
- *Design Budget Increases With Iterations and Changes*

Integrated Product Team Approach:

Pros:

- *Shipbuilder involvement early in process helps avoid surprises*
- *Design to cost cap lowers risk of exceeding budget ceiling*
- *Community has real time input to design process through representatives on IPTs*
  - *Reduce costly change orders during construction*
  - *Ensure ship meets research needs*
- *Allows more innovation by shipbuilder and design agent*
- *Competition Throughout Process Encourages Technical Innovation and Cost Savings*

Cons:

- *Multiple Teams Can Increase Initial Design Cost*
- *Some Control Over Design Process Ceded To Community Representatives and IPTs*
  - *Need Effective Communication Between Community and Representatives*
  - *Mitigate With Team Design Reviews With Larger Community Audience*

Technology Investigation

Propulsion:

- *Efficiency Enhancement Devices*
    - *Contrarotating Props*
    - *Pre/post Swirl Vanes*
    - *Stern Flaps*
- *Podded Propulsors*
- *Fuel Cells*
- *AC Electric Drive*
- *High Temp Superconducting Motors*

Mission Systems:

- *Wideband Sonar*

Handling Systems:

- *Electric Winches*
- *Motion Compensation*
- *CTD Handling Systems*

Auxiliary Systems:

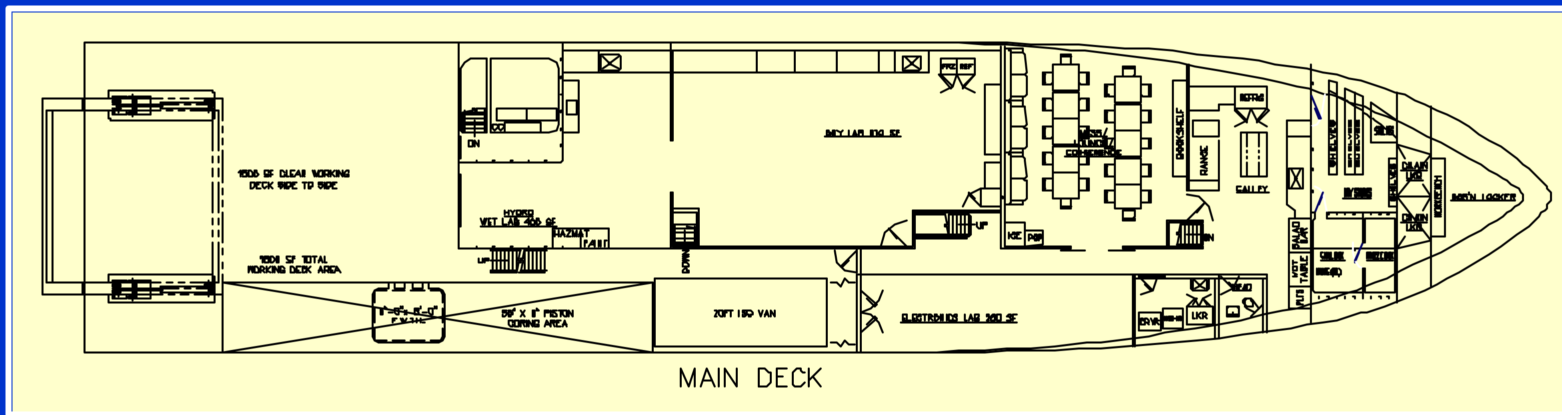
- *Stainless Steel Drain Piping*
- *Composite Piping*
- *Bow Thruster Quieting*

APPENDIX

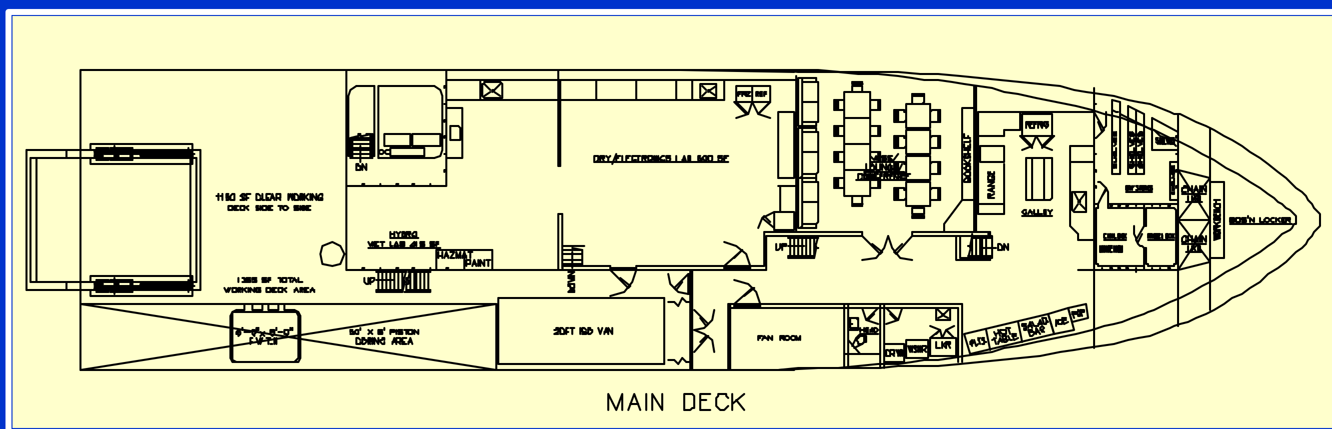
REGIONAL Class AGOR

Concept Definition General Arrangements - Main Deck

Desired SMR Monohull:



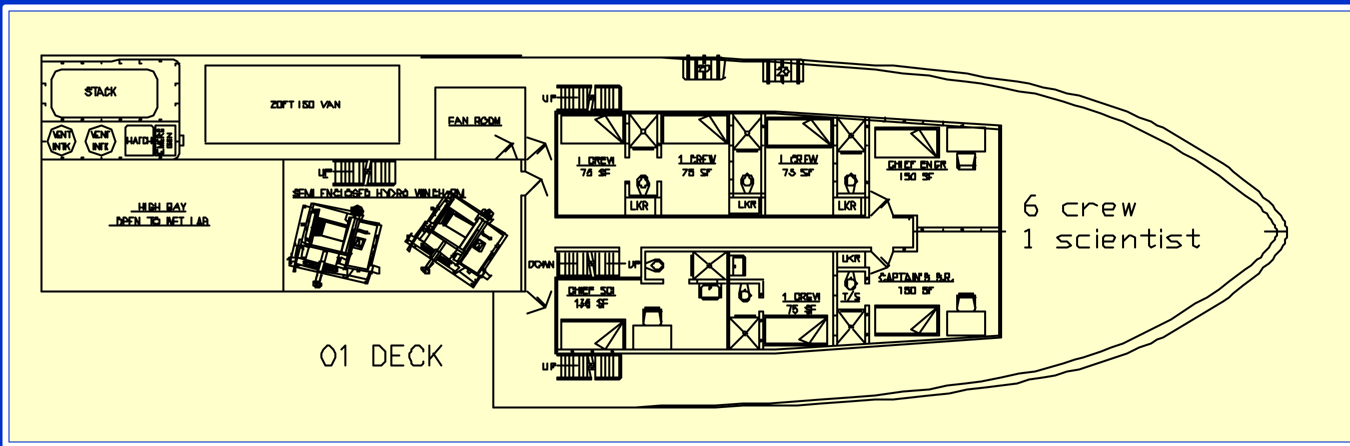
Minimum SMR Monohull:



REGIONAL Class AGOR

Concept Definition — General Arrangements - 01 Lvl

Desired SMR Monohull:



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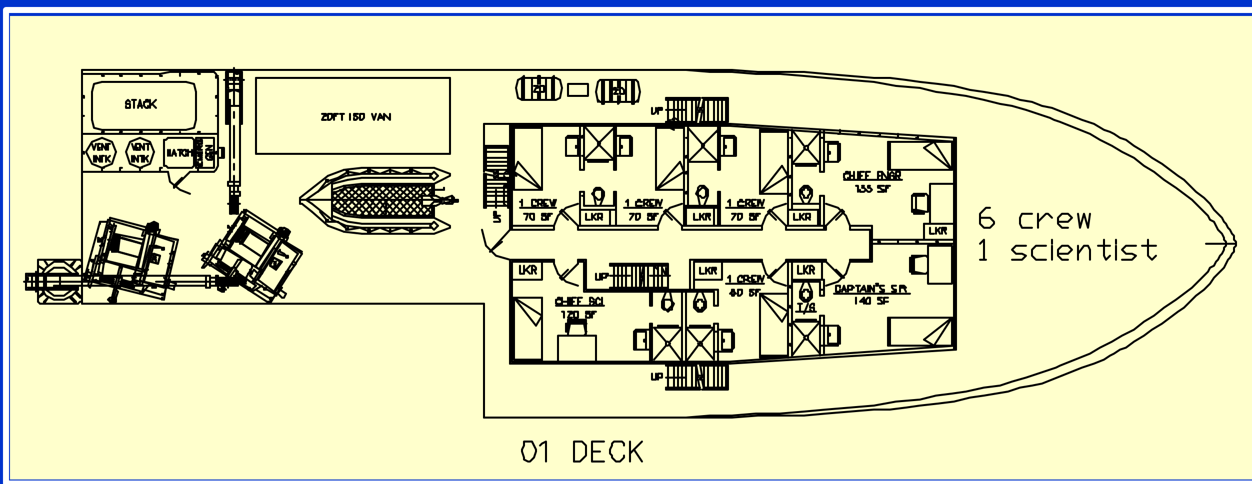
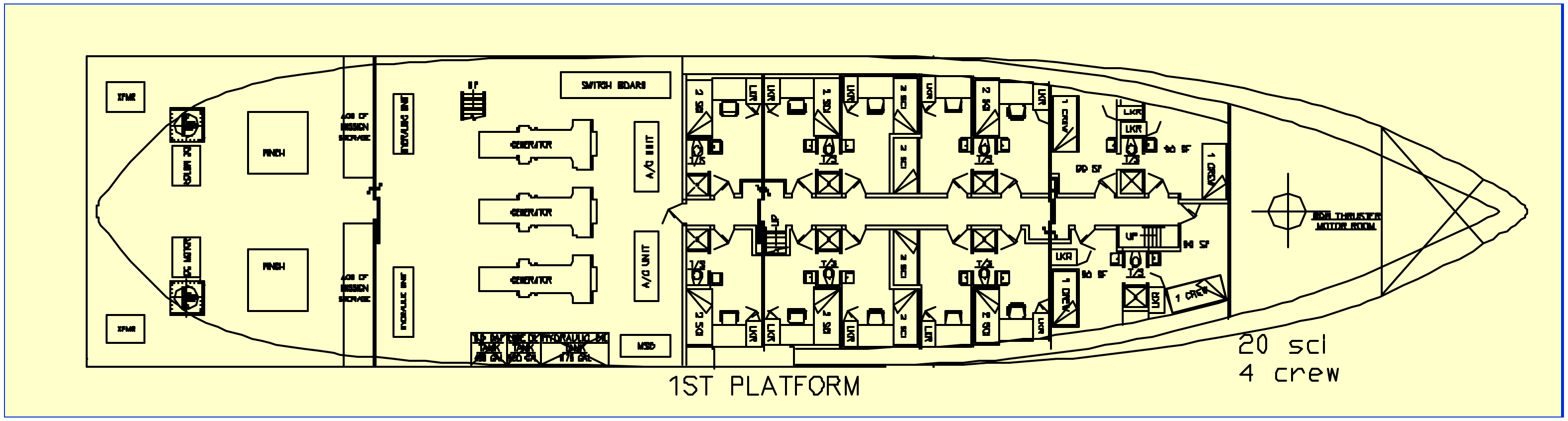


