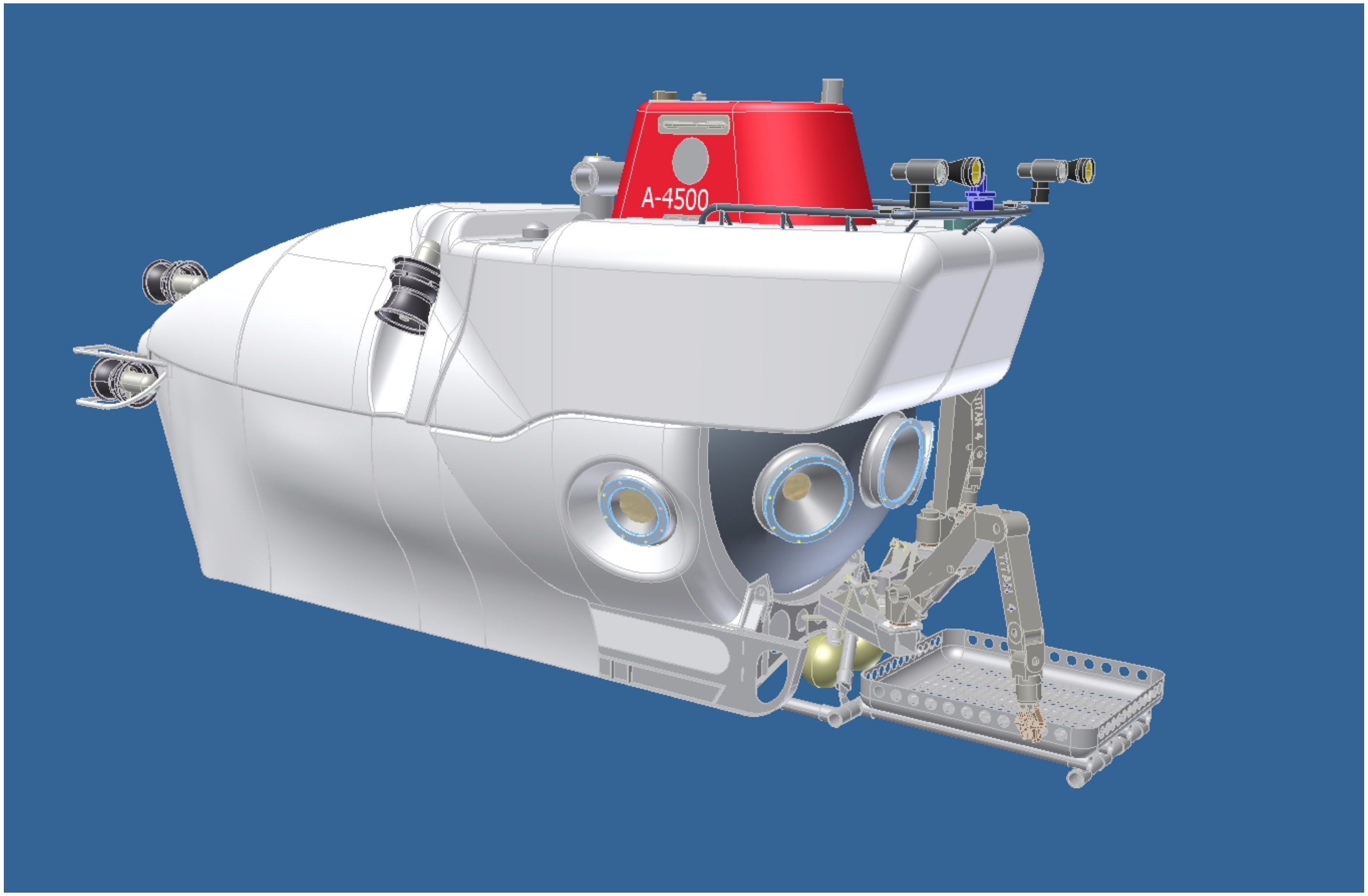
6500m HOV Project
Update



DESSC Meeting -- 13 December 2009

Staged Approach

Develop concept for A-4500 HOV using the 6500m depth-rated personnel sphere now in production

- Satisfy as many replacement HOV design goals as possible
- Leverage replacement HOV design efforts already undertaken
- Reduce total project costs
- Allow for later upgrade to full 6500m vehicle

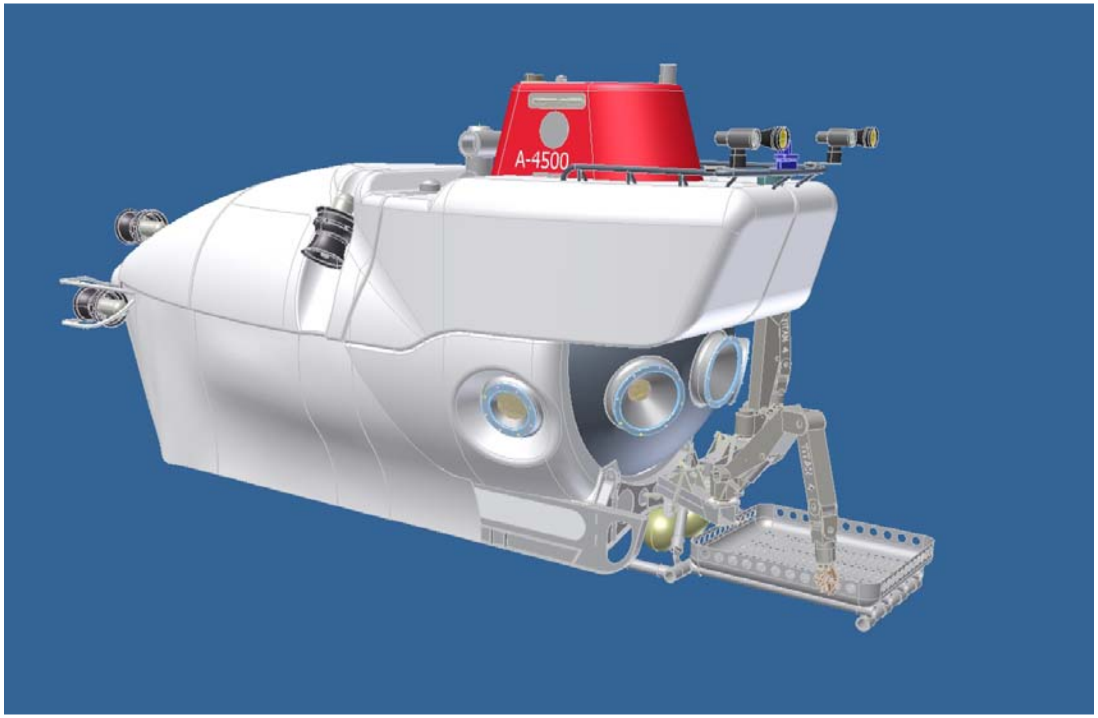
Phase I - Sphere

A-4500 HOV — Stage 1

A-6500 HOV — Stage 2

6500m HOV Project
Overview

- A new submersible for the scientific community built in 2 stages:
  -- Stage 1 A-4500 HOV: December 2011
  -- Stage 2 A-6500 HOV: At a later time
- Preferred design for the Stage 1 A-4500 HOV



6500m HOV Project

Personnel Sphere Construction

Ti Ingots

June 2008

August 2009

Schedule:
Original: Feb. 2010
Projected: March 2011

Cost:
Original: $7M
Projected: $9.58M

6500m HOV Project

Overall Project Requirements

- **Science Requirements**

  Defined by the scientific community

- **Operational Requirements**

  Driven by safety, and the need to make the new HOV reliable, maintainable & scientifically and operationally flexible

- **ABS Classification Requirements**

  Dictates certain features and designs as mandatory; imposes rules on how work is performed and the required inspections

6500m HOV Project

Preferred Vehicle Design

Capabilities Desired by the Scientific Community

- Increased depth capability to 6500 m
- Larger personnel sphere with improved interior ergonomics
- Increased battery capacity
- Increased bottom time at routine operating depths
- Better visibility with more observer view ports and overlapping fields of view between the pilot and two observers
- Improved interior electronics
- Increased science payloads
- Improved lighting and imaging systems
- Automated station keeping
- Increased thruster horsepower (improved maneuverability)
- Increased hydraulic plant capacity (improved manipulator performance)
- Improved data collection, logging, & instrument interface capability
- Improved mid-water research capability

6500m HOV Project
Operational Requirements

- A crew of 3 (1 pilot and 2 scientists) – similar to the configuration of *Alvin* that has been so successful for the past four decades
- A daily single dive routine, permitting other operations to be carried out during battery charging
- An operational support team similar in size to that for *Alvin* so that future operations can be kept to cost and logistical levels that are similar to those for the current vehicle
- Use of R/V *Atlantis* as the support ship without major modifications to the hull or launch/recovery A-frame system
- Flexibility in scientific and operational systems to support multidisciplinary research

6500m HOV Project

ABS Classification Requirements

- Applicable Rules: *ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities*
- Staged approach: each stage will require classification
- Scope of Classification (SOC) document: identifies all critical systems and components of the Stage 1: A-4500 HOV
- Submission Reports required for:

