# Replacement Human Occupied Vehicle Project Summary

## 9-10 June 2008
## Woods Hole, MA

# RHOV Technical Status

# Sphere Fabrication

RHOC
June 2008

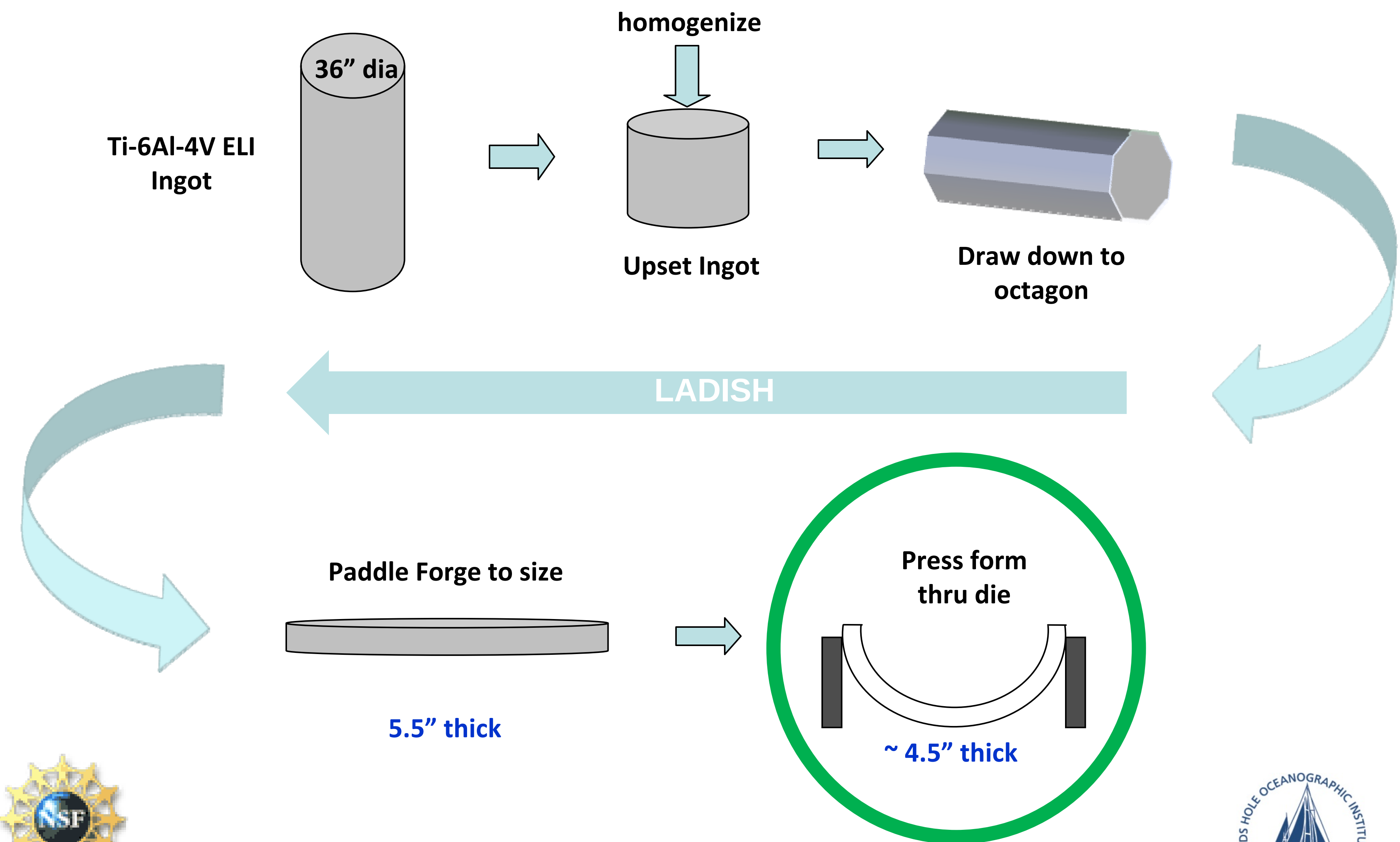
# Sphere Status



- Ladish successfully formed both hemisphere disks
- Hemi forgings will proceed in parallel *vs* series
- Sphere insert forging process has begun
- Stadco preparing to build welding/machining fixture
- EB preliminary weld procedure has been successfully tested, and scheduled for ABS approval in June
- No delays expected with GTAW and Stud weld procedures
- Reviewing Buckling Analysis
- Sphere completion scheduled for mid-July 2010

# Workflow Diagram





# Risks – Personnel Sphere

- 130” Disc Forming
  - ~~Buckling of billet~~
  - ~~Over thinning of disc during paddling~~
- Hemisphere Forming
  - Over thinning of hemisphere dome
- Electron Beam (EB) Welding
  - Girth weld is thicker longer duration than normal
- Post Weld Stress Relief
  - Possible deformity of sphere resulting in de-rating