REGIONAL Class AGOR

Concept Definition

General Arrangements - 1st Plat

Desired SMR Monohull:



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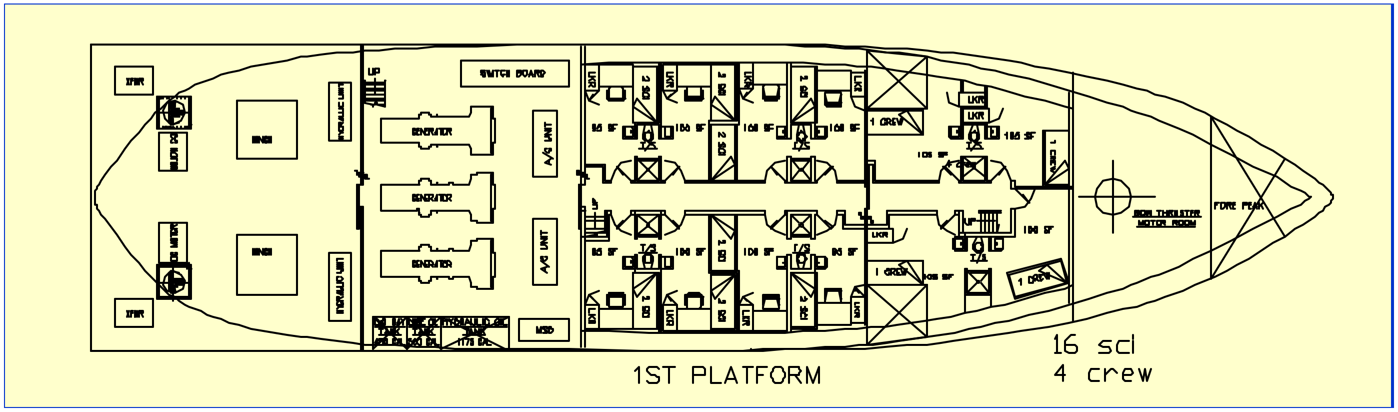
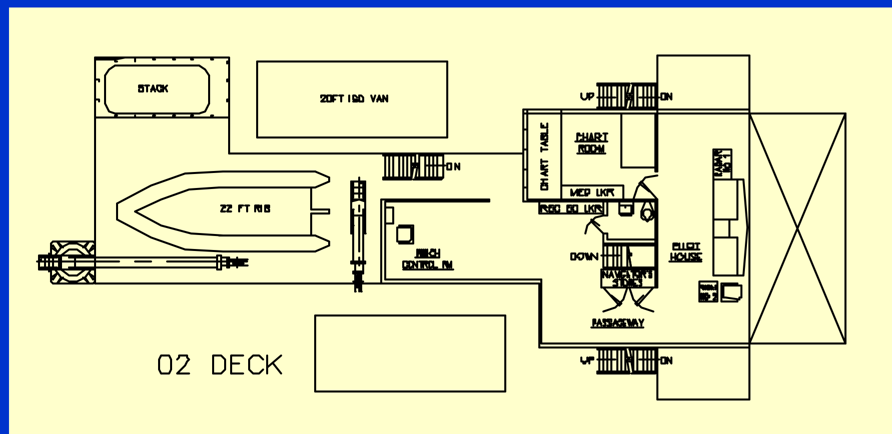


General Arrangements - 02 Lvl

Desired SMR Monohull:



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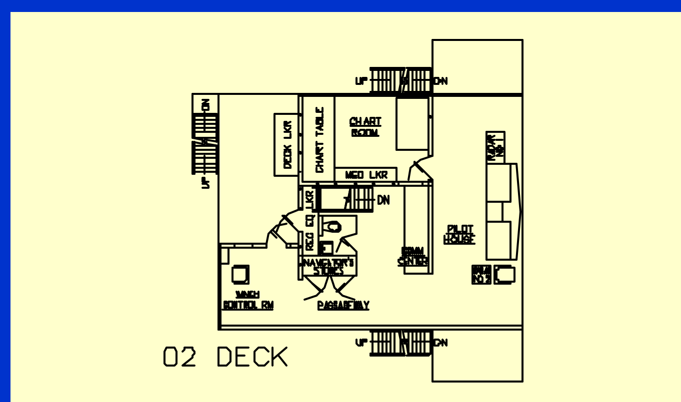
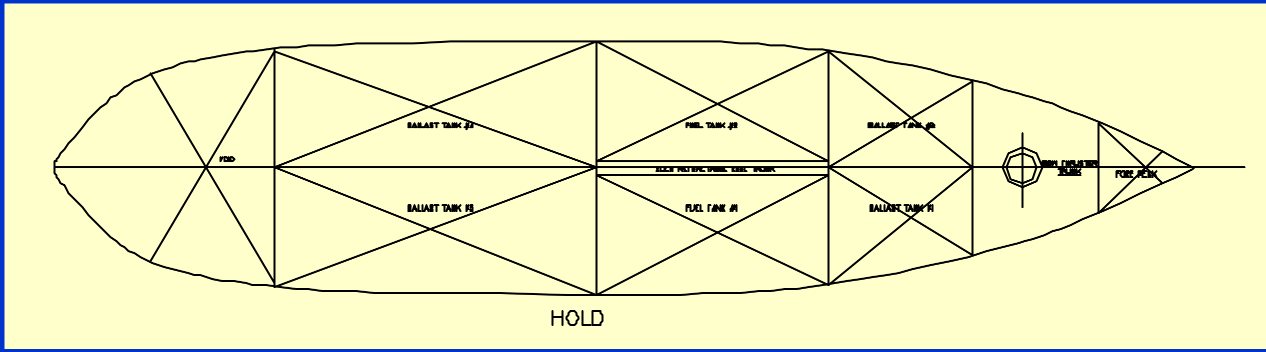


General Arrangements - Tank Top

Desired SMR Monohull:



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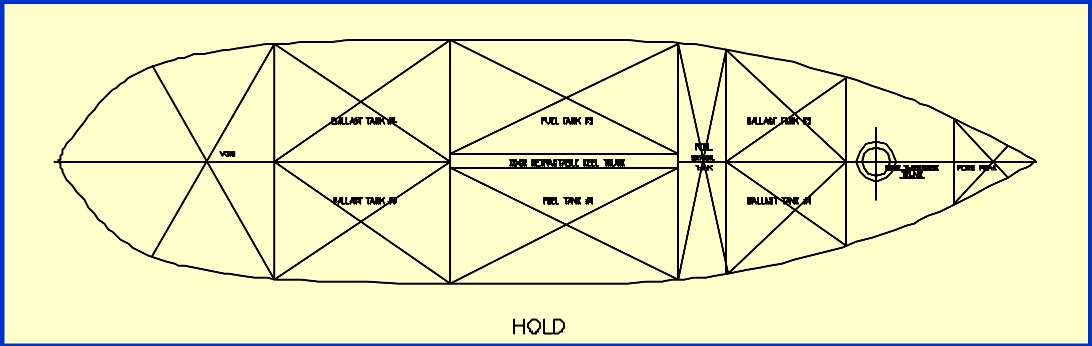
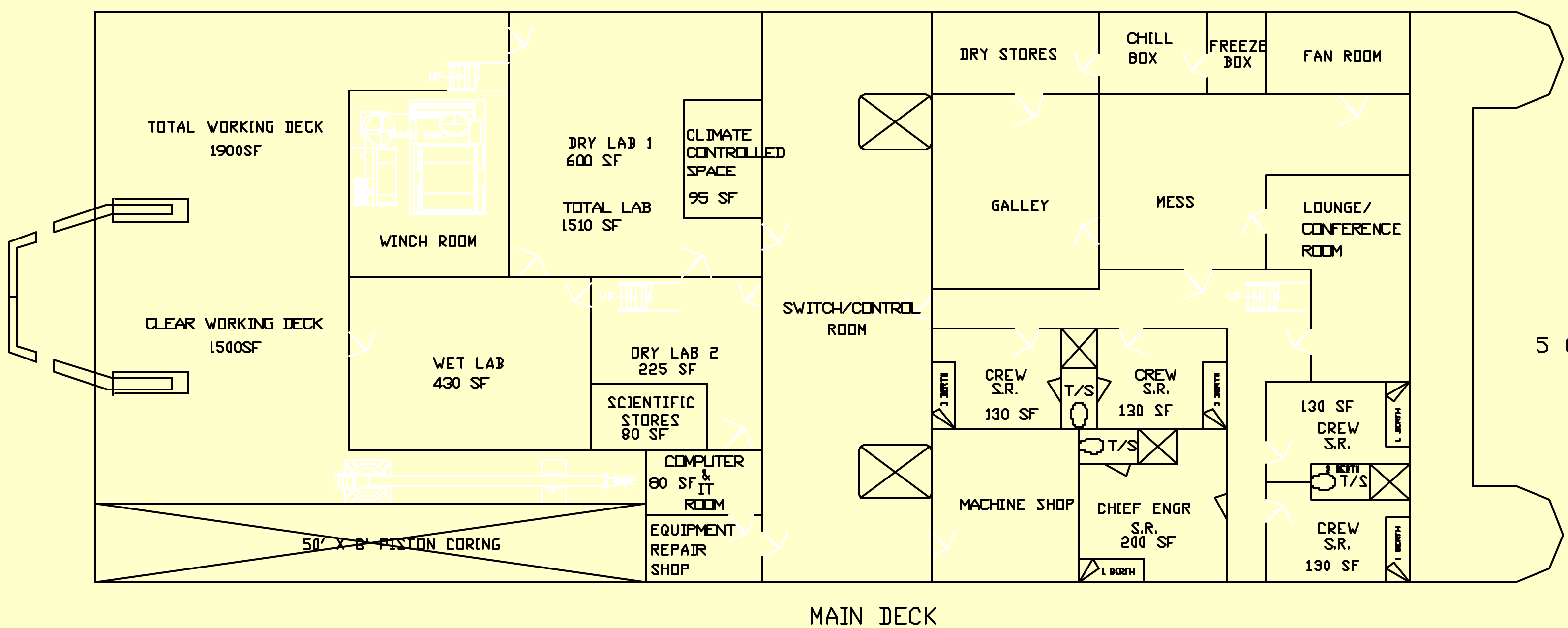