1. Existing Equipment
2. General Group
3. Mechanical Equipment Group
4. Pressure Hull Group
5. Pressure Vessel Group
6. Ballast Group
7. Electrical Installations Group
8. Emergency Systems Group
9. Propulsion Group
10. LARS Group
11. Life Support Systems Group
12. Procedures & Test
13. Manuals Group

A-4500 HOV

Preferred Vehicle Design

Added Science Capabilities →

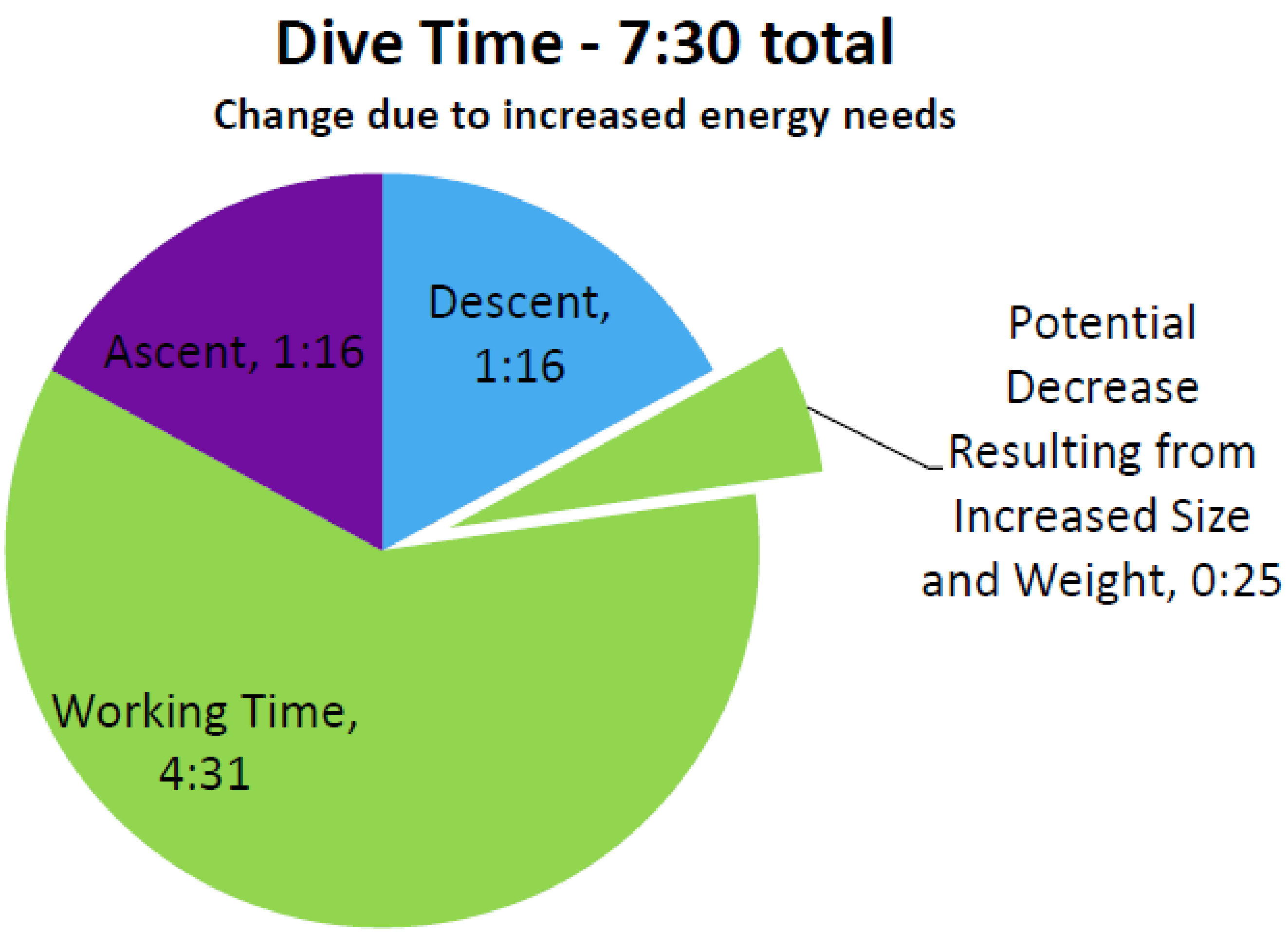
	BASE VEHICLE	Command and Control Enhancements; New Power and Data Bottles	All New 6500 Meter Syntactic Foam	Illumination Enhancements	Imaging Option 1 - Internal Video Infrastructure	Imaging Option 2 - New HD Camera, Upgrade of Existing Camera; UpgradeShipboard Data Duplication System	Imaging Option 3 - Ramped and Strobed LED Lights; External Still Image Storage Capability	Imaging Option 4 - Upgrade of Shipboard Science Processing Station	PREFERRED A-4500 HOV
General Information/ System Engineering	–	$135,927							$135,927
Fixed Buoyancy Assemblies	–		$1,097,088						$1,097,088
Penetrator	–	$64,306							$64,306
Power Bottle	–	$68,253							$68,253
Data Bottle	–	$149,796							$149,796
Junction Boxes	–	$22,070							$22,070
Illumination and Imaging	–			$197,427	$568,560	$356,660	$479,053	$91,750	$1,693,450
Science Data Systems	–	$74,151							$74,151
Command, Control & Computing	–	$598,004							$598,004
Upscope Cost Subtotals	–	**$1,112,506**	**$1,097,088**	**$197,427**	**$568,560**	**$356,660**	**$479,053**	**$91,750**	**$3,903,044**
Total Material and Labor Cost (Cumulative Totals)	**$27,134,836**	**$28,256,342**	**$29,353,430**	**$29,550,857**	**$30,119,417**	**$30,476,077**	**$30,955,130**	**$31,046,880**	**$31,046,880**
								Escalation	**676,014**
								Contingency (95% Level of Confidence)	**3,452,000**
								Total	**$35,174,894**

Subtotals Are For FY2009 dollars
Escalation is estimated at 4%/year
Confidence Level estimated for preferred A-4500M HOV only

	BASE A-4500 HOV	Command and Control Enhancements; New Power and Data Bottles	All New 6500 m Syntactic Foam	Illumination Enhancements	Imaging Option 1 - Internal Video Infrastructure	Imaging Option 2 - New HD Camera, Upgrade of Existing Camera; Upgrade to Shipboard Data Duplication System	Imaging Option 3 - Ramped and Strobed LED Lights; External Still Image Storage Capability	Imaging Option 4 - Shipboard Science Processing Station Upgrade	PREFERRED A-4500 HOV
Larger personnel sphere with improved interior ergonomics	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Increased Field of View for pilot's and observers	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Improved illumination	🔴	🔴	🔴	🟡	🟡	🟡	🟢	🟢	🟢
Improved imaging systems	🔴	🔴	🔴	🔴	🔴	🟡	🟡	🟡	🟡
Improved data collection, logging, and interface capability	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Improved interior electronics	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Automatic position keeping	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Increased thruster horsepower and better maneuverability	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Enhanced mid-water research capability	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Increased science payloads	🔴	🔴	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Increased battery capacity	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
Increased on-bottom time	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
Increased hydraulic plant capacity (improved manipulator performance)	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
Increased operating Depth to 6500 meters	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
Upscope cost impact	—	**$1,112,506**	**$1,097,088**	**$197,427**	**$568,560**	**$356,660**	**$479,053**	**$91,750**	**$3,903,044**

A-4500 HOV

Dive Time Reduction Estimate



A-4500 HOV

Budget for Preferred A-4500 HOV Design

A-4500 HOV Cost of Preferred Design	$31,046,880
With Escalation	$31,722,894
Contingency	$ 3,452,000
Total Cost Estimate	**$35,174,894**