# Personnel Sphere Fabrication Schedule

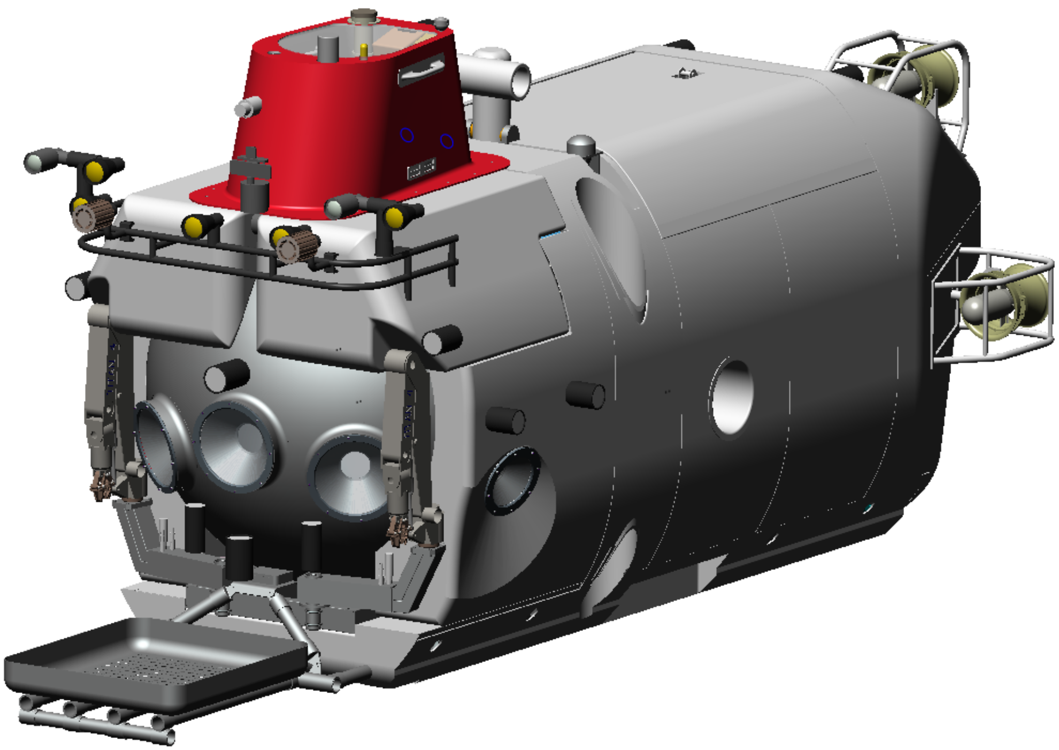


| | |
|---|---|
| • Forge Disks into Hemispheres | 6/19/08 |
| • ABS/SwRI Inspection of Hemispheres | 7/08 |
| • Heat Treat Hemispheres (Bodycote) | 8/08 |
| • Rough machine Hemispheres | 9/08-10/08 |
| • Hemisphere Vacuum Anneal (Bodycote) | 12/08 |
| • Hemisphere machining | 12/08-3/09 |
| • Hemisphere Girth weld | 3/09 |
| • Insert Welding | 4/09-10/09 |
| • Post Weld Stress Relief | 12/09 |
| • Final Assembly | 3/10 |
| • Hydro Test | 6/10 |
| • Sphere Complete | 7/10 |

# Video
# RHOV Personnel Sphere
# Forging Update May 2008

# RHOV Vehicle Design Update

RHOC
June 2008



# Project Status



## RHOV Design Effort

Scope scaled back to include only systems that overlapped with *Alvin* upgrade concept development.

- Key Vendor Visits
  - Penetrator
  - Foam
  - Battery
- Battery Risk Assessment
  - NSWC Technology Investigation
  - *Shinkai* Evaluation
  - 1 Atmosphere Approach
- I/O Architecture Design
- Hydrodynamic Modeling

# Penetrators



**Teledyne D.G. O'Brien**
Seabrook, NH

- Fiber and copper penetrator development considered low risk
- RHOV double bulkhead penetrator design similar to *Alvin*
- No ABS experience but several MIL-STD-24217 compliant designs
- In-house pressure testing facility rated to 20,000 psi (14,235 psi required for RHOV)

**Testing and Qualification procedure development should begin immediately to reduce risk**

# Syntactic Foam



**Trelleborg Emerson and Cummings, Inc.**
Mansfield, MA

Foam production in Mansfield, MA, facility
Micro-balloon production in Randolph, MA, facility

- RHOV design based on DS-33 foam
- DS-33 requires modified test procedure for use on RHOV
- 580 cubic feet required to yield the necessary 300 cubic feet
- 18 month lead time

**Testing and Qualification procedure development should begin immediately to reduce risk**

# Battery



**Lithion Inc. (Yardney Technical Products Inc.)**
Pawcatuck, CT

Yardney believes they can meet Pressure Balanced Oil Filled (PBOF) battery specification using 55 Ah cell with steel bellows based on the following experience:

- Several high reliability applications:
  - Orion Crew Exploration Vehicle
  - Advanced Seal Delivery System
  - Mars Lander
- Have Lithium battery cells in service with 38,000 cycles (40% depth of discharge)
- Developed *Sea Cliff* Silver Zinc PBOF battery

However:

- No pressure balanced oil filled Lithium applications
- No ABS experience

**Testing and Qualification procedure development should begin immediately to reduce risk**

# NSWC Brief on Battery Technologies

RHOC
June 2008

John Inman, NSWC Subject Matter Expert (SME), believes that a SAFE Pressure Balanced Oil Filled Lithium Chemistry battery can and will be developed using current technology.

Li Cell Vendors:

- Yardney
- Eagle Picher Kokam
- International Battery

Development:

- Battery monitoring system
- Cell construction and chemistry
- Capacity vs. age
- Storage

Testing:

- Develop test requirements with vendor
- Overcharging testing
- Propagation testing
- Testing and Analysis must lead to a mitigation plan

# NSWC Battery Development Assistance



NSWC is willing to collaborate with WHOI and cell manufacturer in the development of purchase and test specifications

NSWC has solicited a quotation for Design Feasibility and prototype demonstration of PBOF Li cells to include:

- Cell Gassing Volumetric Analysis
- Compensation Method development
- Five prototype cells for testing
- Test Plan development
- WHOI assisted cell testing

# Shinkai PBOF Li Battery



- JAMSTEC switched *Shinkai 6500* battery from Silver Zinc (AgZn) to a GS Yuasa-developed Lithium Cobalt Oxide ($LiCoO_2$) battery in 2004 because of performance, cost, and maintenance issues

- **The *Shinkai 6500* battery does not meet RHOV requirements:**
  - Voltage: 108VDC vs. 240VDC required
  - Charge/Discharge Cycles: 180 vs. 2000
  - Energy: 43.2KwHr vs. 84KwHr

- Yuasa was solicited for RHOV battery quote; their quote was highest and double the next lowest competitor’s

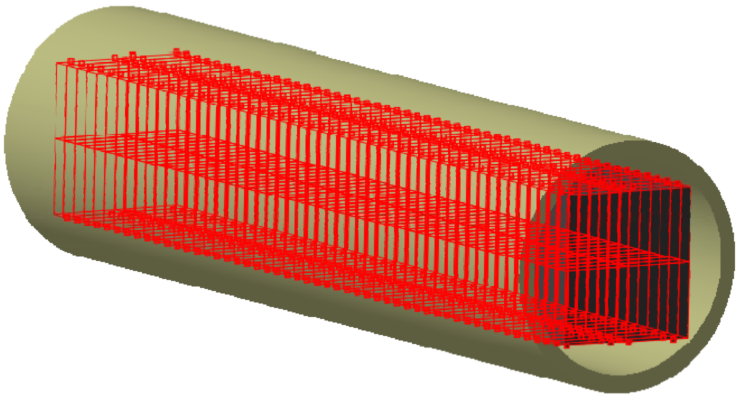
- Extensive NRE costs for new cell qualification, 240 volt configuration, sense electronics development, etc.