REGIONAL Class AGOR

Concept Definition

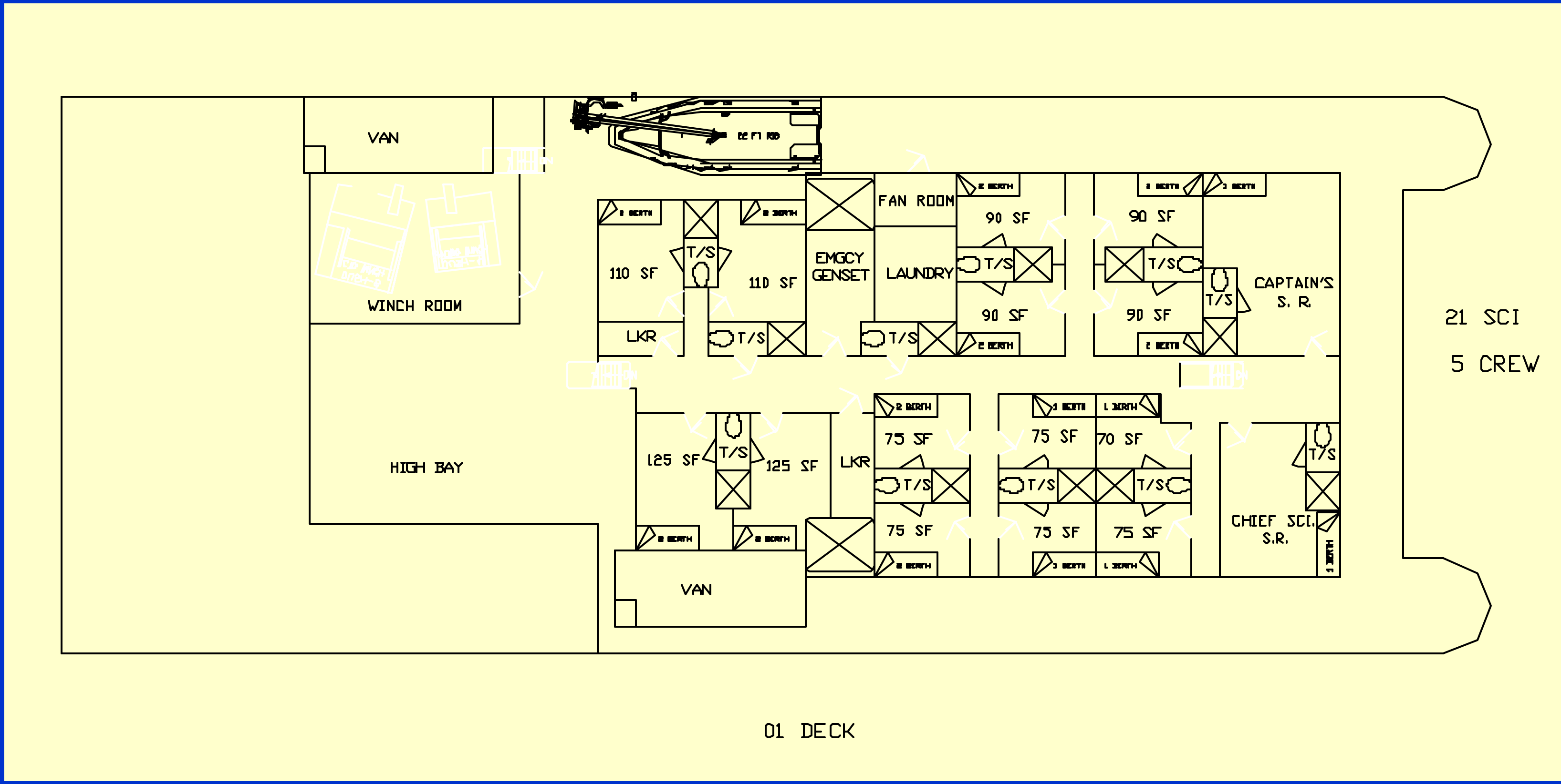
Desired SMR SWATH:



REGIONAL Class AGOR

Concept Definition

Desired SMR SWATH:



Propulsion - Monohull

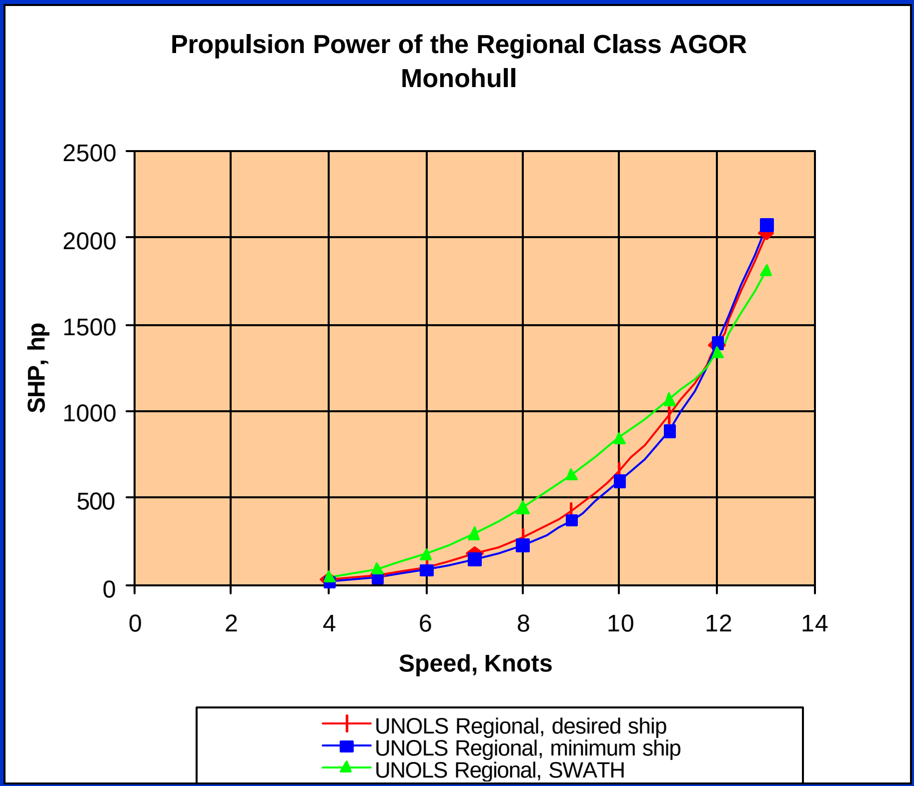
- *Main Propulsion System*
  - *Integrated Diesel Electric System*
    - *2 Caterpillar 3412C Gensets. 2 x 590 kw @60 Hz*
    - *1 Caterpillar 3406C Genset. 1 x 320 kw @60 Hz*
  - *Propulsion Motor and Propeller Unit*
    - *2 x 550 kw, 1800 rpm DC motors*
    - *2 x steerable fixed pitch Z-drive.*
    - *Propeller diameter = 5.6 feet.*
- *Dynamic Positioning System*
  - *Bow Thruster*
    - *1 x Elliott White Gill T3S-32. 4,000 kg Static Thrust.*