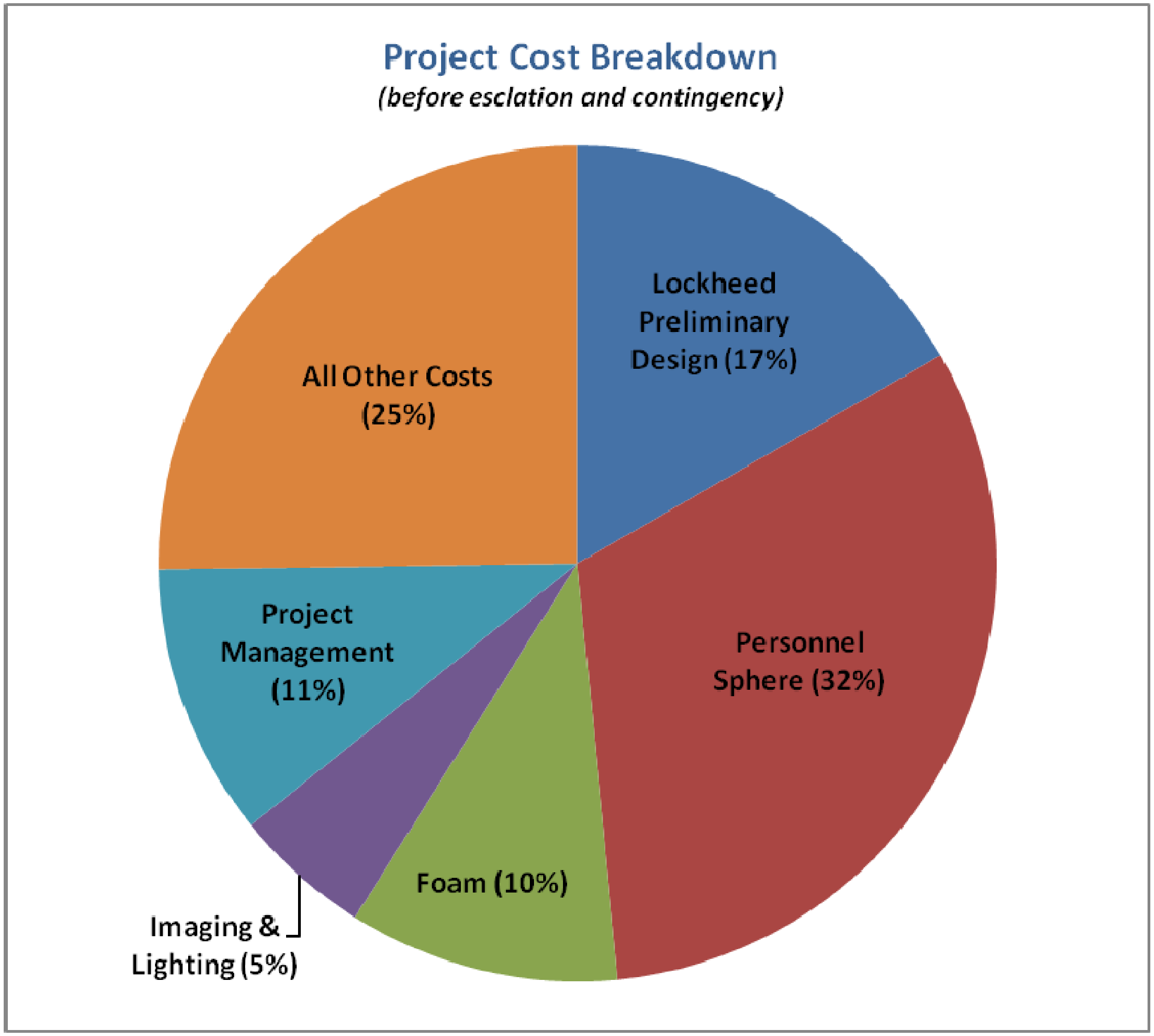
Current Funding

NSF	$22,910,000
WHOI	$ 5,000,000
Ship Modifications	$ 200,000
Total Funding Available	**$28,110,000**

Funding Variance $7,064,889

A-4500 HOV

Project Cost Breakdown



A-4500 HOV

Upgrade to A-6500 HOV

Added Science Capabilities

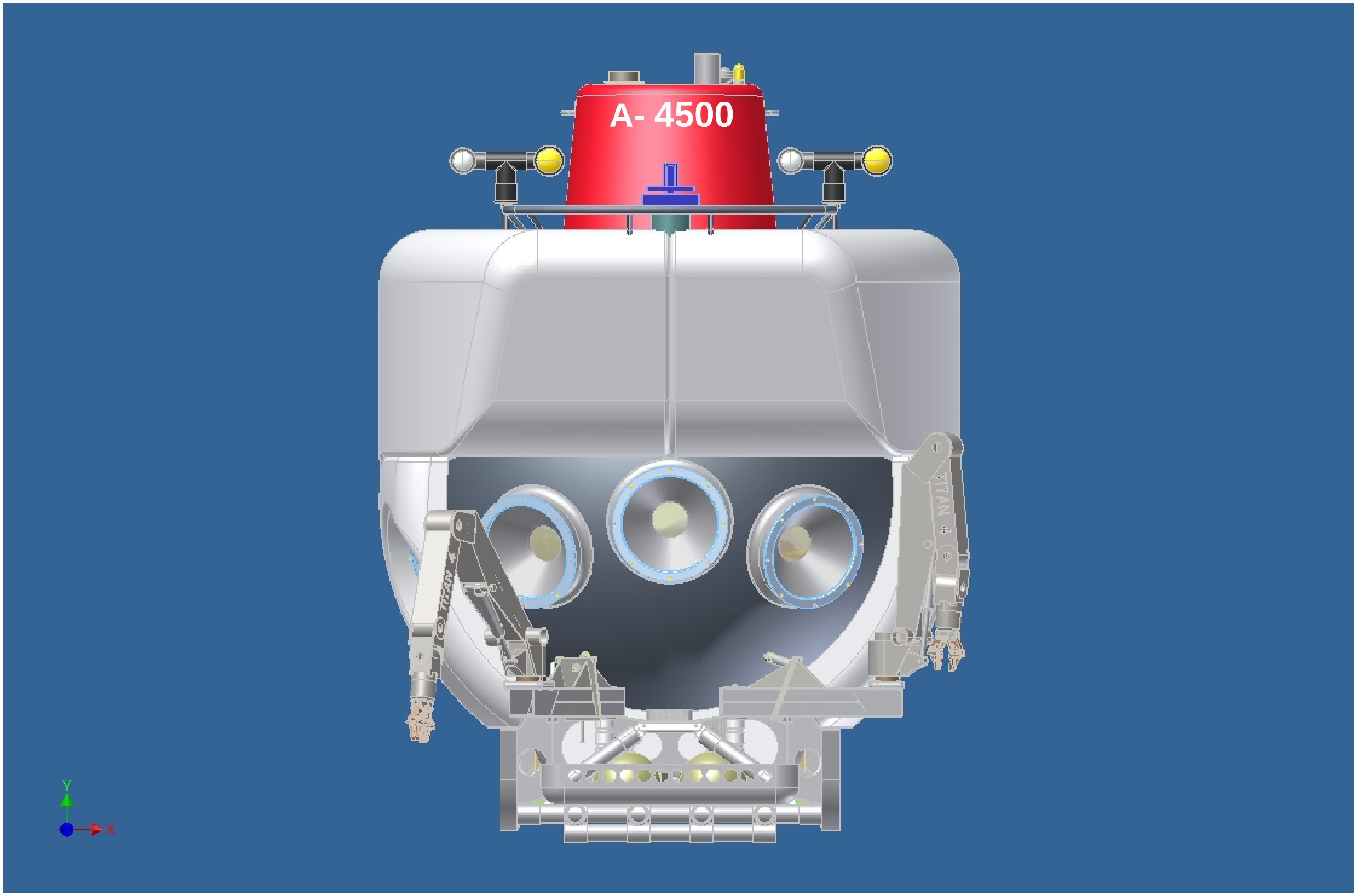
	PREFERRED A-4500 HOV	Imaging Option 5: Still Image Mosaic Processing Tools	Imaging Option 6: Addition of New Manipulator Video and Still Cameras and Mosaic Camera	Imaging Option 7: Addition of Software Tools for HD Editing	Variable Ballast Sphere Replacement	Li-ion Batteries	New Motors, Thrusters and Lateral Thruster	Upgrade of Remaining 6500m Components	6500 m HOV
Associated Tasks		Add Still Image Mosaic Processing tools.	New External Video System Interface Bottle Manipulator Video Camera Mosaic Cameras Manipulator Still Camera	Add Non Linear Editing and processing tools for High Definition editing and archiving.	Variable Ballast Sphere Replacement Replacement of approximately 50 cubic feet of midbody foam	Development of PBOF Cell Pressure Testing Program Safety Testing Program Load Testing Program Cell Monitoring System Design	Propulsion System Electrical Design Propulsion System Software interface design Motor controller	ABS charges System Engineering Replacement shrouds skins and fairings New Hydraulic System	-
ROM costs	-	Option 5 $45,875 A-6500 Imaging ROM 10-19-09	Option 6 $911,433 A-6500 Imaging ROM 10-19-09	Option 7 $80,682 A-6500 Imaging ROM 10-19-09	Variable Ballast Spheres $1,502,508 31 Aug 09 cost estimate Associated Midbody foam $384,000 31 Aug 09 cost estimate	Development Costs $672,000 Yuasa 14 Nov 08 quote Procurement of 250 cells @ $14,000 each $3,500,000 Yuasa 14 Nov 08 quote	Propulsion redesign $58,610 31 Aug 09 cost estimate Motor control pressure vessels $172,900 31 Aug 09 cost	ABS $50,000 Estimated Skins $104,000 31 Aug 09 cost estimate Hydraulic system $66,000 31 Aug 09 cost estimate	-
Upscope Cost Subtotals with 10% PM costs added	**-**	**$50,463**	**$1,002,576**	**$88,750**	**$2,075,159**	**$4,699,200**	**$255,135**	**$506,000**	**$8,677,283**
Total Material and Labor Cost (Cumulative Totals)	**$35,174,894**	**$35,225,357**	**$36,227,933**	**$36,316,683**	**$38,391,842**	**$43,091,042**	**$43,346,177**	**$43,852,177**	**$43,852,177**

Escalation	**$1,879,958**
Contingency (95% Level of Confidence)	**N/A**
Total	**$45,732,135**