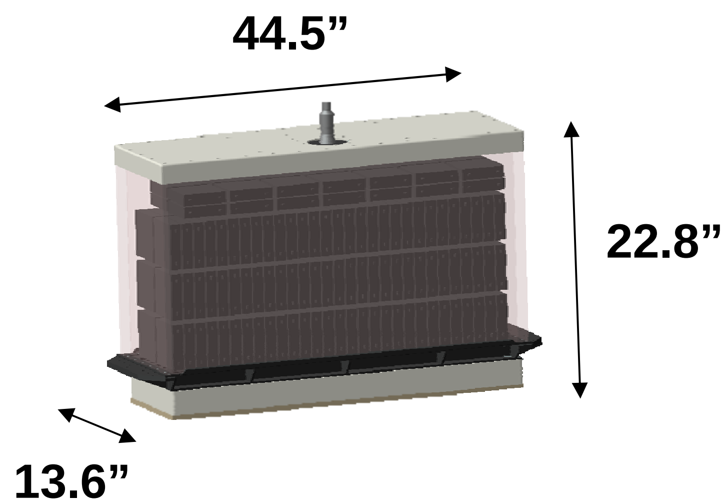
- Lessons learned on the design and implementation for the *Shinkai 6500* can be used to improve performance on the RHOV

# Battery Pressure Housing



A Quick Study conducted on 1 atmosphere battery housings concluded that the option is viable for 4500 meter vehicle, but may present weight problems if designed for 6500 meter depth





# RHOV I/O Architecture Meeting



Reviewed critical system designs applicable to both the RHOV and upgraded *Alvin* vehicle.

- Telemetry System
- Power Switching
- Computer Architecture
- Video System
- High Voltage Selection

WHOI and LM Lead Engineers agreed on way forward

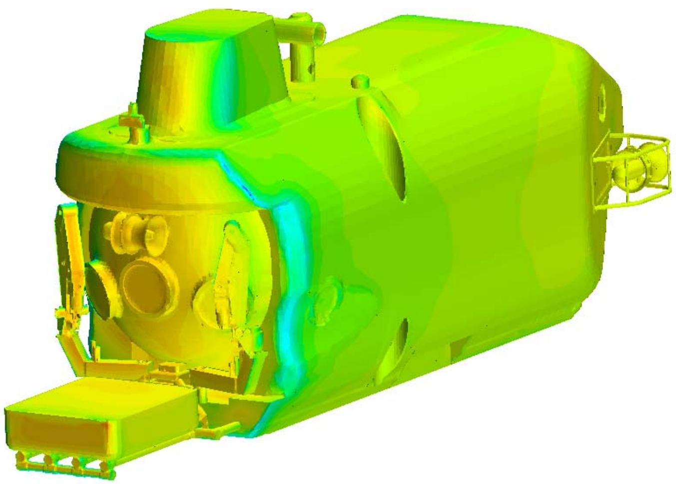
Focus on safety, reliability and maintainability

# Hydrodynamic Analysis

LM completed work on a High Fidelity RHOV model and determined the static drag coefficients for 3 axes

Hydrodynamic analysis required to determine buoyancy, thrust and horsepower requirements:

- Refined analysis method
- Verified RHOV initial analysis
- Confirmed an optimized RHOV shape



Case 1: Static: Forward @ 2.5 kts±10° Yaw
Static Drag ~ 485.5 lbs
Case 2: Static: Ascent @ 44 m/min, ±10° Roll
Static Drag ~ 530 lbs
Case 3: Static: Descent @ 44 m/min, ±10° Roll
Static Drag ~ 495 lbs