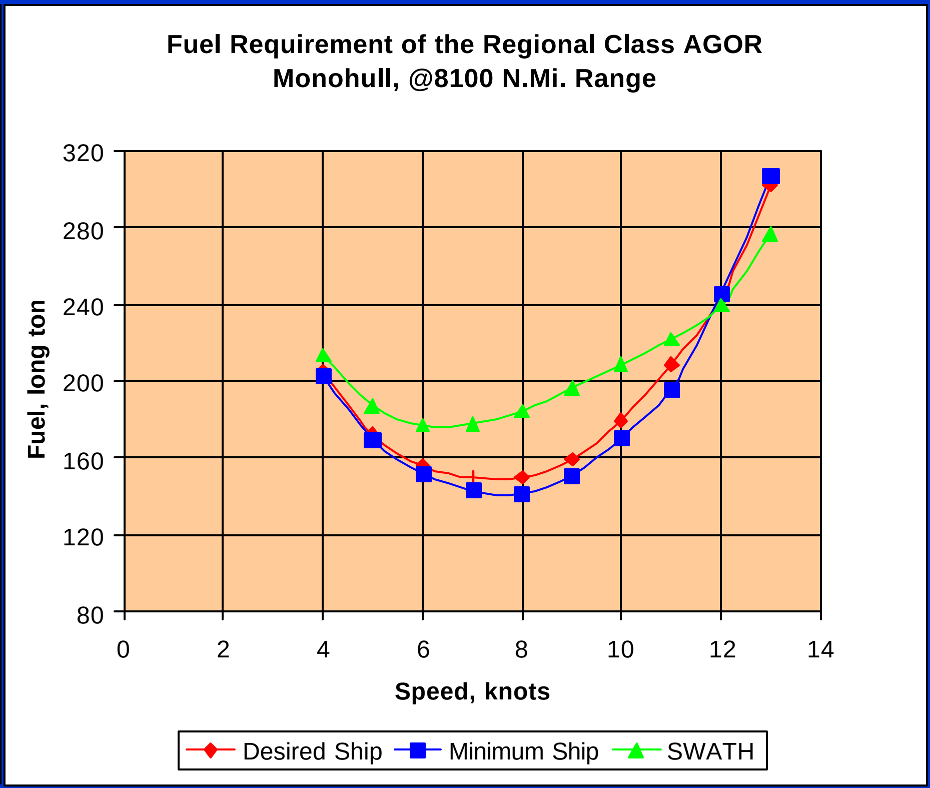
Propulsion - SWATH

- ***Main Propulsion System***
  - *Integrated Diesel Electric System*
    - *3 Caterpillar 3412C Gensets. 3 x 590 kw @60 Hz*
  - *Propulsion Motor and Propeller Unit*
    - *2 x 650 kw, 1800 rpm DC motors*
    - *2 x fixed pitch propeller. Propeller diameter = 6.5 feet.*
- ***Dynamic Positioning System***
  - *Bow Thruster*
    - *2 x Elliott White Gill T3S-24. 2,200 kg Static Thrust Each.*

Speed-Power and Endurance

Speed Power and Fuel Consumption





Concept Variants Vs. SMRs

Parameter	***Capability or Characteristic***	***Desired Ship***	***Minimum Ship***
Length	40 - 55 m (131' - 180')	176’ LOA	155’ LOA
Accommodations	16 to 20 non-crew personnel	20	16
Operational characteristics			
Endurance	21 days; surge capacity 30 days (15 transit and 15 station)	YES	YES
Range	8,000 nautical miles at optimal transit speeds	8100	8100
Speed	12 knots; 10 knots sustainable through sea state 4; 7 knots in SS 5	YES	YES
Sea keeping	Ability to work in sea states 4 (1.25 - 2.5 m wave heights); >50% operational in SS 5 (2.5 - 4 m wave heights).	YES	YES
Station keeping	Best available GPS and Dynamic positioning.	YES	YES
Track line following	Maintain a track line within ± 5 meters of intended track and with a heading deviation (crab angle) of less than 45 degrees with 25 knots of wind, up to sea state 4 (1.25 - 2.5 m wave heights), and 2 knots of beam current.	YES	YES
Ship control	0.1 knots from 0-5 knots; 0.2 knots from 6-12 knots	YES	YES
Over-the-side and weight handling			
Winches Wires Cranes Frames	New-generation integrated winch/crane handling systems. 2 hydro winches (10,000 m wire rope, electromechanical cable or fiber-optic cable - 1/4" to 1/2"); Trawl winch for 10,000 m 0.680 Fiber Optic and 9/16 trawl wire or next generation of wires - Interchangeable storage drums. A crane that can reach all working deck areas and capable of offloading vans and equipment weighing up to 8,000 lbs to a pier or vehicle in port is required: 16,000 lbs is desirable. Second, smaller articulated crane (4,000 lb capacity) with installation locations forward, amidships, and aft is desirable. Stern frame (min clear height of 15'; clear base of 15-20').	YES	YES
Towing	10,000 lbs tension at 6 knots; 20,000 lbs at 4 knots. Winches capable of sustaining towing operations continuously for days.	YES	YES

Concept Variants Vs. SMRs

Science working spaces		***Desired Ship***	***Minimum Ship***
Working deck area	1,000 sq ft minimum clear area aft of deck houses; desirable 1,500 sq ft. Additional contiguous minimum 50' x 10' area along one side for coring, etc. Total amount of clear working area available on the aft main deck should be at least 1,300 sq ft.	1500 sf clear 50’x10’ 1800 sf total	1150 sf clear 50’x8’ 1365 sf total
Laboratories	Total lab space should be a minimum of 1,000 sq ft (1,500 sq ft is desirable) including: Main (dry) lab area (800 sq ft) designed to be flexible for subdivision; A fume hood and sink should be in the main and wet lab (2 sinks in main lab). Uncontaminated seawater in labs. Separate wet lab/hydro lab (400 sq ft) located contiguous to sampling areas. Electronics/computer lab; separate or part of main lab. A separate electronics repair shop/work space for resident (and visiting) technicians is desirable. High bay/hanger space for multiple purposes adjacent to the aft main deck is desirable; may be combined with wet lab/hydro lab. Climate controlled workspace or chamber (~100 sq ft) as lab or in van.	1470 sf total 810 sf main 400 sf wet 260 sf electr. High bay	1015 sf total 600 sf main 415 sf wet
Vans	Positions for 2 standardized 8 ft by 20 ft portable deck vans as lab, berthing, storage or specialized use. Space for 1-2 additional smaller vans is desirable.	2	2
Storage	~ 400-500 cubic feet of storage space that could also be used as shop or workspace when needed is desirable.	YES	NO
Science load	Variable science load should be least 50 LT.	YES	YES
Workboats	A 16-ft or larger inflatable boat located for ease of launching and recovery is required.	22’ RIB	16’ RIB
Masts On deck incubations Marine mammal & bird observations	Design criteria are presented so these science operation areas are not overlooked.	YES	YES

Concept Variants Vs. SMRs

Science and shipboard systems		***Desired Ship***	***Minimum Ship***
Navigation	Best available GPS and Dynamic positioning.	YES	YES
Data network and onboard computing Communications: Internal & External	Navigation, computing, voice, and data communications (within ship and to shore) through the best available systems using current expert advice. Systems should be specified as close to actual delivery as possible.	YES	YES
Real time data acquisition system	Multibeam; 12 & 3.5 kHz; transducer wells; ADCP; portable seismic system; magnetometer; IMET (bow mast availability); clean power. Acoustically as quiet as possible. Minimize bubble sweep down.	YES	YES
Underway data collection & sampling	Promotes design of flexible and functional systems for data collection and sampling using advice from experts at the time of design and specification.	YES	YES
Visiting system installation and power	Build in capability to accommodate a variety of equipment.	YES	YES
Discharges	Ensure discharges do not impact science, health, and environment.	YES	YES
Construction, operation & maintenance			
Maintainability Operability Life cycle costs Regulatory issues	Statements to ensure that the design and construction of these vessels take into account the ability to maintain and operate within domestic and international regulations in a reliable and cost effective manner.	YES	YES