Subtotals Are For FY2009 dollars
Escalation is estimated at 4%/year
Confidence Level estimated for preferred A-4500 HOV only

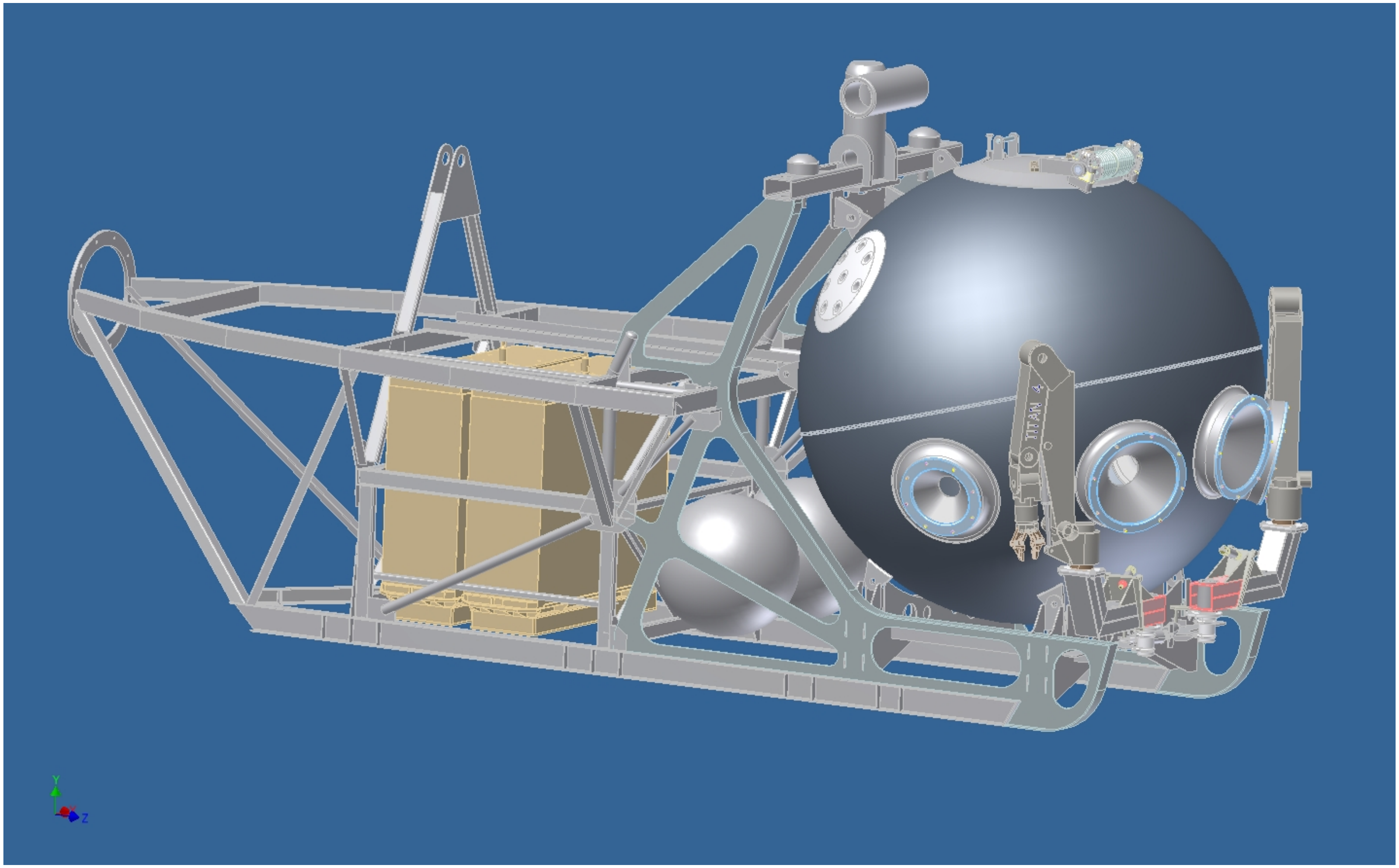
	PREFFERED A-4500 HOV	Imaging Option 5: Still Image Mosaic Processing Tools	Imaging Option 6: Addition of New Manipulator Video and Still Cameras and Mosaic Camera	Imaging Option 7: Addition of Software Tools for HD Editing	Variable Ballast Sphere Replacement	Li-ion Batteries	New Motors, Thrusters and Lateral Thruster	Upgrade of Remaining 6500m Components	A-6500 HOV
Larger personnel sphere with improved interior ergonomics	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Increased Field of View for pilot's and observers	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Improved illumination	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Improved imaging systems	🟡	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Improved data collection, logging, and interface capability	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Improved interior electronics	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Automatic position keeping	🟡	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟢
Increased thruster horsepower and better maneuverability	🟡	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟢
Enhanced mid-water research capability	🟡	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟢
Increased science payloads	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟢	🟢
Increased battery capacity	🔴	🔴	🔴	🔴	🔴	🟢	🟢	🟢	🟢
Increased on-bottom time	🔴	🔴	🔴	🔴	🔴	🟢	🟢	🟢	🟢
Increased hydraulic plant capacity (improved manipulator performance)	🔴	🔴	🔴	🔴	🔴	🟡	🟢	🟢	🟢
Increased operating Depth to 6500 meters	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🟢	🟢
Upscope Cost Impact	-	**$50,463**	**$1,002,576**	**$88,750**	**$2,075,159**	**$4,699,200**	**$255,135**	**$506,000**	**$8,677,283**