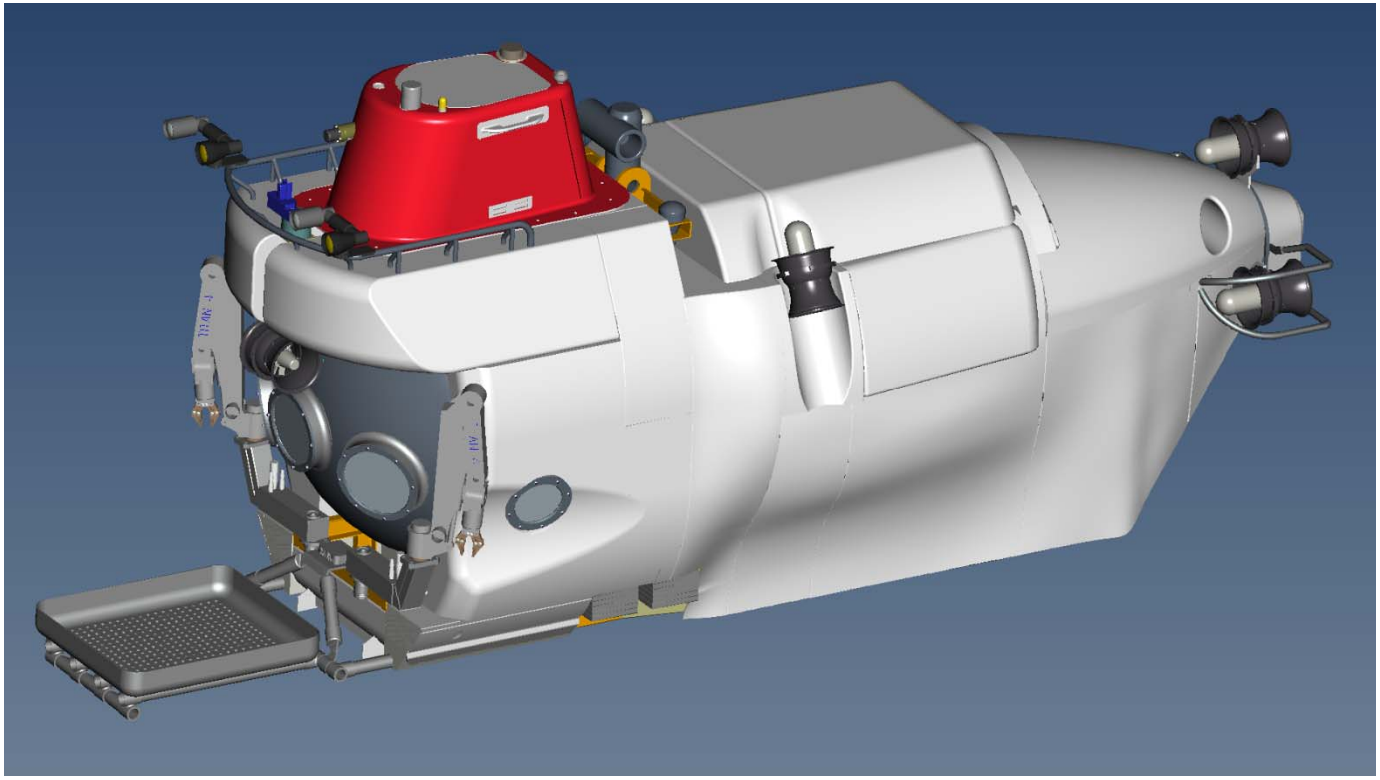
# Hydrodynamic Analysis



| Model | Direction | Drag (lbs) | Margin Included | Comment |
|---|---|---|---|---|
| RHOV-14 | FWD | 780 | 20% | LM – PDR Analysis |
| RHOV-14 | Ascent | 758 | 17.8% | LM – PDR Analysis |
| RHOV-14 | Descent | 732 | 17.8% | LM – PDR Analysis |
| RHOV-18 | FWD | 449.4 | 0% * | LM – Updated Analysis |
| RHOV-18 | FWD | 485.5 | 0% * | CD-adapco Analysis |
| RHOV-18 | Ascent | 530 | 0% * | CD-adapco Analysis |
| RHOV-18 | Descent | 495 | 0% * | CD-adapco Analysis |
| * - Updated margin values have not been determined | | | | |

- Drag for models determined at arbitrary velocity
- Results improved for RHOV-18 design

# *Alvin* Upgrade Option



# Project Goals



Develop concept for *Alvin* Upgrade using the titanium personnel sphere now in production

- Satisfy as many target RHOV design goals as possible
- Keep RHOV improvements
- Leverage RHOV design efforts
- Reduce project costs
- Allow for phased upgrade to full 6500m vehicle over time

# Design Goals for RHOV from NRC Study



## Design Goals

- Increased bottom time
- Increased battery capacity
- Improved fields of view
- Improved interior ergonomics
- Improved interior electronics
- Automatic position keeping
- Reduced seabed disturbance
- Increased science payload
- Increased operating depth

Further information: www.unols.org/committees/dessc/replacement_HOV/replacement_hov.html

# *Alvin* Upgrade Capabilities vs. RHOV Goals



**RHOV Goals Accomplished:**

- ✓ Increased on-bottom time
- ✓ Increased battery capacity
- ✓ Larger personnel sphere; more interior space and improved ergonomics
- ✓ Improved field of view for pilots and observers
- ✓ Improved interior electronics
- ✓ Automated position keeping
- ✓ Sampling basket load limits significantly increased
- ✓ Improved lighting and video systems
- ✓ Increased hydraulic plant capacity (improved manipulator performance)
- ✓ Increased thruster horsepower (better maneuverability)
- ✓ Improved mid-water research capability

# *Alvin* Upgrade Capabilities vs. RHOV Goals



**RHOV Goals Not Accomplished:**

X Increased operating depth to 6500m

X Reduced seabed disturbance (will continue to rely on drop weights for ascent/decent)

X Multi-purpose, large capacity seawater ballast system (for trim, variable ballast, ascent/descent)

X Elimination of mercury trim system

**Enhancements still feasible with upgraded *Alvin*:**

✓ Could upgrade later to operating depth to 6500m

✓ Could upgrade later with enhanced 3-D HiDef imaging system; microfiber cable for high bandwidth, two-way comms to surface

# Project Evolution



- Concept Development
- General Arrangement
- Weight and Trim
- Hydrodynamic Analysis
- Structural Analysis

# Concept Development



- Revised System Operations Requirements
- Revised Vehicle Design Fabrication Specification
- Made Assumptions
- Developed Task List
- Assigned Responsibilities

# General Arrangement



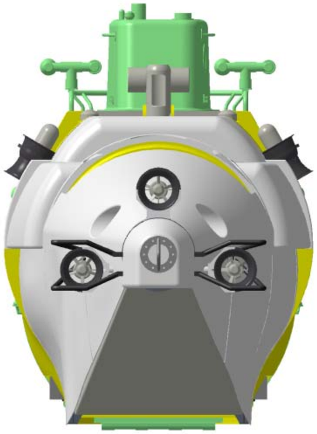
- Generate complete model of *Alvin* frame
- Fuse RHOV frame to *Alvin* frame
- Model reusable *Alvin* components
- Generate new component concept models
- Identify RHOV components

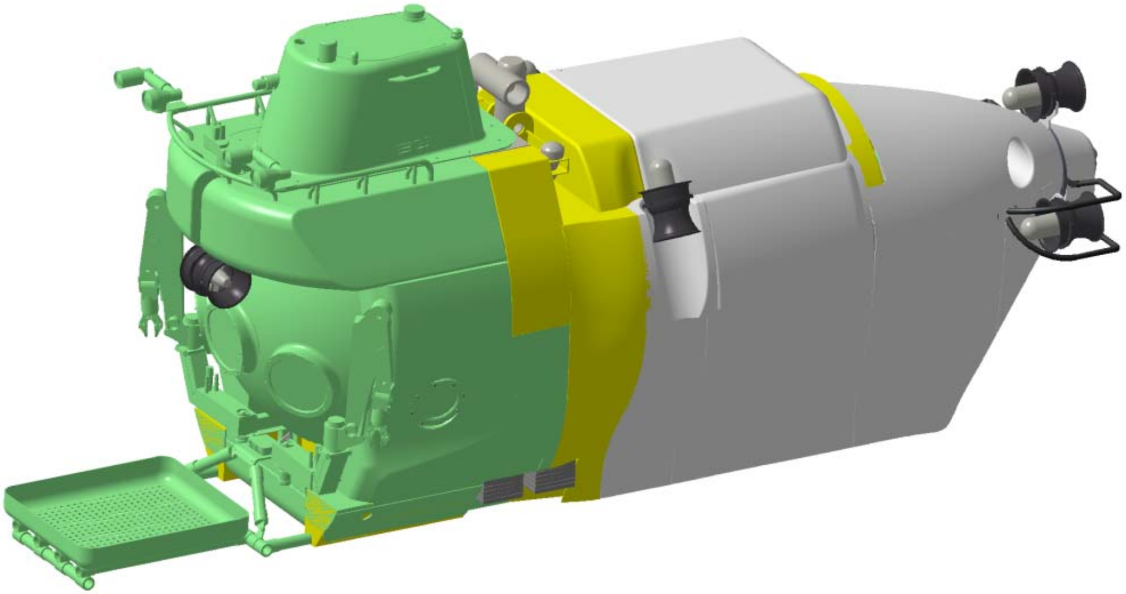
# Hydrodynamic Shape



**Color codes:**

| | |
|---|---|
| **RHOV** | **Green** |
| **New** | **Yellow** |
| ***Alvin*** | **Grays** |