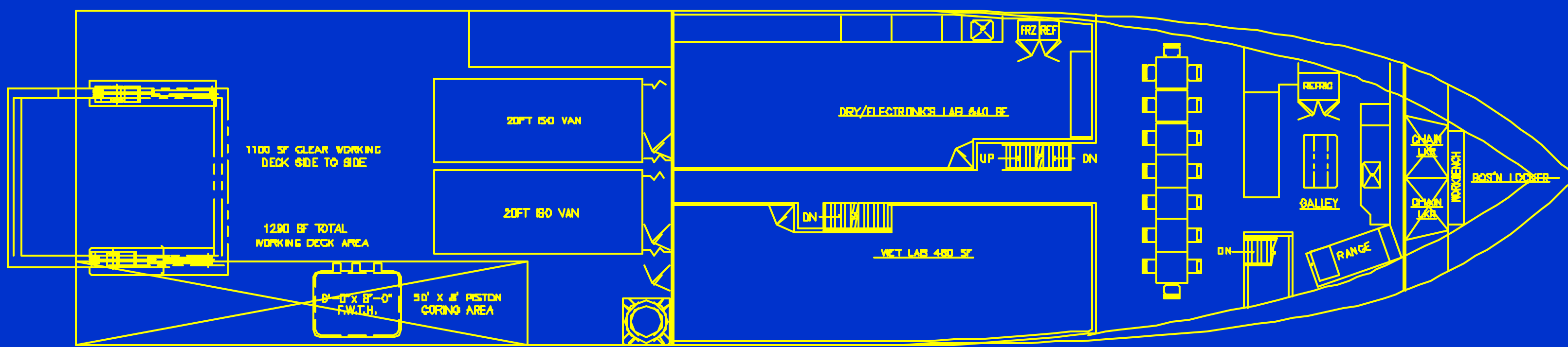
Tonnage Analysis

REGIONAL Class AGOR

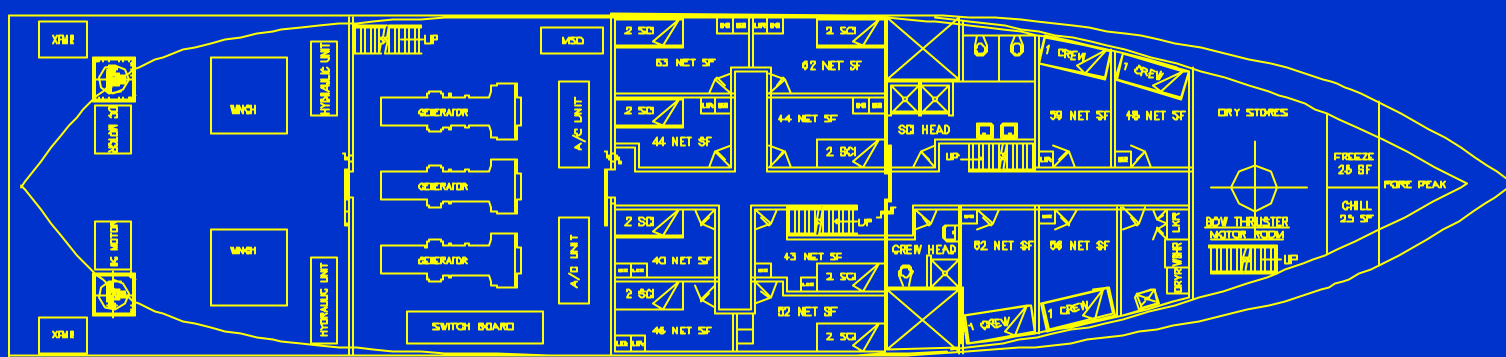
Concept Definition

Tonnage Analysis

<300 Domestic Ton Concept

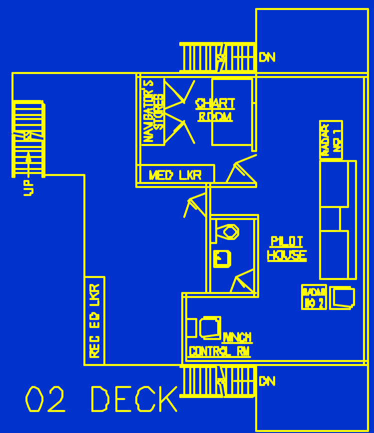


MAIN DECK

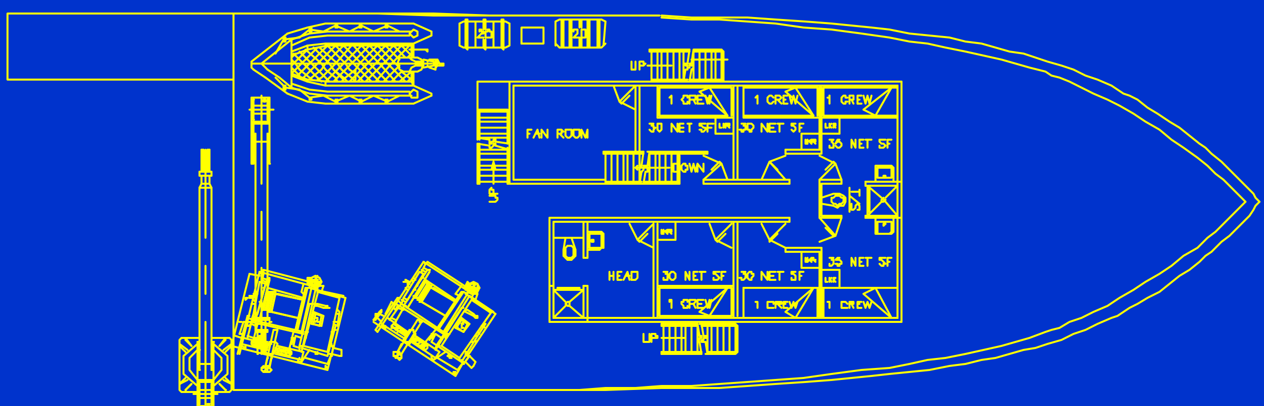


1ST PLATFORM

<300 Domestic Ton Concept



02 DECK



01 DECK

REGIONAL Class AGOR
Concept Definition

Tonnage Analysis

US Tonnage Calculation Summary For Concept Variants

	Minimum	Desired	<300 GRT
Gross Volumetric Additions	**CF**	**CF**	**CF**
Under Deck Tonnage			
BL - 1st Platform	0	0	0
1st Plat - Main Deck	35472	39617	30752
Super Structure Tonnage			
Main Deck to 01 Fwd (Hull)	17317	22288	18104
Main Deck to 01 Aft (House)	7808	8388	0
01 Level to 02 Level	8800	14752	4661
ISO Vans	0	0	0
02 Level	5272	5608	3096
Stack	1445	1445	1445
Engine Room Ventilation	416	416	416
Subtotal Gross Tonnage	765	925	585
Subtotal Gross Tonnage (CF)	76530	92514	58474
Spaces Exempt from Inclusion in Gross Tonnage			
Galley	-1856	-2124	-2400
Stack	-1445	-1445	-1445
Engine Room Ventilation	-416	-416	-416
E/R Stack & Ventilation IWO Labs	-1328	-1328	-1328
Water Closet (Shared Heads)	-312	-383	-744
Ballast (Roll Tank & Forepeak above Double Bottom)	-1704	-1165	-1704
Pilot House	-1840	-1840	-1840
Subtotal Gross Tonnage (CF)	67629	84738	48597
Subtotal Gross Tonnage	***676***	***847***	***486***
Engine Room Deduction			
-Engine Room Volume/100	-7488	-7488	-6496
Z-Drive Motor Room	-4248	-4248	-3952
Bow Thruster Motor	-312	-312	-312
Subtotal E/R Deduction (CF)	-12048	-12048	-10760
Subtotal E/R Deduction	-120	-120	-108
Engine Room % of GRT	-18%	-14%	-22%
Engine Room GRT Deduction	***-216***	***-271***	***-188***
Total US GRT	***460***	***576***	***298***

International Tonnage Calculation Summary For Concept Variants

	Minimum	Desired	<300 GRT
Gross Volumetric Additions	**CF**	**CF**	**CF**
BL - 1st Platform	26333	29965	23972.11
1st Plat - Main Deck	36141	41126	32900.77
Main Deck to 01 Fwd (Hull)	17644	22709	16062.12
Main Deck to 01 Aft (House)	7944	8388	0
01 Level to 02 Level	8800	14752	5614
02 Level	5272	5608	3766
ISO Vans	2560	2560	2560
Roll Tank	0	1337	0
Stack	1445	1445	1445
Engine Room Ventilation	416	416	416
Total Volume(CF)	106555	128306	86736
Total Volume(CM)	3018	3634	2456
K1	0.27	0.27	0.27
GRT	***814***	***985***	***658***

REGIONAL Class AGOR

Concept Definition

Tonnage Analysis

Theoretical US Tonnage For Each SMR

Item	Minimum SMR Gross Tonnage	Desired SMR Gross Tonnage	Driver	Assumptions	Suggestions to Reduce Tonnage
Mission					
Working Deck	0	0	SMR	Given	N/A
Mission Storage	0	64	SMR	Given	Decrease
Lab Space	**80**	135	SMR	Given (8 ft deck hts for Min, 9ft deck hts for Desired)	Decrease Deck Ht & Req'd Area
A-Frame	0	0	SMR	Given	N/A
Traction Winches	**46**	46	SMR	2/3 Box Dimension of Agor24 Winches. Based on Concept Arrangements	Place on Working Deck
Hydrographic Winches	0	27	SMR	Agor24 Winches. Based on Concept Arrangements	Unsheltered
Vans	0	0	SMR	Exempt	
High Bay	0	27	SMR	Based on Concept Arrangements	Eliminate
Winch Control Room	5	11		Based on Concept Arrangements	Detach from Pilot House
Propulsion					
Machinery	0	0	Speed,Electric Load	Exempt	Exempt
Fuel	0	0	SMR, Range	Exempt - Below Tank Top	
Ballast Tankage	0	0	Arrangement, Weight	Exempt - Below Tank Top	
Z-Drives	0	0	Dynamic Positioning	Exempt	Exempt
Bow Thruster	0	0	Dynamic Positioning	Exempt	Exempt
Habitability					
Crew Accommodations	**70**	70	SMR	Assumes 75 SF for 8 crew + 140 SF for Master & CE	Increase # of berths / accommodation
Scientist Accommodations	**64**	80	SMR	Assumes 100 SF for 16 Scientists including Chief Sci.	Increase # of berths / accommodation
Mess	**33**	41	Complement	Based on Concept Arrangements	Eat in Shifts
Stores	5	7	Complement/Range	Based on MSC stores calculations plus height of overhead (8 or 9 ft vs 6.5 ft)	
Fresh Water	0	0	Complement	Based on MSC Fresh Water calculations	Below Tank Top
T/S (Singles)	7	9	SMR/Accommodations	Based on # of shared T/S on Concept Arrangements @ 16.25SF ea.	Increase # of Personnel per T/S
Galley	0	0		Based on Concept Arrangements	Exempt
Misc					
Pilot House	0	0			Exempt
Roll Tank	0	0			Exempt
Total Volume(CF)	31102	51756			
Total GRT	**311**	**518**			
Actual Total GRT	460	531			
delta	149	14			

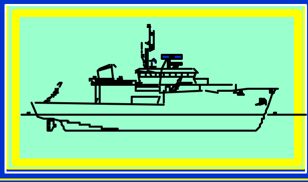
REGIONAL Class AGOR

Concept Definition

Tonnage Analysis

Theoretical US Tonnage For Min SMR Variant and Min CFR Variant

Item	Minimum SMR Gross Tonnage	Minimum CFR Gross Tonnage	Driver	Assumptions for Minimum CFR
Mission				
Working Deck	0	0	SMR	Given
Mission Storage	0	0	SMR	Given
Lab Space	80	**80**	SMR	Given
A-Frame	0	0	SMR	Given
Traction Winches	46	**0**	SMR Neglected	Winches on working deck
Hydrographic Winches	0	0		Unsheltered
Vans	0	0	SMR	
High Bay	0	0	N/A	N/A
Winch Control Room	5	3		1/2 Minimum
Propulsion				
Machinery	0	0	Speed,Electric Load	
Fuel	0	0	Range	Exempt - Below Tank Top
Ballast Tankage	0	0	Arrangement, Weight	Exempt - Below Tank Top
Z-Drives	0	0	Dynamic Positioning	
Bow Thruster	0	0	Dynamic Positioning	
Habitability				
Crew Accommodations	70	**27**	CFR	Assumes CFR Minimum Areas & Volumes
Scientist Accommodations	64	**33**	CFR	Assumes CFR Minimum Areas & Volumes
Mess	33	**17**	Complement	1/2 Minimum (Meals in 2 shifts)
Stores	5	5	Complement/Range	Based on MSC stores calculations plus height of overhead (7 ft)
Fresh Water	0	0	Complement	Exempt - Below Tank Top
T/S (Singles)	7	**0**	CFR	All T/S Shared
Galley	0	0		
Misc				
Pilot House	0	0		
Roll Tank	0	0		
Total Volume(CF)	31102	16385		
Total GRT	**311**	**164**		
Minship Actual/Theoretical Delta		149		
Predicted GRT		313		