A-4500 HOV
Front View



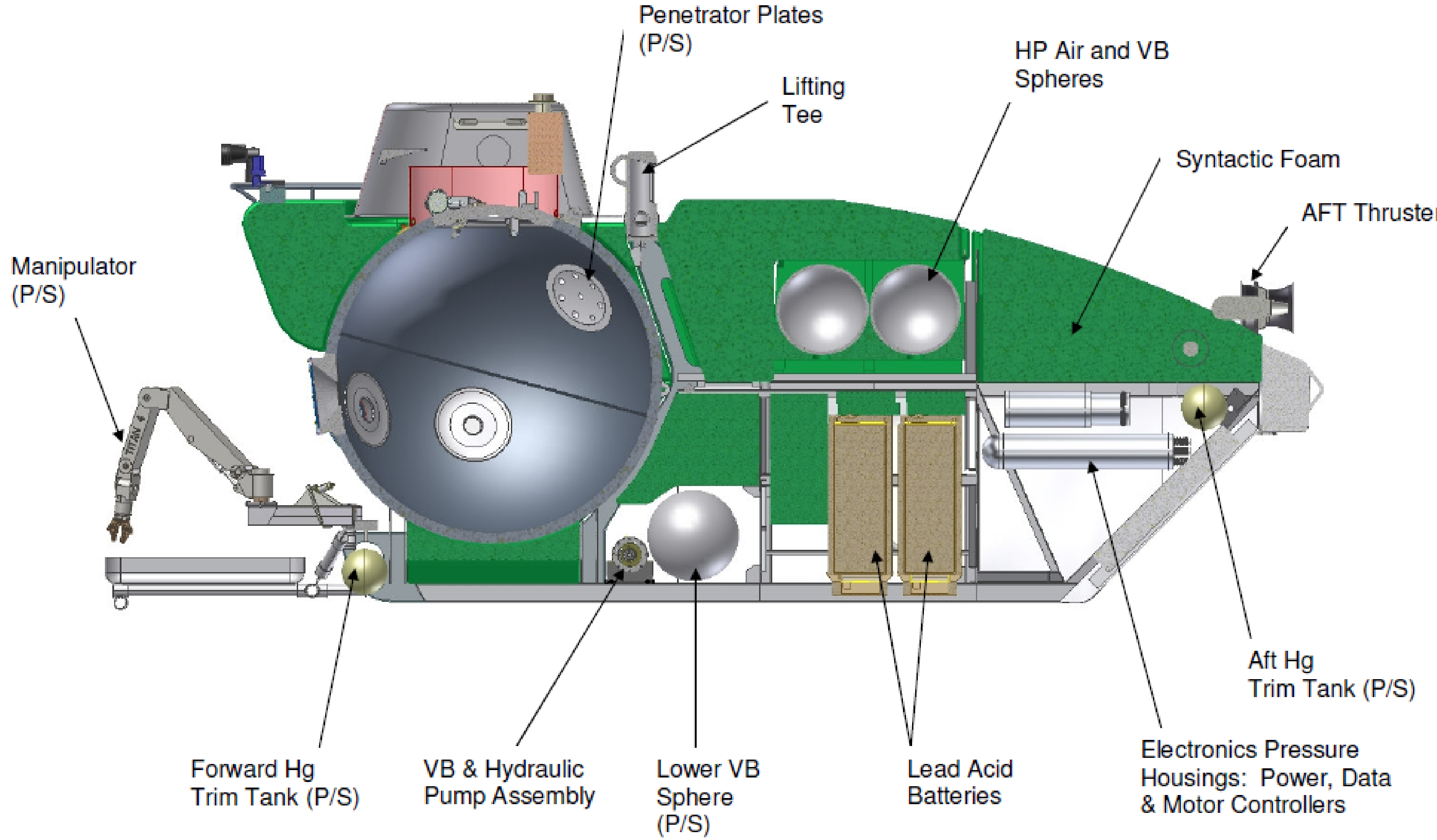
A-4500 HOV

Proposed Frame Modifications



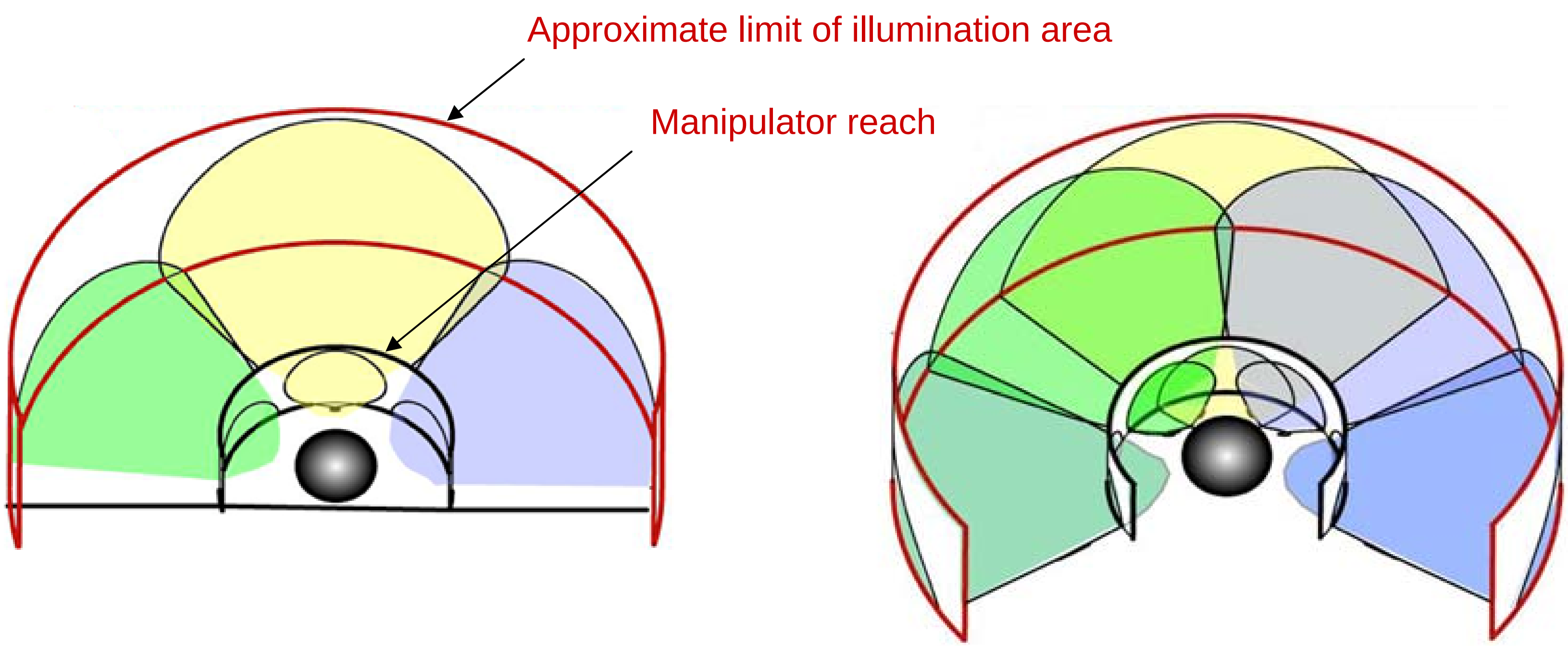
A-4500 HOV

Arrangement Concept



A-4500 HOV

Viewport Field of View Comparison



Current *Alvin*

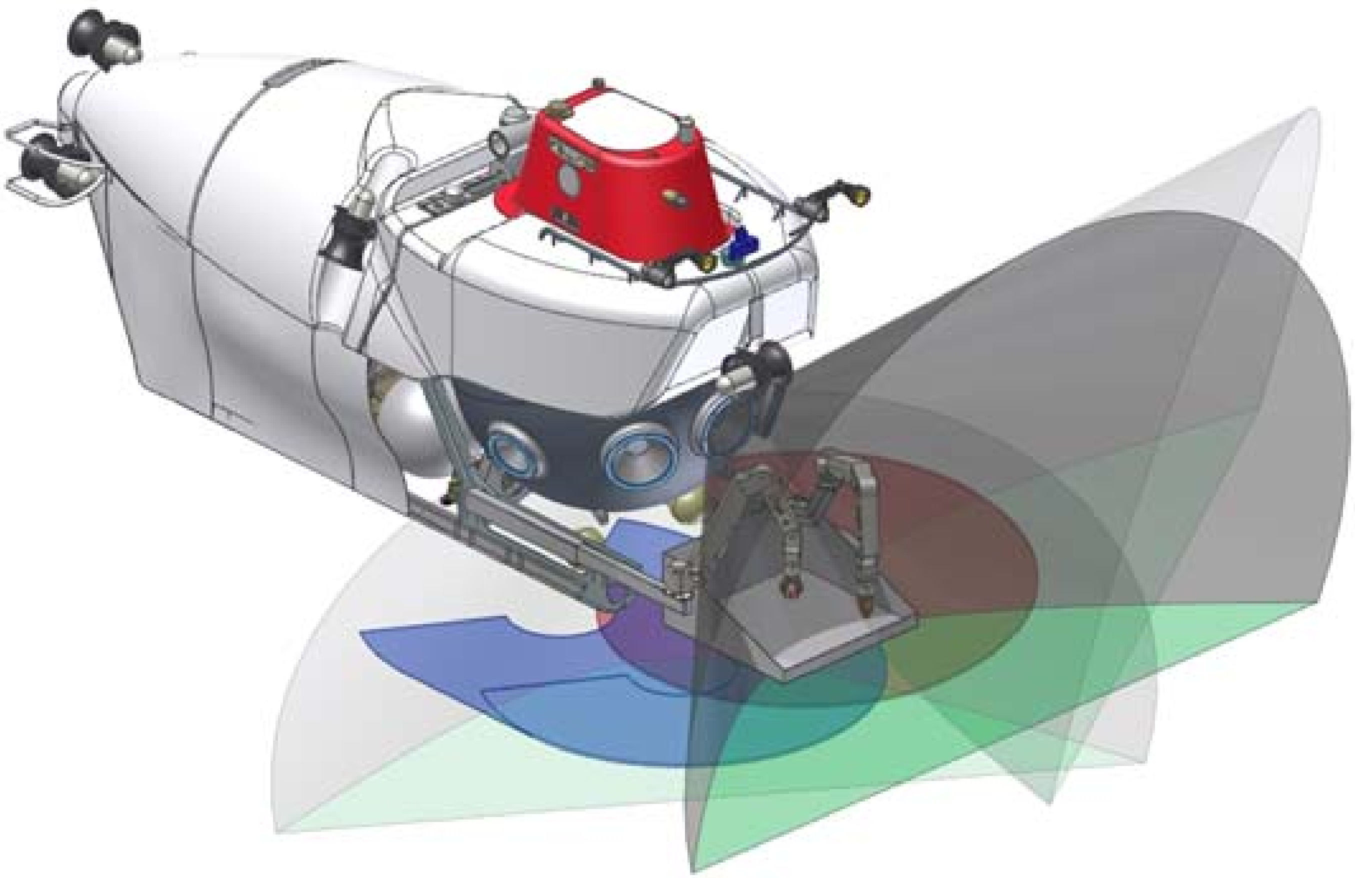
180° field of view

A-6500

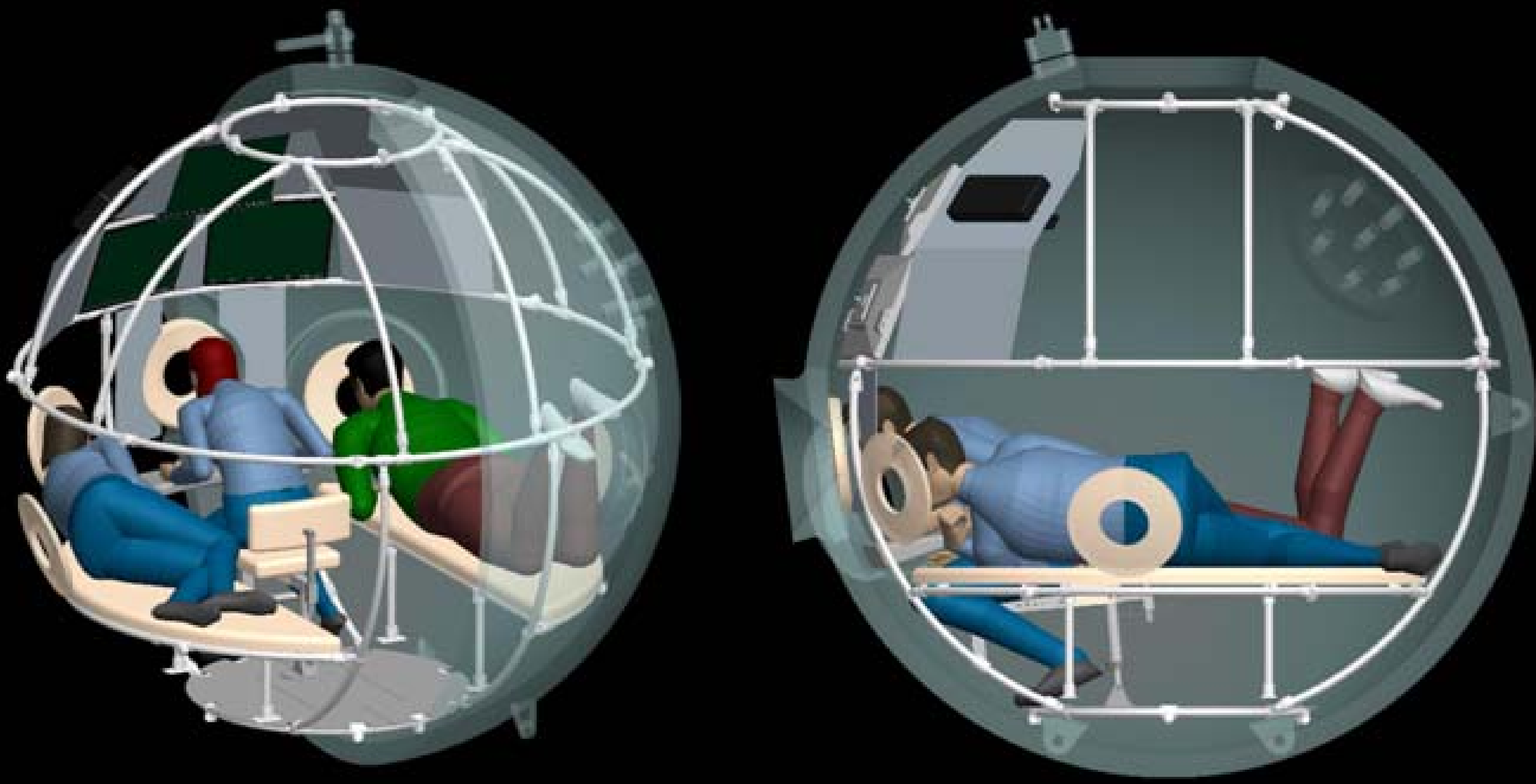
245° field of view

A-4500 HOV

Arrangement Concept

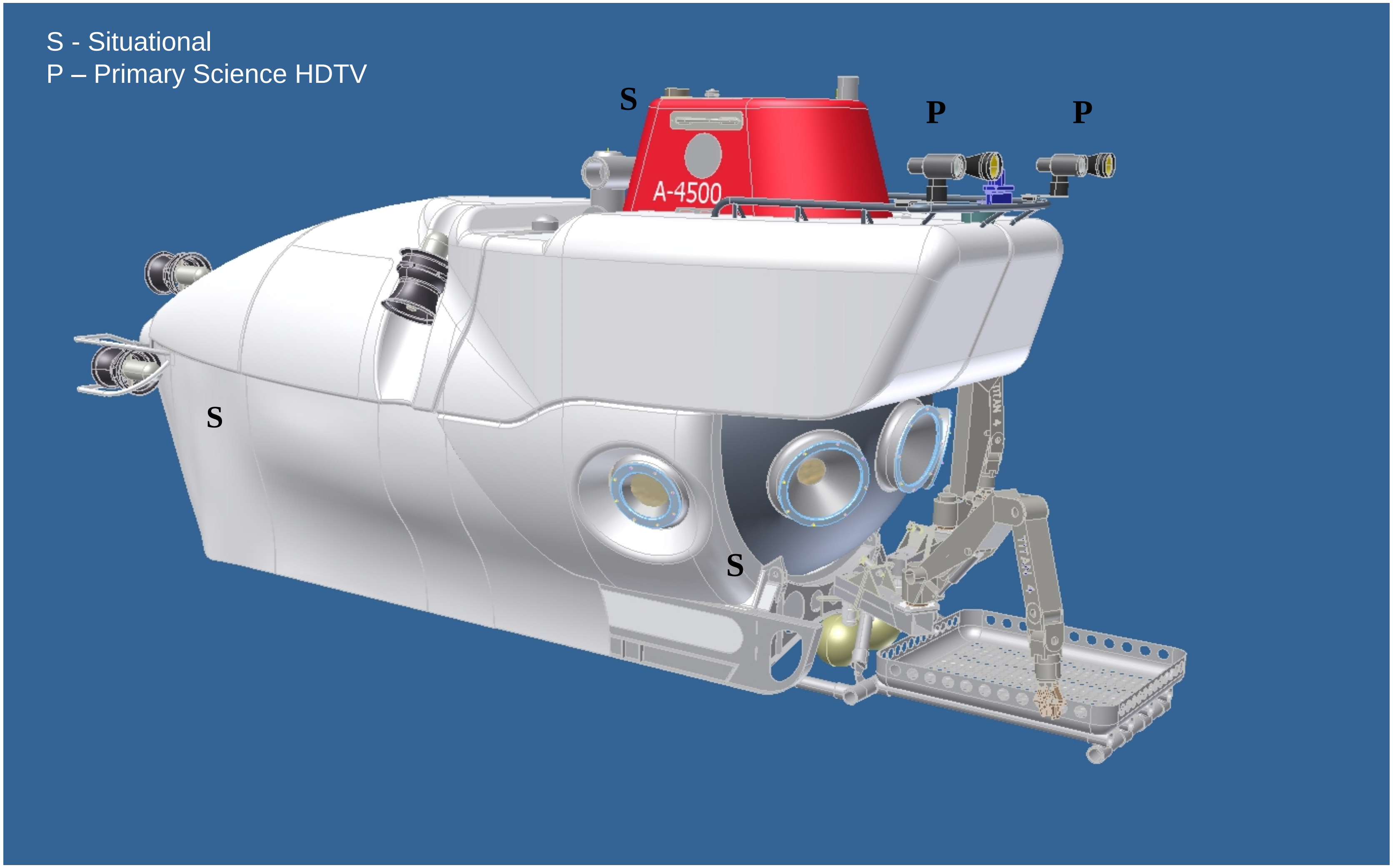


A-4500 HOV
Internal Arrangement Study



A-4500 HOV

