# R/V Falkor Full Ocean Depth HROV Progress Report

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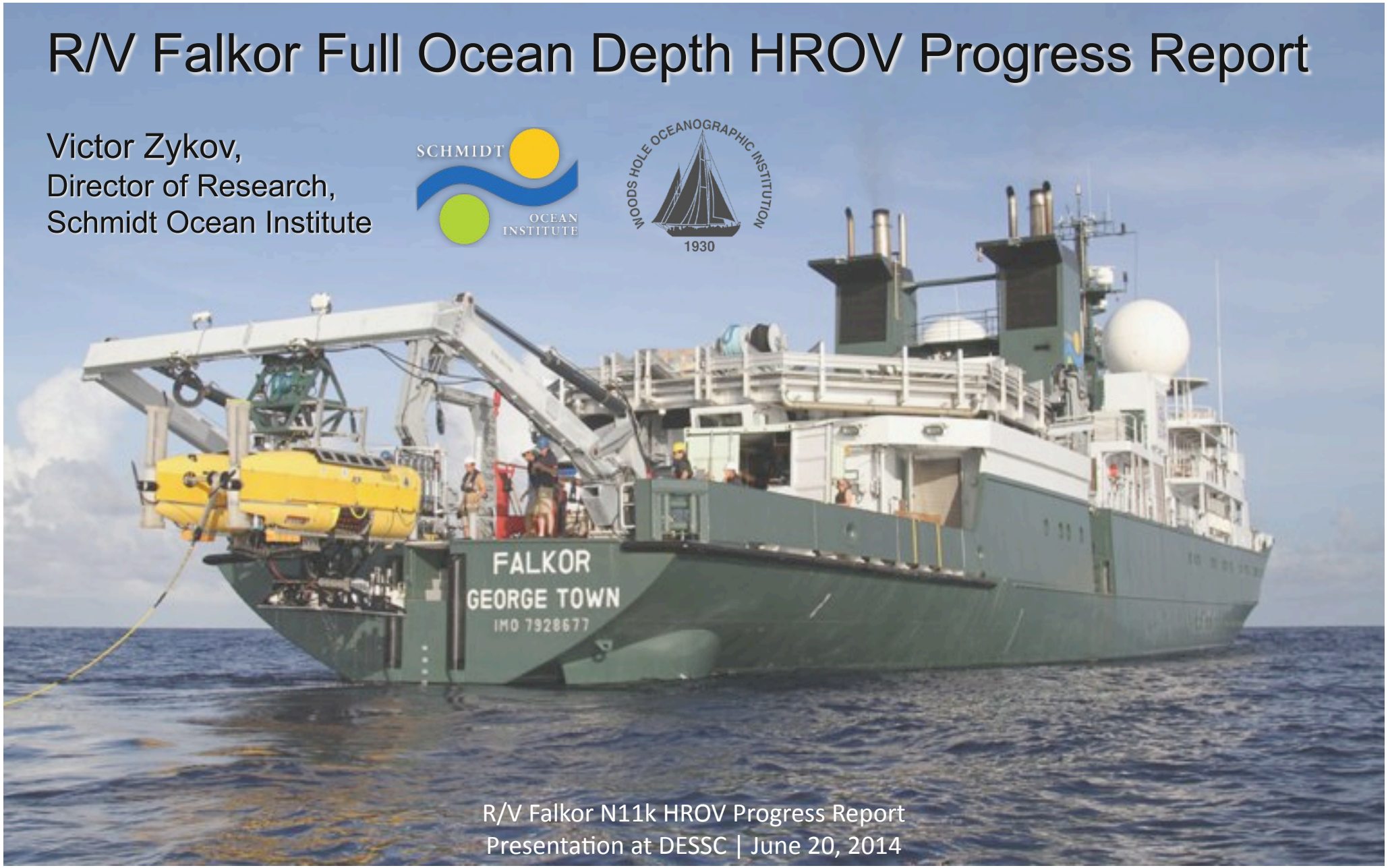



R/V Falkor N11k HROV Progress Report
Presentation at DESSC | June 20, 2014

# SOI N11k HROV Program Objectives

- In collaboration with WHOI NDSF and DeepSea Challenger, develop a technologically advanced 11k HROV (ROV or AUV) for R/V Falkor, supporting:
  - Robust access to abyssal and hadal zones for scientific research
  - UHD / 3DHD / panoramic HD video acquisition and streaming
  - Scientific data collection (seafloor mapping, chemical and thermal data collection, photomosaicing, etc.)
  - Versatile scientific sample collection
  - Object manipulation (e.g. collection and deployment of equipment)
- HROV will satisfy SOI operational requirements
  - HROV will be optimized for operation on R/V Falkor
  - HROV will support single body launch and recovery