REGIONAL Class AGOR

Concept Definition

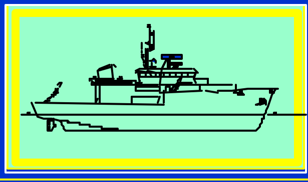
Regulatory Impacts

CFR Requirements

Requirements	***Minimum Hull***	***Desired Hull***	***Hull with 300 gross registered tons or less***
International Voyage (188.05-10)	>500 gross tons and on a voyage between the contiguous states of the United States, and the states of Hawaii or Alaska. <500 gross tons, Not International Voyage	>500 gross tons and on a voyage between the contiguous states of the United States, and the states of Hawaii or Alaska. >500 gross tons, Yes International Voyage	Not inspected. Subchapter U of Oceanographic Research Vessel will not apply to this vessel
Hull Structure	Compliance with the ABS standards	Compliance with the ABS standards	
Navigation Bridge Visibility (190.02)	Required by ships which are 100 meters or more in length not required	Required by ships which are 100 meters or more in length . not required	
Subdivision and Stability	Inspected under Subchapter U. SubChapter S	Inspected under Subchapter U. SubChapter S	Recommended to following 46 CFR 28.580 as stability guide line.
-Collision Bulkhead	- located after 5%*Lbp and fwd 10+5%*Lbp: 7.25 to 17.25: OK - the collision bulkhead must extend to the deck above the bulkhead deck ?	- located after 5%*Lbp and fwd 10+5%*Lbp: 8.25 to 18.25: OK - the collision bulkhead must extend to the deck above the bulkhead deck ?	- Located after 5% * Lbp.
-Subdivision	Subdivision - Type II. Each compartment length must be at least 10+3%*Lbp = 14.35 feet. OK	Subdivision - Type II. Each compartment length must be at least 10+3%*Lbp = 14.95 feet. OK	Each compartment length must be at least 10+3%*Lbp = 14.95 feet. OK
-Double bottom	Each vessel over 165 feet and under 200 feet in LBP must have a double bottom that extends from the forward end of the machinery space to the fore peak bulkhead. Not required	Each vessel over 165 feet and under 200 feet in LBP must have a double bottom that extends from the forward end of the machinery space to the fore peak bulkhead. Not required	
-Intact Stability	OK	OK	OK. Requirements in 46 CFR 28.500 is very similar to criteria in Subchapter S
-Damage Stability	One compartment flooding.	One compartment flooding.	One compartment flooding

Regulatory Impacts (Continued)

General Fire Protection (190.05)	- Chemical storerooms shall be constructed of steel. OK - Chemical storerooms shall not be located in horizontal proximity to nor below accommodation areas. OK - Chemical storerooms shall not be located adjacent o the collision bulkhead. OK	- Chemical storerooms shall be constructed of steel. OK - Chemical storerooms shall not be located in horizontal proximity to nor below accommodation areas. OK - Chemical storerooms shall not be located adjacent o the collision bulkhead. OK	-
Structural Fire Protection (190.07)	- Apply to all vessels of 300 gross tons and over, carrying in excess of 16 persons in the scientific party. OK - A Class divisions for the boundary bulkheads of general laboratory areas, chemical storerooms, galleys, and emergency generator rooms. OK - Approved materials for structural insulation, deck covering, bulkhead panels: (164.006 to 164.012)	- Apply to all vessels of 300 gross tons and over, carrying in excess of 16 persons in the scientific party. OK - A Class divisions for the boundary bulkheads of general laboratory areas, chemical storerooms, galleys, and emergency generator rooms. OK - Approved materials for structural insulation, deck covering, bulkhead panels: (164.006 to 164.012)	-
Means of Escape	- Two means required for all general areas. These two means of escape shall be as remote as possible. OK - All interior stairways, other than those within the machinery spaces, shall have minimum width of 28 inches. The angle of inclination of the stairways shall not exceed 50^0. OK - Public spaces having a deck area of over 300 ft^2 shall have at least two exists. OK	- Two means required for all general areas. These two means of escape shall be as remote as possible. OK - All interior stairways, other than those within the machinery spaces, shall have minimum width of 28 inches. The angle of inclination of the stairways shall not exceed 50^0. OK - Public spaces having a deck area of over 300 ft^2 shall have at least two exists. OK	-
Ventilation	- Not in details	- Not in details	-



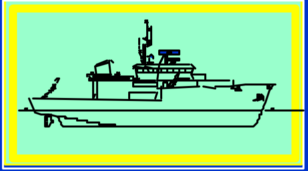
REGIONAL Class AGOR Concept Definition

Regulatory Impacts (Continued)

Accommodations for Officers, Crew, and Scientific Personnel	- Crew quarters shall not be located farther forward in the vessel than a vertical plane located at 5 percent of the vessel’s length abaft the forward side of the stem at the designed summer load line. OK - Each licensed officer shall be provided a separated stateroom. OK - Crew accommodation room shall not berth more than four persons. OK - Scientific accommodation rooms shall not berth more than six persons. OK - Each crew accommodation room shall have a size of at least 30 square feet per person. More than enough - Each scientific accommodation room shall have a size of at least 20 square feet per person. More than enough - No more than one berth shall be placed above another. OK - A berth shall be at least 30 inches wide by 76 inches long. OK - There shall be at least one toilet, one washbasin, and one shower for each eight members. OK - Messrooom shall be located near to the galley. OK -	- Crew quarters shall not be located farther forward in the vessel than a vertical plane located at 5 percent of the vessel’s length abaft the forward side of the stem at the designed summer load line. OK - Each licensed officer shall be provided a separated stateroom. OK - Crew accommodation room shall not berth more than four persons. OK - Scientific accommodation rooms shall not berth more than six persons. OK - Each crew accommodation room shall have a size of at least 30 square feet per person. More than enough - Each scientific accommodation room shall have a size of at least 20 square feet per person. More than enough - No more than one berth shall be placed above another. OK - A berth shall be at least 30 inches wide by 76 inches long. OK - There shall be at least one toilet, one washbasin, and one shower for each eight members. OK - Messrooom shall be located near to the galley. OK	

Regulatory Impacts (Continued)

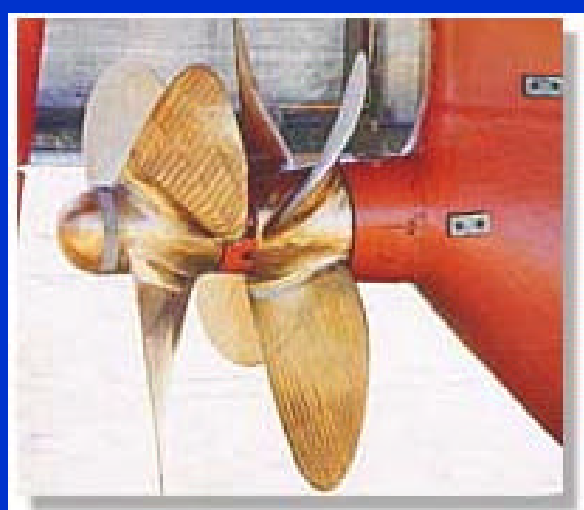
Accommodations for Officers, Crew, and Scientific Personnel (Continued)	- Each vessel which in the ordinary course of its voyage is more than 3 days' duration and which carries a crew of 12 or more, shall be provided with a hospital space, except: o The crew is berthed in single occupancy staterooms and one room is designated and fitted for use as a treatment and/or isolation room. OK -	Each vessel which in the ordinary course of its voyage is more than 3 days' duration and which carries a crew of 12 or more, shall be provided with a hospital space, except: o The crew is berthed in single occupancy staterooms and one room is designated and fitted for use as a treatment and/or isolation room. OK	-
Lifesaving Equipments (192.10-10)	- Lifeboats shall be not less than 24 feet. In no case shall life boats of less than 16 feet in length be used. - In addition to the lifeboats, each vessel on an international voyage and each vessel in ocean or coastwise service must carry lifecrafts of sufficient aggregate capacity to accommodation at least 50 percent of the person on board -	- Lifeboats shall be not less than 24 feet. In no case shall life boats of less than 16 feet in length be used. - In addition to the lifeboats, each vessel on an international voyage and each vessel in ocean or coastwise service must carry lifecrafts of sufficient aggregate capacity to accommodation at least 50 percent of the person on board -	-
Marine Engineering (Subchapter F)	- 46 CFR (Subchapter F)	- 46 CFR (Subchapter F)	Recommended to follow 46 CFR Subchapter F
Electrical Engineering (Subchapter J)	- 46 CFR (Subchapter J)	- 46 CFR (Subchapter J)	Recommended to follow 46 CFR Subchapter J
Load Line (Subchapter E)	-	-	-



Technology Investigation

Efficiency Enhancement Devices

- *Contra Rotating Propellers*
  - *Recovers the rotating energy loss originating from a fore propeller by a contra-rotating aft propeller*
  - *Improves propulsion efficiency by 10 to 15%*
  - *Reduces cavitation*
  - *Complicated design and high cost*