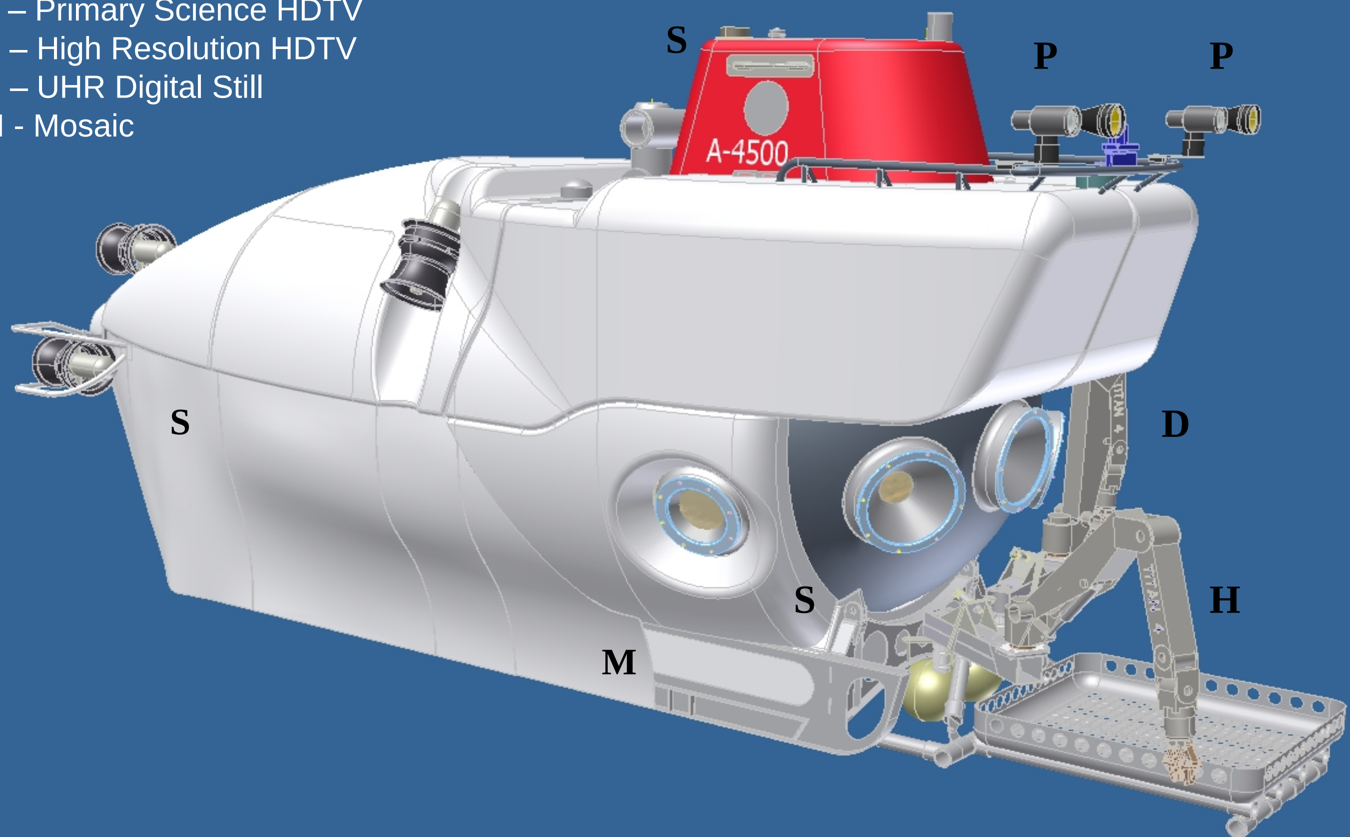
Imaging Camera Types & Locations



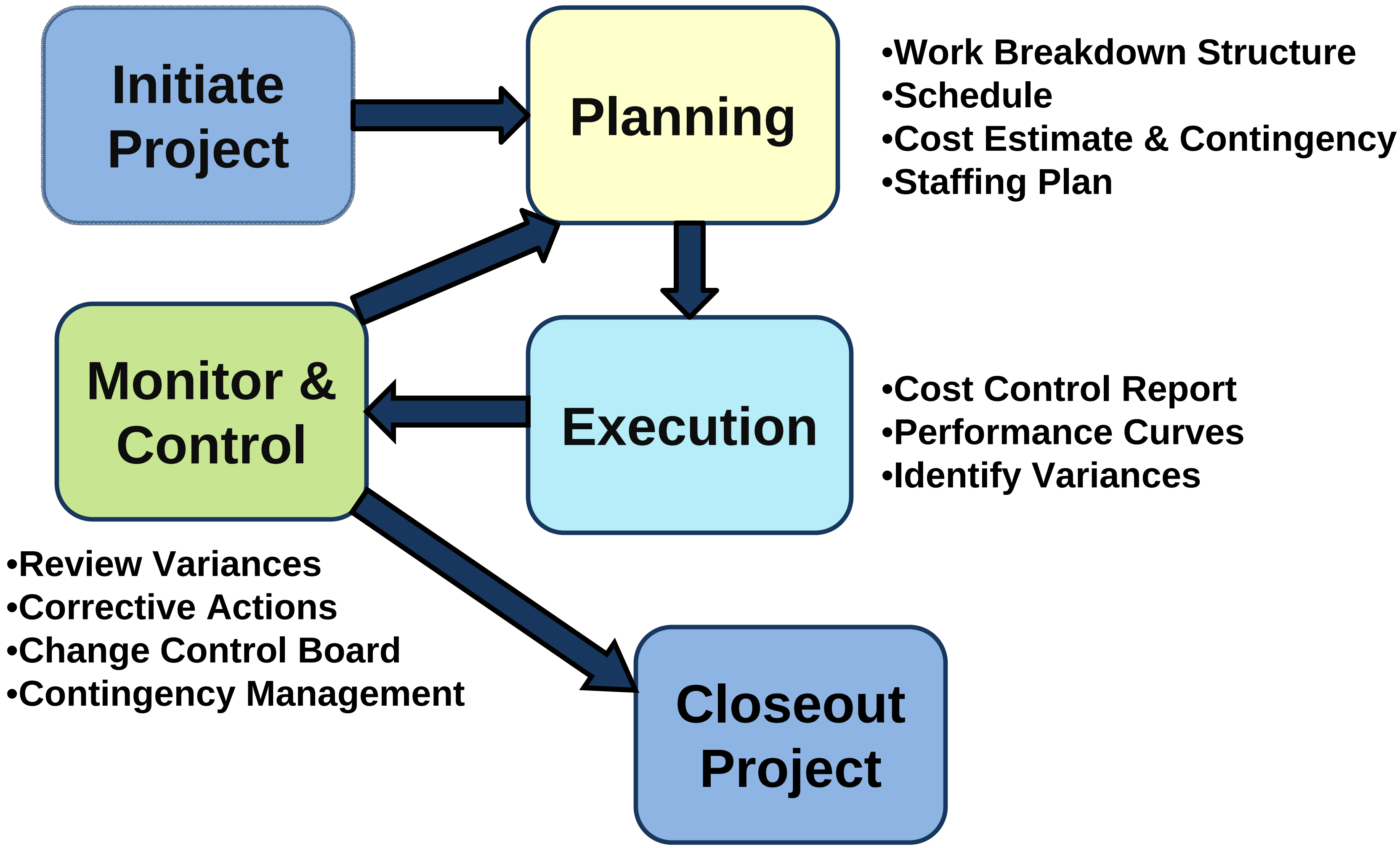
A-4500 HOV

Imaging Camera Types & Locations

S - Situational
P – Primary Science HDTV
H – High Resolution HDTV
D – UHR Digital Still
M - Mosaic



A-4500 HOV
Tools for Project Management

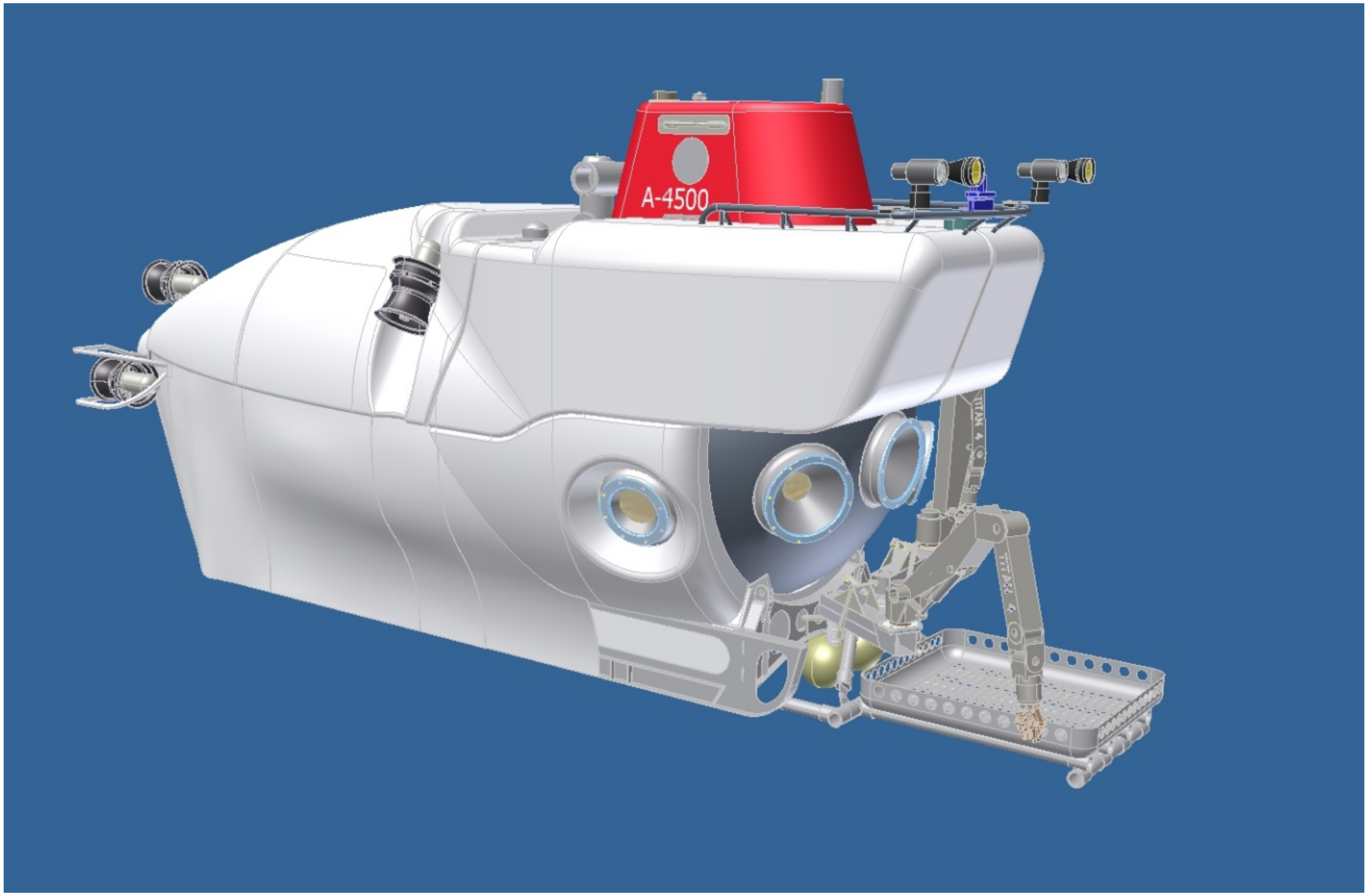


A-4500 HOV
Construction and Testing

A - 4500 HOV Timeline

Start Project 2011									
TASKS	Sub System Procure & Fab	April	May	June	July	August	Sept	October	Nov
Pre-Construction Fabrication									
De-Mobilization and Disassembly (Approx. 3 Weeks)									
Refurbishment & New Construction (Approx. 10 Weeks)									
Vehicle Assembly (Approx. 10 Weeks)									
High Bay Test Program and Ship Re-Mobilization (Approx. 3 Weeks)									
Sea Trials (Approx. 4 Weeks)									
Science Trials (Approx. 4 Weeks)									

A-4500 HOV
Science "Proving" Cruise



Rationale

- Classification of the RHOV or completion of any new vehicle’s engineering trials is NOT the same as having a vehicle ready for science operations.