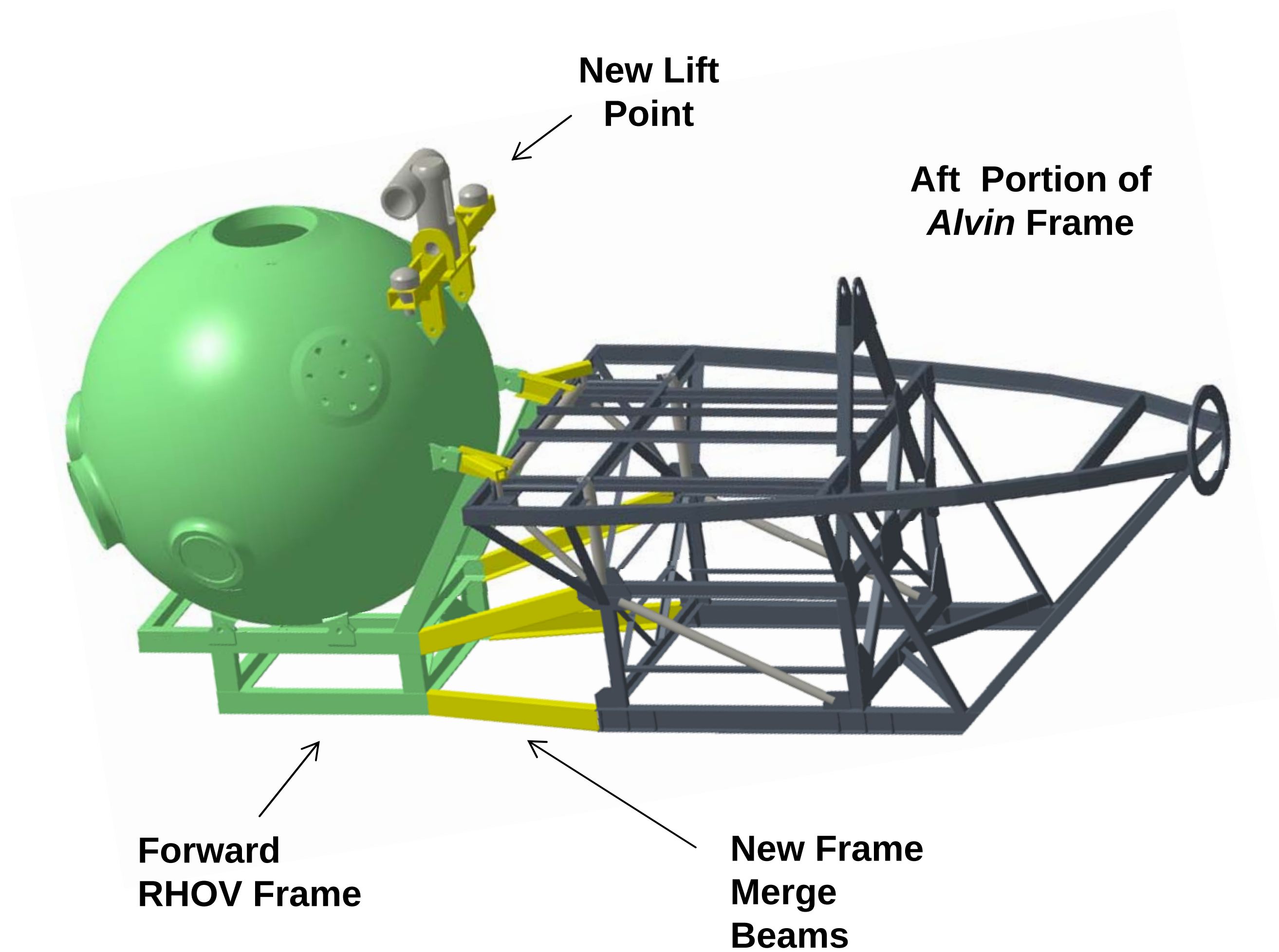
# *Alvin* Recyclables



- Frame (Partial)
- Foam (50%)
- Thrusters
- VB pump, valves, and hydraulics
- High Pressure Air system
- Hydraulic Power Unit
- Motor Controller Cans (2)
- Aft Skins
- Aft Main Ballast Tank