REGIONAL Class AGOR

Concept Definition

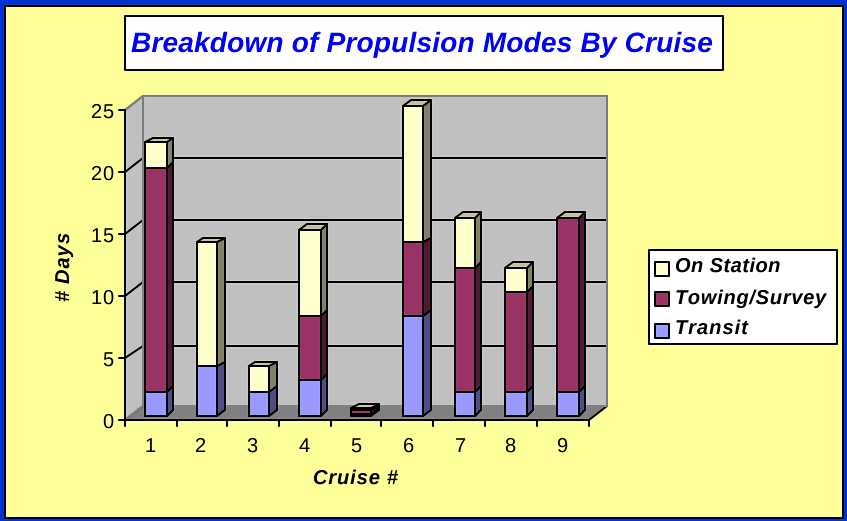
Efficiency Enhancement Devices

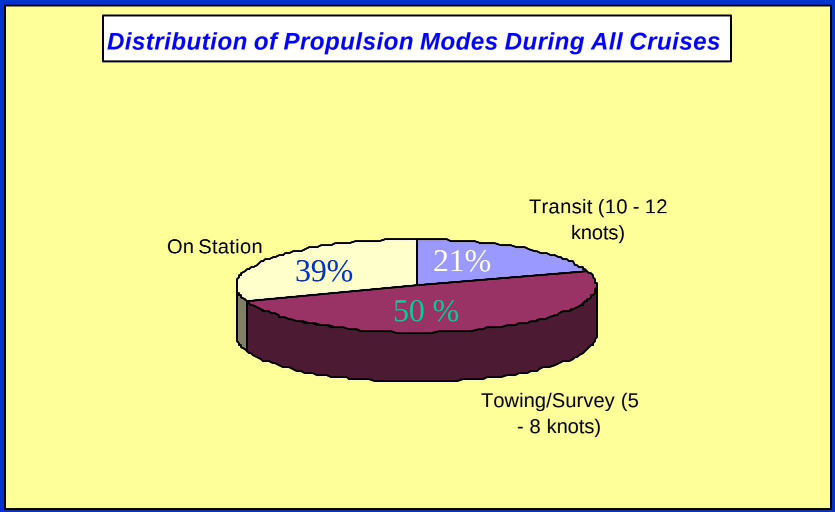
- Pre and Post Swirl Vanes
  - Various types of pre-swirl and post-swirl energy-saving devices.
  - Propulsive efficiency gain ranges from 3 to 15%
  - Effectiveness is sensitive to speed
  - Complication in design

- Stern Flap
  - Modifies stern wave system
  - Resistance improvement in the range of 5 to 15%
  - Reduces propeller cavitation
  - Greater effectiveness if planned in the initial design
  - Cost Impact is Small
  - May Impact Stern Wire Handling
  - AGOR Speed Tends To Be Low Which Limits Effectiveness

REGIONAL Class AGOR Concept Definition

Efficiency Enhancement Devices





Typical Efficiency Savings Calculation for Desired Monohull:

Total Annual Fuel Cost	**=**	**$225,163**
Annual Fuel Cost in Transit	**=**	**$46,525**
Efficiency Savings		**10%**
Annual Fuel Savings	**=**	**$4,652**

Savings Not Dramatic For a Regional AGOR Operating Profile

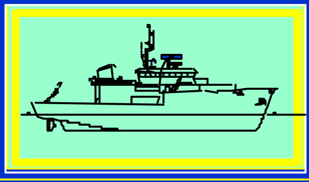
Fuel Cells:

Pros:

- *Higher Energy Efficiency*
- *Low Environmental Emissions*
- *Low Maintenance costs*
- *Low Noise Signature*
- *Potential For Marine Application, Particularly As Ship's Service Power Source*
  - *Regional AGOR Profile Dominated By Zero, Low Speed Operation*

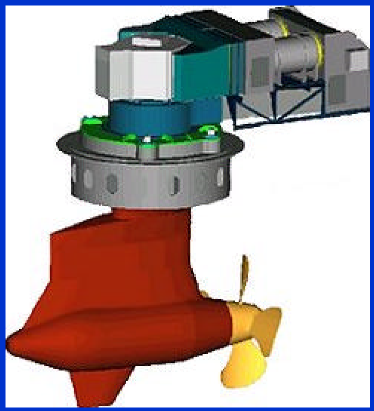
Cons:

- *Developmental*
  - *NAVSEA, ONR, USCG Involved in Research Efforts*
- *Higher Initial Cost Presently and For Some Time*
- *No Marine Service Experience*
- *Lacks "Stiffness" As An Electrical Source - Poor Response To Transients*
- *May Not Be Commercially Viable Until At Least 2015*



REGIONAL Class AGOR
Concept Definition

Podded Electric Propulsors



- Excellent Maneuverability
- Reduced Machinery Space Requirements
- Fewer Moving Parts (No Gears)
- Offered By Several Manufacturers
- Regional AGOR Propulsor Size of 550 to 650 KW at Low End of Size Range
- Long Term Reliability Not Certain

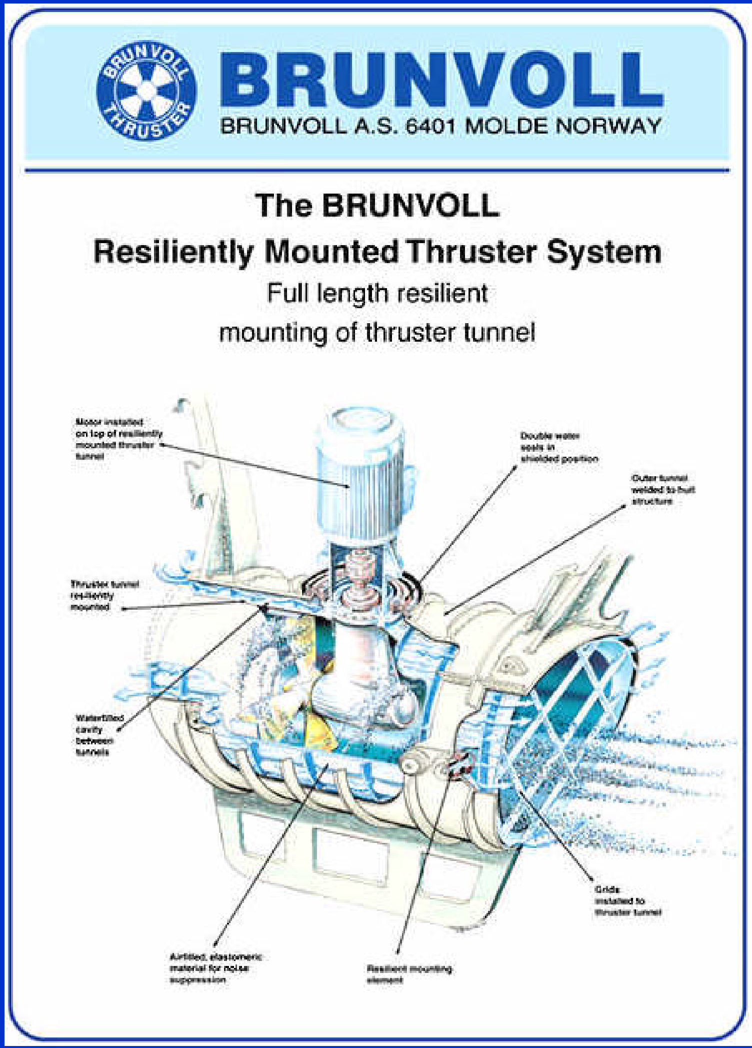
- ABB has Compact Unit For Small Vessels (400KW and Up)
  - Permanent Magnet Motor
  - Smaller Diameter Pod
    - Less Wake Interference
  - Cooled Directly By Outside Seawater

Electric Drive Comparison

Parameter	DC	AC - Pulse Width Modulated	AC - Load Commutated Inverter	AC - Cyclo Converter
Drive Cost	Lowest	Higher Initial and Spare Parts	Higher Initial and Spare Parts	Higher Initial and Spare Parts
Drive Size	Smaller	Larger than DC	Larger than PWM	Larger than PWM
Drive Weight	Lighter than AC	Heavier than DC	Heavier than PWM	Heavier than PWM
Drive Complexity	Simpler than AC	More complex than DC	More complex than DC	More complex than DC, PWM, LCI
Drive Maintenance	Less Maintenance Required	More complex - more maintenance	More complex - more maintenance	More complex - more maintenance
Drive Reliability	Very reliable	Susceptible to power system fluctuations	Components less reliable and susceptible to damage from transients	Less reliable than DC
Drive Environment	Less Sensitive to Temperature	More sensitive to temperature	Less space conditioning required than PWM, but more than DC	Less space conditioning required than PWM, but more than DC
Available Torque	Full torque available continuously at all speeds	If low propeller speeds (below 10% of rated) are operational requirements, may not be a good fit depending on the manufacturer	If low propeller speeds (below 10% of rated) are operational requirements, not a good fit	If low propeller speeds (below 10% of rated) are operational requirements, not a good fit.
Torque Pulsations	Torque pulsations generally worse at lower speeds	High frequency torque pulsations (at the PWM frequency) may be present on the shaft, but generally minimal	Low frequency torque pulsations, predominately at low speeds. Multiple winding motors can be used to minimize effect	Low frequency torque pulsations, predominately at low speeds. Multiple winding motors can be used to minimize effect
Crew Training	Less complex	More complex than DC	More complex than DC and PWM	More complex than DC, PWM, and LCI
Noise	Lower ambient noise and hull noise transmitted to the water	Addition isolation mounting and noise insulation may be required in noise sensitive applications	Less impact than PWM, but more than DC	Less impact than PWM, but more than LCI or DC.
AC Power System Quality	Defined and repetitive harmonics. Simple trap filters are effective and relatively inexpensive. Additionally 12 and 24 pulse systems can be used, but these add to cost, complexity and weight	Additional more complex and more expensive filters required. High chance of EMI coupling between cables due to higher frequency noise if it is not eliminated	May require additional filtering on the AC bus.	AC power system distortion control much more expensive than DC, PWM and LCI
Integration Engineering	Simpler system requires less integration engineering, thus lower front end engineering effort and cost	More complex system requires more up front engineering effort and cost. Additional engineering required to evaluate possible power quality issues	More complex than DC so engineering greater than DC, but less than CC	More complex than DC, LCI and PWM so additional front engineering required.
Motor Size	Larger than AC induction or synchronous motors	Requires less space than DC, LCI and CC (synchronous motor type).	Requires less space than DC, but more than PWM.	If induction motor, requires less space than DC or PWM
Motor Cost	Higher initial cost	Lower initial cost than DC, LCI and CC (synchronous motor type).	Greater cost than PWM, but less than DC.	If induction motor, type lower initial cost than DC or LCI. If synchronous motor type greater cost than PWM, but less than DC and same as LCI