- See recent experiences with *Sentry* and *Nereus*

Recommendation

To seek support from NSF for a Science "Proving" Cruise that will:-

- demonstrate the readiness of the new vehicle
- attract new users to take advantage of the asset

(Builds on a model used in UK for delivery of *Isis* ROV)

Constraints

- Range of capabilities that need to be “proven”
- Geographic limitations to what is practical
- Science must be sufficiently compelling to pass NSF peer-review

Required scientific capabilities

- Direct **observations** of the deep ocean and seafloor
- High-resolution **imaging**/documentation of observations
- Systematic **exploration** of new, uninvestigated regions
- Systematic **surveys** of seabed and overlying water column
- **Sampling** at the seafloor and in the overlying water column
- **Interaction with instrumentation** at the seafloor
- **Descent**, **transit** between work areas & **ascent**

Science capabilities to be tested
(1 of 3: Simplest First!)

- Dive to 4500m, check fields of view, cameras, data-streams
- Map flat seafloor without artifacts to prove correct set-up
- Simple use of manipulators – e.g. push core?
- Test transiting capability (speed, energy consumption)

Science capabilities to be tested
(2 of 3: Increasing complexity)

- Find something suitably photogenic to "prove" new cameras
- Find interesting/complex terrain to map with Reson system
- Photo-mosaic? (*esp*. for new auto-XY command & control)

Science capabilities to be tested

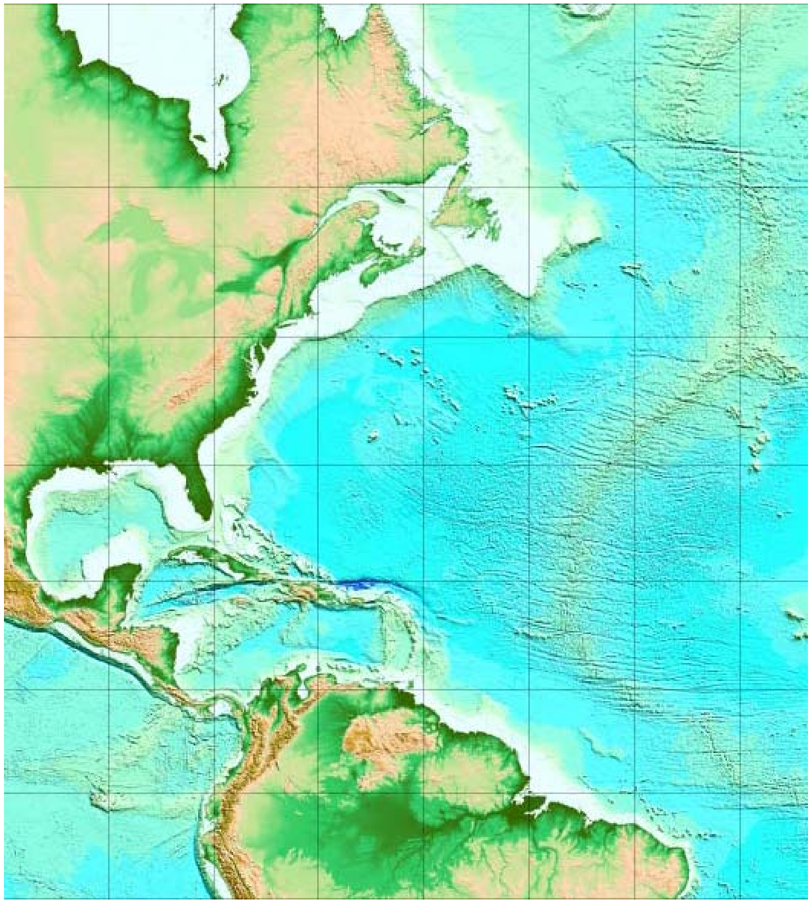
(3 of 3: Most Challenging)

- Conduct detailed & delicate manipulations in and around a spatially complex setting (e.g. vent, seep, coral site?)
- Make use of user-provided as well as NDSF tools
- Use both "free-standing" & "interfaced-to-RHOV" user tools

Geographic Limitations

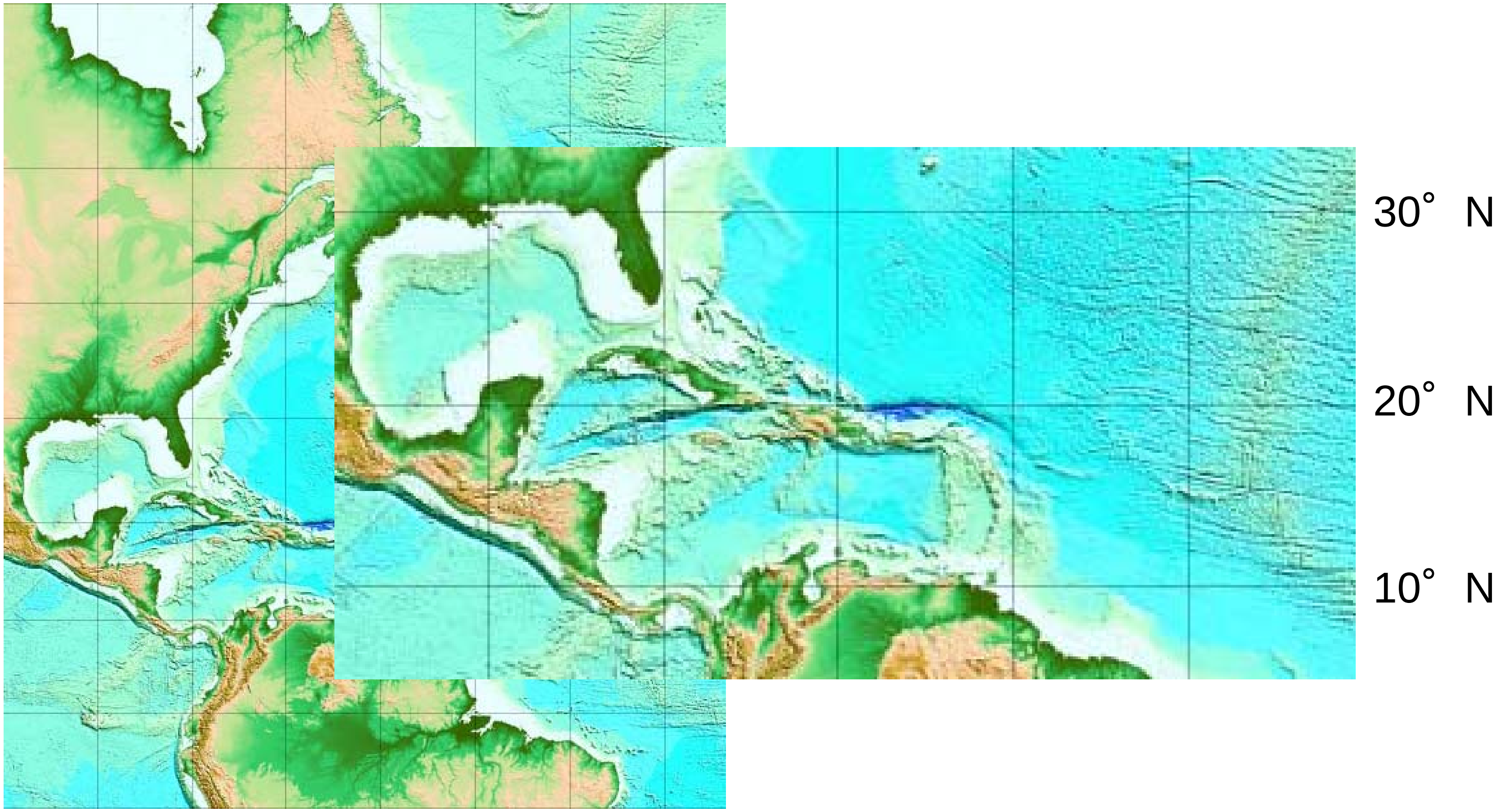
- Needs to be close enough to Woods Hole to return to port post-cruise for any major fixes (East of Panama Canal, at a minimum)
- Should be close to a convenient port to enable this cruise to follow ABS Classification off Bermuda
- Needs to be in a region that is feasible for scheduling at *any* time of year – e.g., Nov 2011 (South of Bermuda, at a minimum?)

Geographic Limitations



A-4500 HOV
Science “Proving” Cruise

Geographic Limitations



Moving Forward

- Scientific Volunteers (and ideas) needed & openly solicited
- Timeline: Early 2010 submission to be ready for Nov 2011
- PI(s): to be determined based on interest, ideas
- Coordination – CSDS (cgerman@whoi.edu) ready to do any "heavy lifting" required to make sure *something* goes ahead.

A-4500 HOV