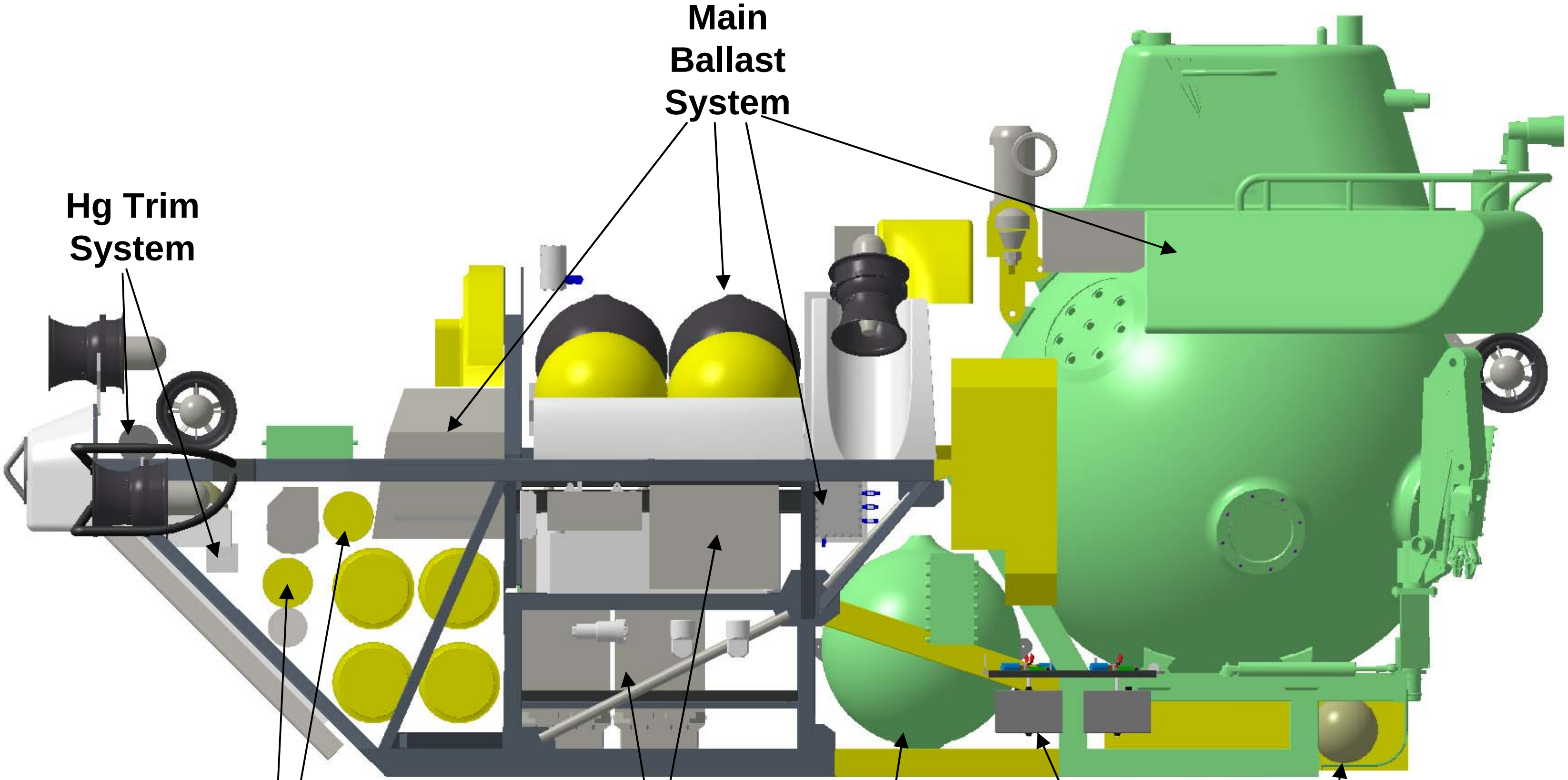
# Frame Modifications





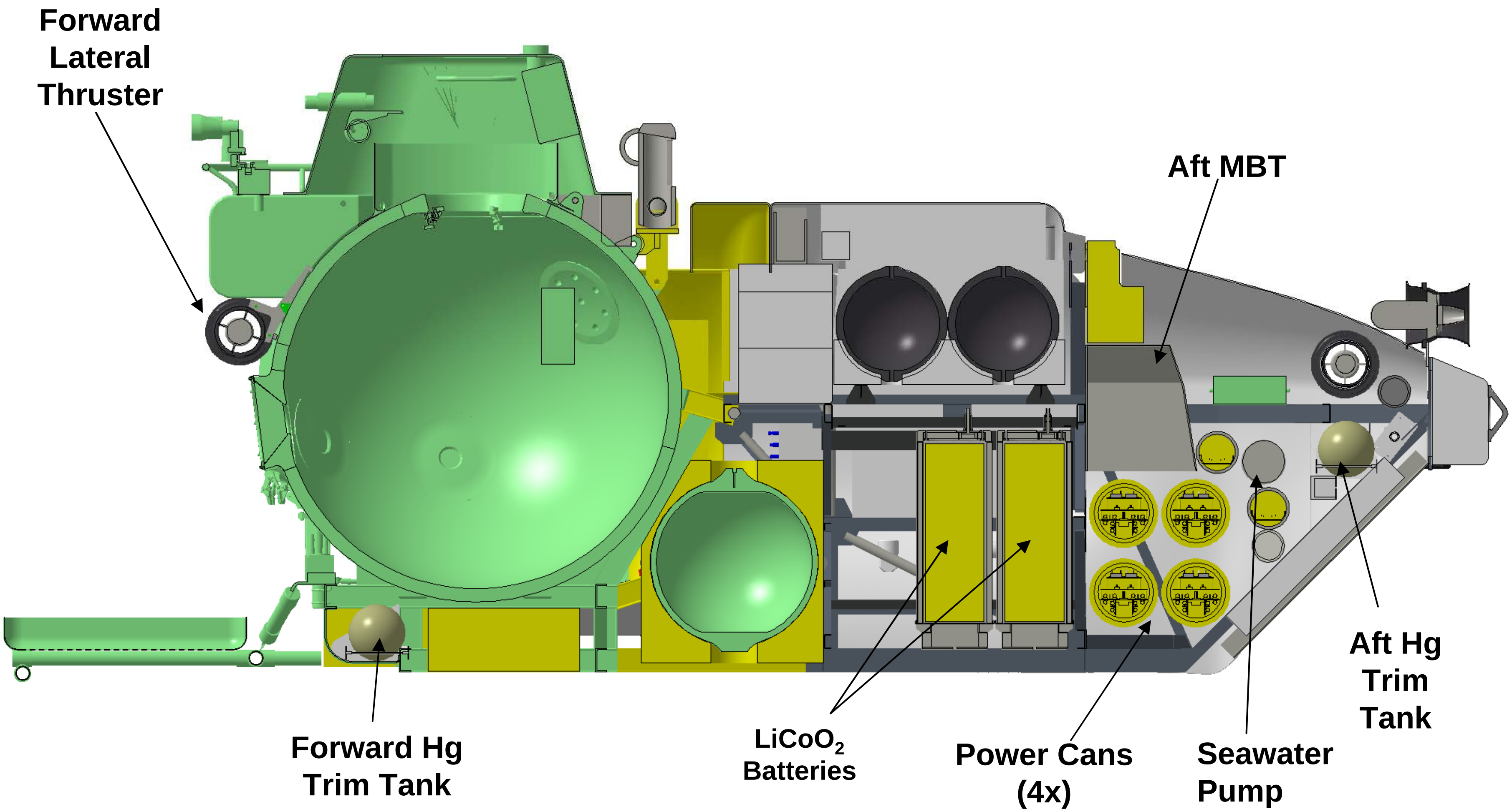
# Starboard Side





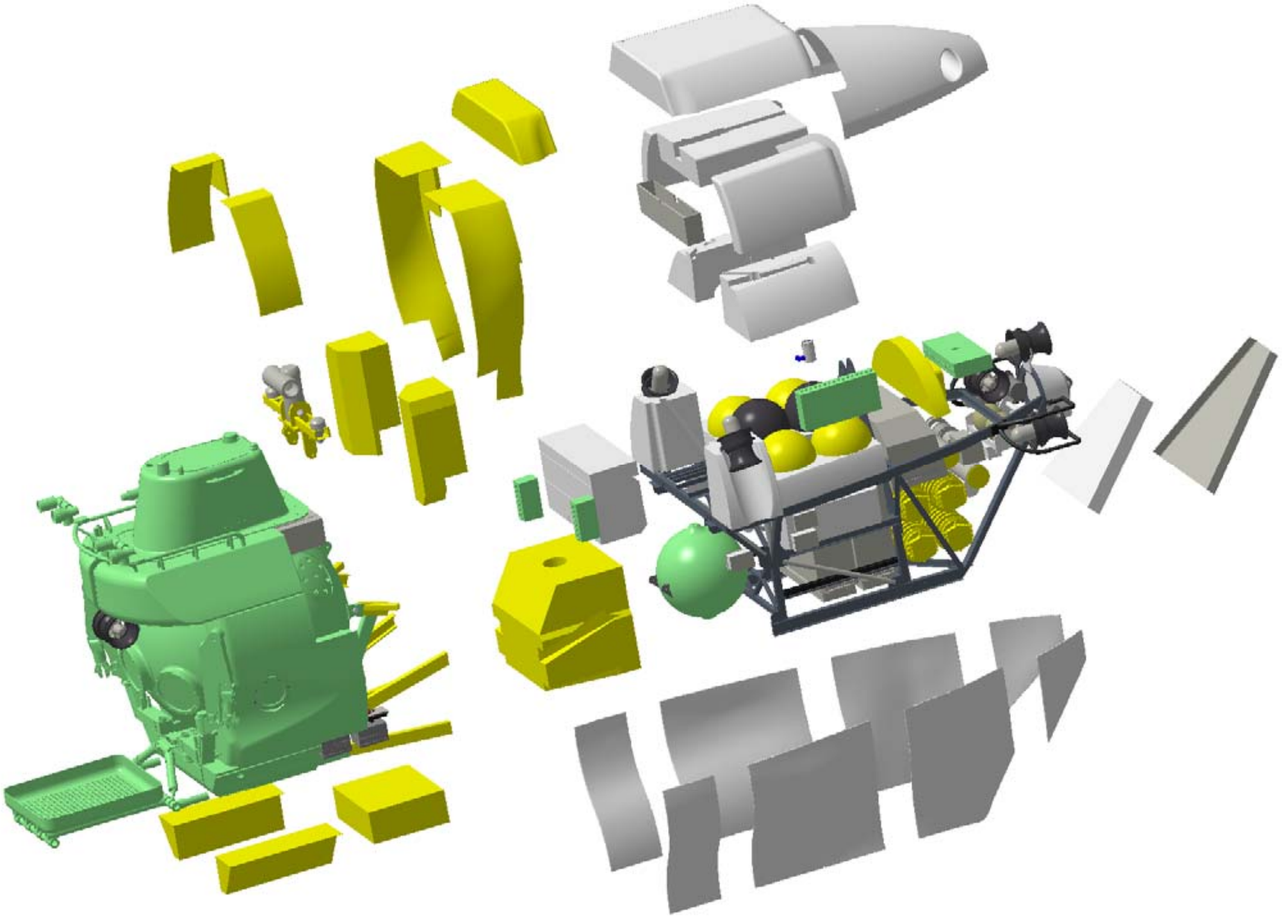

# Cross Section





# Exploded View





# Weight and Trim Snapshot



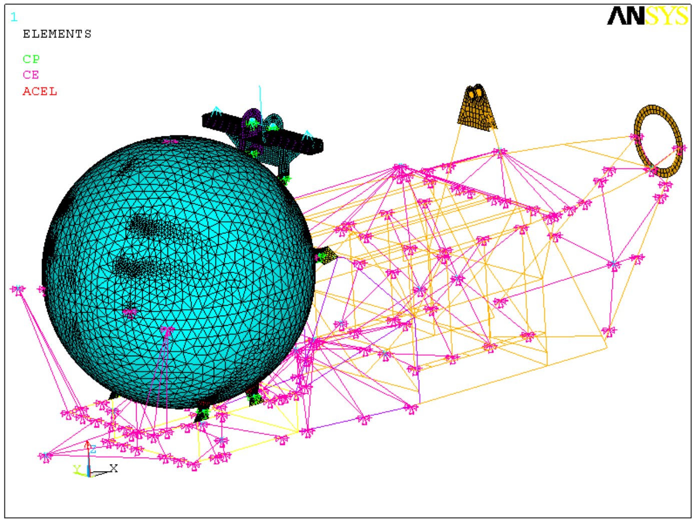
| *240V $LiCoO_2$ Launch* | |
|---|---|
| *Hook LCG* | *81.00”* |