Bow Thruster Quieting:

- Bow thruster noise impacts habitability on monohulls
- REVELLE Modifications
- Resilient Thruster Mounting
- Elastomeric Material For Noise Absorption
- Skewed Impeller
- Air Injection



Handling Systems:

- Motion (Heave) Compensation
  - Passive – Constant Tension at constant depth
  - Active – Constant Tension all depths
  - Active motors - series of smaller motors on winch
    - Require extra power
    - Bulky/ Extra weight
  - Ram Tensioners – compressed gas cylinder with series of sheaves
- Motion Constraint
  - Knuckle boom crane to lower sheave toward water
  - Reduce personnel, improve safety, raise sea state limitations
- Electric Winches Vice Hydraulic

CTD Handling System

(Manufactured by Dynacon)

- Passive heave compensated boom crane with traction winch
- Requires 36’ x 6.75’ of deck area
- Requires a separate 93 kW electro-hydraulic power unit
- Up to 11,000 meters of 0.322 inch diameter cable
- Installed on Japanese vessels

Mission Systems

- Wideband multibeam sonar
  - Under Development by Simrad, Expected Late 2004
  - Modular Transducers

EM 710 Main Specifications (Preliminary)

Frequency Range	70-100kHz
Beam Steering (Stabilization for Vessel Motions)	Yaw, Pitch & Roll
Beamwidth Options (Transmit x Receive)	0.5 x 1; 1 x 1; 1 x 2; 2 x 2 degrees
Transducer Size Options; Length x Width — 0.5 degree	200 x 15 cm (Transmit)
1 degree	100 x 15 cm (Transmit or Receive)
2 degree	50 x 15 cm (Transmit or Receive)
Transducer Geometry	Mills Cross (with Flat Arrays)
Min-max Water Depth with FM Sweep	5-2000m (0.5 x 1 degree)
Min-max Water Depth with CW Pulse	5-1000m (1 x 1 degree)
Maximum Angular Coverage	To be determined
Soundings per Ping	200-400
Sounding Distribution across Swath	Equi-distant & Equi-angular

Auxiliary Systems

- *Stainless steel drain piping*
  - *Installed on KILO MOANA*
  - *Push Fit*
  - *Reduced weight*
  - *Corrosion resistance*
- *Composite piping*
  - *Approved by USCG*
  - *Corrosion resistant*
  - *Expensive*
  - *For AGORs, high end standard materials (Cu-Ni) adequate for SW service*
  - *May have some application in weight sensitive designs (SWATHs)*

Propulsion

- High Temperature Superconducting Motors
  - Much smaller in size compared to conventional electric motors
  - Requires cryogenic cooling
  - Very developmental

Comparison of Propulsor Types:

Type	Comments
Direct Drive Electric	Requires a low speed motor which generally means that the motor will be heaver and more costly. Gives reasonably good flexibility to shaft line and machinery space design.
Electric with Reduction Gear	Uses a higher speed motor which means that it will be lighter and smaller, but requires the installation of a gear box. Less flexibility in shaft and machinery space design.
Z-Drive	Provides for more flexibility in shaft line and machinery space arrangements. Generally can use a higher speed motor. Well suited for DPS operations as the propulsor can rotate through 360^{o}.
Podded drive	Provides for even greater shaft line and machinery space design flexibility than the z-drive as the main motor is outside the hull. Some of the newer systems are much more efficient than fixed shafts, but also more complex. New podded motors are available from about 0.4 MW up to about 25 MW. The drawback is that the motor is below the waterline and repairs often require drydocking. Excellent for DPS operations as well. Vendors indicate that they have no problems with their pod designs, but not confirmed and little service experience.
Single Screw, Single Motor	Reduces the costs of vessel construction but creates reliability issues since there is only a single motor/shaft. Dual winding motor can be used to provide redundancy for the drives, but a motor or shaft bearing failure still puts the vessel out of service. Not well suited for DPS.
Single Screw, Dual Motor	Same as single screw, single motor except that two motors are provided increasing the reliability. Generally dual motors require significantly more space than a single motor so machinery space and shaft line designs are more limited. Not well suited for DPS.
Twin Screw	Provides much more redundancy than a single shaft since no single motor or bearing failure will take the vessel completely out of service. Costs are significantly higher than single shaft design.

Comparison of Power Plant Types

Type	Comments
Diesel Electric	An integrated diesel electric plant provides for far greater flexibility since the prime movers can be located in a space separate from the propulsion shaft. The number of generators on-line at any given time is a function of power demand from house loads and the propulsion system. This allows for optimal loading of the generators if they are properly sized based on the vessels operating profiles. In larger propulsion system applications that require the use of large medium or slow speed diesels, the response time of the diesels may become an issue.
Gas turbine Electric	Same advantages as an integrated diesel electric power plant. Typically used on larger propulsion system applications that require a lot of power. The gas turbines provide for much faster dynamic response times and do not have the same problems as diesels with light loading. The big drawback is fuel consumption.
Combine Cycle Gas Turbine Electric	Same as gas turbine above, but uses waste heat from the gas turbine exhaust to generate steam. This steam can be used to for operating a steam turbine generator or for heating on the vessel. It increases the fuel efficiency but significantly complicates the plant. Generally this type plant would be for very large propulsion systems on a vessel with high house load requirements.

Comparison of Propulsion Motor Types:

Type	Comments
DC Motor	Generally larger and heaver than comparable AC motors of the same horsepower. Requires use of many brushes in the armature circuit which creates maintenance issues.
DC Motor (permanent magnet)	Similar to DC motor above but does not require separate field excitation circuit.
AC Induction Motor	Simplest and smallest type motor with low maintenance requirements.
AC Synchronous (slip ring)	Less complex and requires less maintenance than a DC motor, but larger, heaver and more complex than an induction motor. Does however give the ability to vary the power factor of the propulsion loads. Motor has a few brushes to provide excitation current to the motor.
AC Synchronous (brushless)	Same as slip ring motor except that no brushes are used. A brushless exciter is used to provide excitation. This requires the use of rotating diodes on the rotor of the motor which makes it more complex and generally makes the motor a little longer.
AC Synchronous (permanent magnet)	Same as slip ring except that no external exciter is required. The permanent magnets on the rotor provide the magnetic field. This is newer technology and has been used on podded motors to reduce the number of external power connections to the motor located in the underwater pod.
AC Induction (super cooled)	Super cooled technology is still in its early development stages. While it provides for a much smaller motor, the support systems are very complex and costly. I do not believe that these systems are ready yet for commercial marine applications due to costs and reliability issues.

Comparison of Electric Propulsion Drive Types:

Type	Comments
6 Pulse	Simplest type drive, but creates significant harmonic distortion issues.
12 pulse	Uses two 6 pulse drives connected through a phase shift transformer. Significantly reduces the harmonics on the AC power system, but requires the use large phase shift transformers. Uses two smaller drives rather one large one.
24 Pulse	Uses four 6 pulse drives connected through phase shift transformers. Again it reduces the AC power system harmonics, but also requires more transformers and drives.
DC Drives	Simplest drives, but creates harmonic issues and requires use of high maintenance DC motors.
AC Cycloconverter	Straight AC to AC conversion. Very complicated control algorithms and significant AC power system distortion that is not easily rectified. Generally used on large high torque motor applications, such as ice breakers.
AC Load Commutated Inverter (LCI)	AC-DC-AC conversion. Complicated and generally used on medium to large size AC propulsion systems. Not good for applications requiring extended low speed operations.
AC Pulse Width Modulated (PWM)	AC-DC-AC conversion. New control technology allows these drives to operate at lower speeds and develop enough torque in the low speed ranges. They are also now available in much higher horsepower ratings by paralleling the inverter (DC-AC) power bridges. Generally requires output reactors or multiple winding motors for larger applications.
AC Drive with Diode Front End	Uses AC-DC-AC conversion with a diode front end (AC-DC). Simple but creates typical 6 pulse harmonics. Can use 12 or 24 pulse front ends to reduce the harmonics. Drawback is that the diode front end does not allow for regeneration during crash stop maneuvers. Not an issue if pods or z-drives are used. When used with a fixed shaft however, it requires the use of external dynamic breaking resistors during crash stop maneuvers. Can be used on PWM and LCI drives.
AC Drive with Active Front End	The advantage over the diode front end is that it can utilize regeneration during crash stop maneuvers to slow down the motor. Depending on what types of active components are used, the drive may not have harmonic distortion problems. Can be used on PWM and LCI drives.

Comparison of Harmonic Filter Types:

Type	Comments
Passive Filter	Passive filters use capacitors, inductors and resistors and are tuned to a fixed harmonic frequency. A separate tuned filter (5th, 7th, 11th, etc.) leg is generally used. They tend to be big and generate a lot of heat. They can also create significant design and operational issues on a power system. If not properly designed they can create resonance issues on a power system making the entire system unstable. They can also cause generator over-excitation problems when light propulsion system loads are present.
Active Filter	Newer technology has decreased these units in size, but they are still more costly than passive filters. Effectively they are an electronic system that monitors the AC bus and generates currents equal and opposite to the harmonic currents generated by the propulsion system drives. This effectively cancels out the harmonic distortion. They need to be located at the source of the harmonic current (propulsion system drives) to minimize the total harmonic distortion. Typically a harmonic filter has to have about 1/3 the current capacity as the propulsion drive it is associated with. If 12 or 24 pulse propulsion drives are used, their size can be significantly reduced. These systems are more complicated that passive filters but do not have as many system integration issues as their passive counterparts. These are relatively new to the marine industry, but are becoming more popular as their costs come down.