| *Hook Wt (L)* | *37313 #* |
| *Hook Angle (L)* | *+6.48º/+3.74º* |
| *Descent WW* | *-551 #* |
| *Trim w/o Payload* | *+29.57º/-18.80º* |

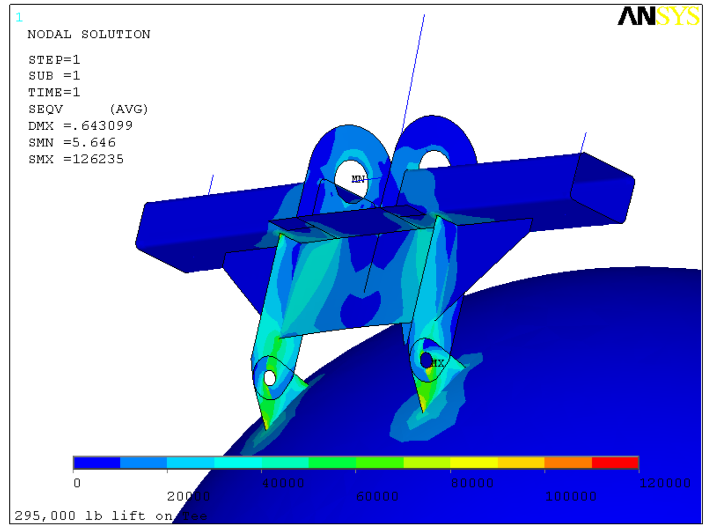
| *240V $LiCoO_2$ Recovery* | |
|---|---|
| *Trim w/ Payload* | *+9.48º/-33.95º* |
| *Ascent WW* | *+433 #* |
| *Hook Wt (R)* | *36313 #* |
| *Hook Angle (R)* | *+5.94º/+3.09º* |

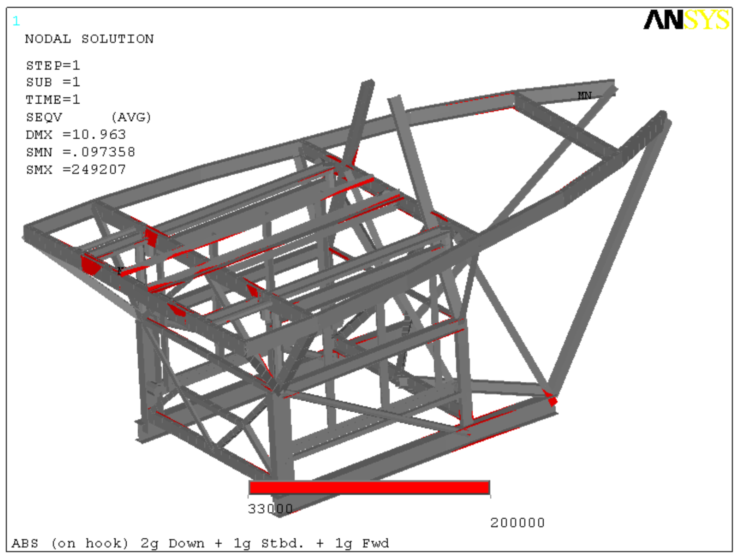
- Vehicle air weight 38,000 pounds
- Worst case trim range of +9/-18 degrees

# Structural Analysis





# Performance Specifications



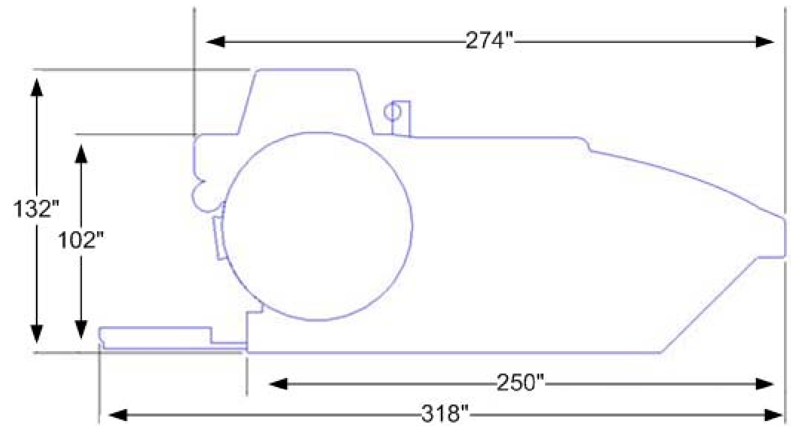
| | *ALVIN* | *ALVIN* Upgrade |
|---|---|---|
| **Max Depth** | 4,500M | 4,500M |
| **Hook Weight** | 36,000 lbs | 37,313 lbs |
| **Ascent/Descent Method (2500M)** | Steel Drop Weights | Steel Drop Weights |
| **Descent Time (2500M)** | 1.5 hrs | 1.3 hrs |
| **Ascent Time (2500M)** | 1.5 hrs | 1.2 hrs |
| **Bottom Time (2500M)** | 5-6 hrs | 7-8 hrs |
| **Pitch Trim System** | Mercury | Mercury |
| **Pitch Trim Angle** | +11/-15 deg | +9.5/-19.0 deg |

# Energy Specifications

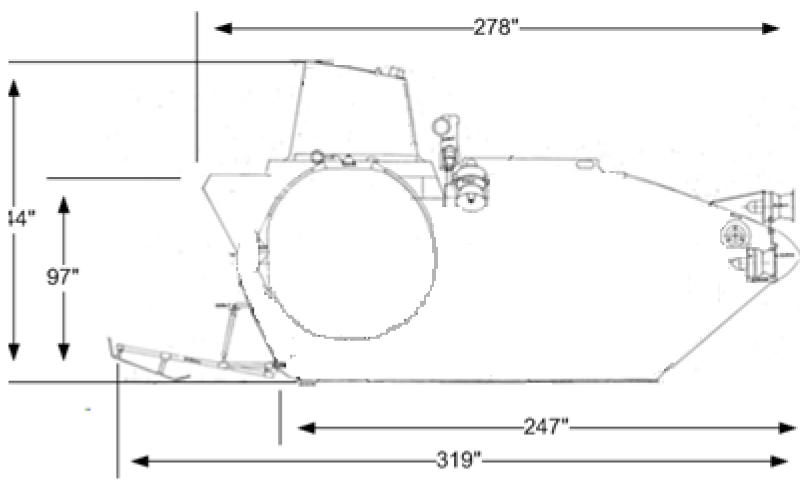


| | *ALVIN* | *ALVIN* Upgrade |
|---|---|---|
| Energy Source | Lead Acid Battery | Lithium Battery |
| Battery Weight | 5,300 lbs | 3,100 lbs |
| Total Useable Energy | 57.6 kWHr | 84kWHr |
| Main Bus Voltage | 120 VDC | 240 VDC |
| Science Payload ( Internal plus External ) | 400 lbs at release | 400 lbs |
| Science Hydraulic Circuits | 6 functions | 6 functions |
| Science Power Available | 1000 Watts (12 & 26 volts) | 800 Watts Interior<br>1,000 Watts Exterior |

# Overall Vehicle Dimensions




**Upgraded**
***Alvin***




***Alvin***

# Technical Risks



**New Risks**

- NSF Approval to Re-scope project
- ABS Certification Issues
  - Frame
  - Pressure Vessels
- Schedule Delays
- Management/Engineering Resources

**Avoided Risks**

- Foam
- Variable Ballast System
- A-Frame Capacity Issues