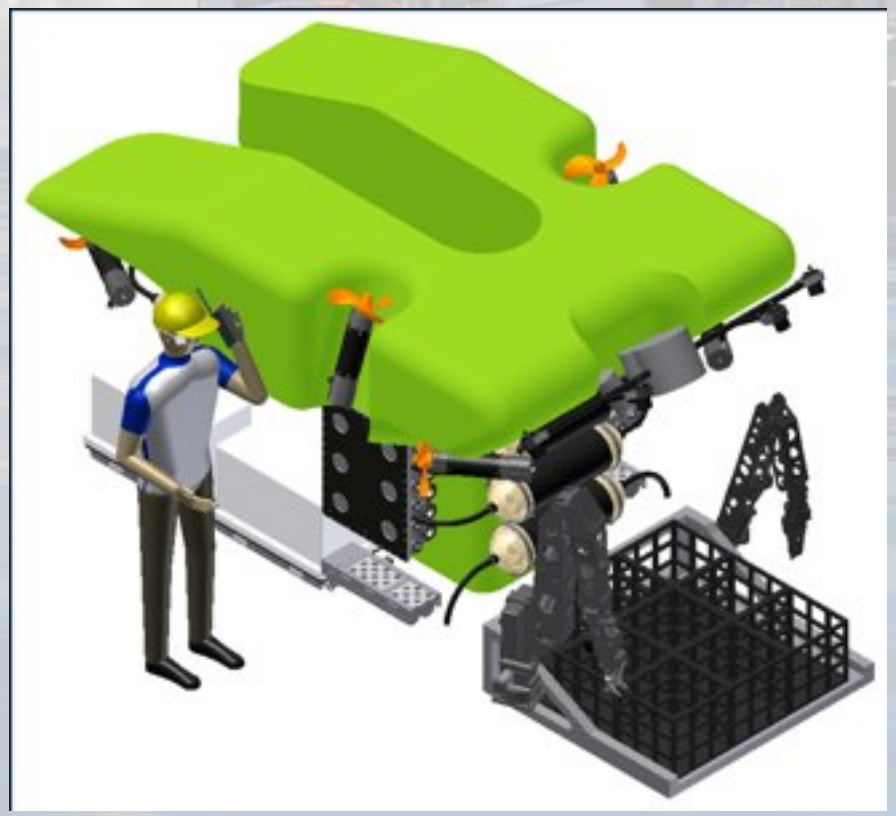
# SOI N11k HROV Development Timeline

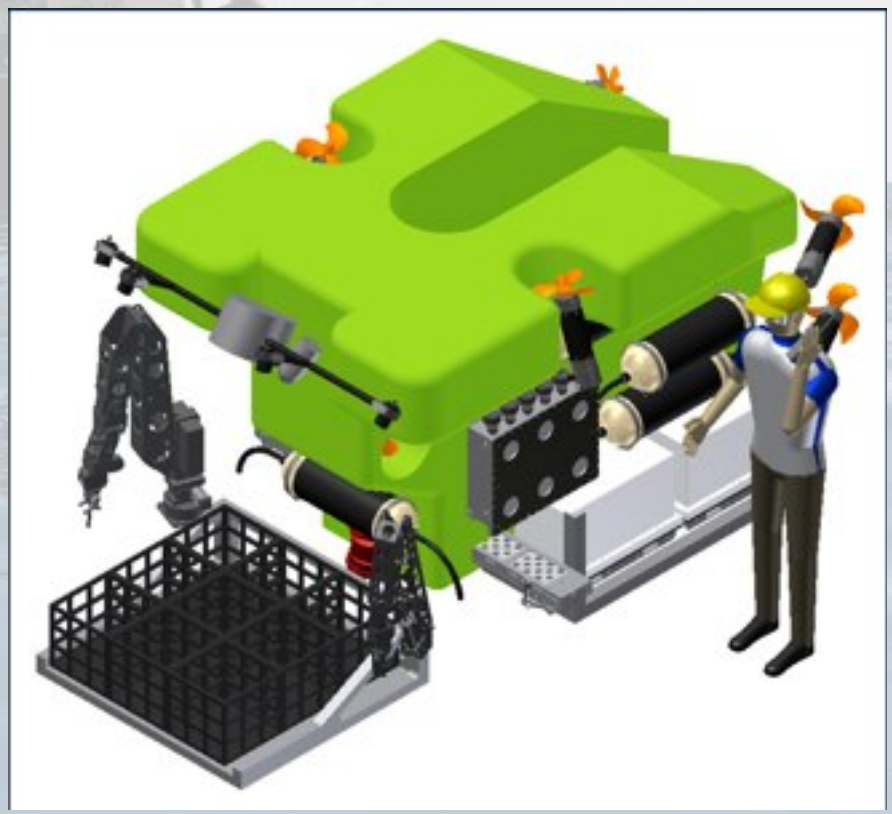
- Phase 0 –Objectives Definition: Sep 2013 – Nov 2013
- Phase 1 - Conceptual Design: Dec 2013 - Feb 2014
- Phase 2 - Preliminary Design: Mar 2014 - July 2014
  - System Requirements Review: May 14, 2014
  - Preliminary Design Review: July 23, 2014
- Phase 3 - Final Design and Build: Aug 2014 – Aug 2015
- Phase 4 - Testing and Evaluation: Sep 2015 – Mar 2016
  - Engineering Trials: Sep 2015, Jan 2016
  - Science Verification Cruises: Feb 2016, Mar 2016
- Committed Scientific Deployments: mid-2016

# SOI HROV Science Advisory Group

- SOI HROV SAG Chair: Dr. Christopher German, WHOI
- Science Advisory Group:
  - Dr. Bill Chadwick, OSU
  - Dr. Patricia Fryer, U. Hawaii
  - Dr. Alan Jamieson, U. Aberdeen, UK
  - Dr. Chuck Fisher, PSU
  - Dr. Antje Boetius, MPI-Bremen, Germany
  - Dr. Julie Huber, MBL
  - Dr. David Butterfield, NOAA
  - Dr. Marv Lilley, U. Washington
  - Dr. Bruce Robison, MBARI

# Preliminary Arrangement (pending review)





Air weight < 28.9 kN (6500 lb); Science payload 1.8 kN (400 lb);
Dimensions within 350cm length x 180cm width x 190cm height

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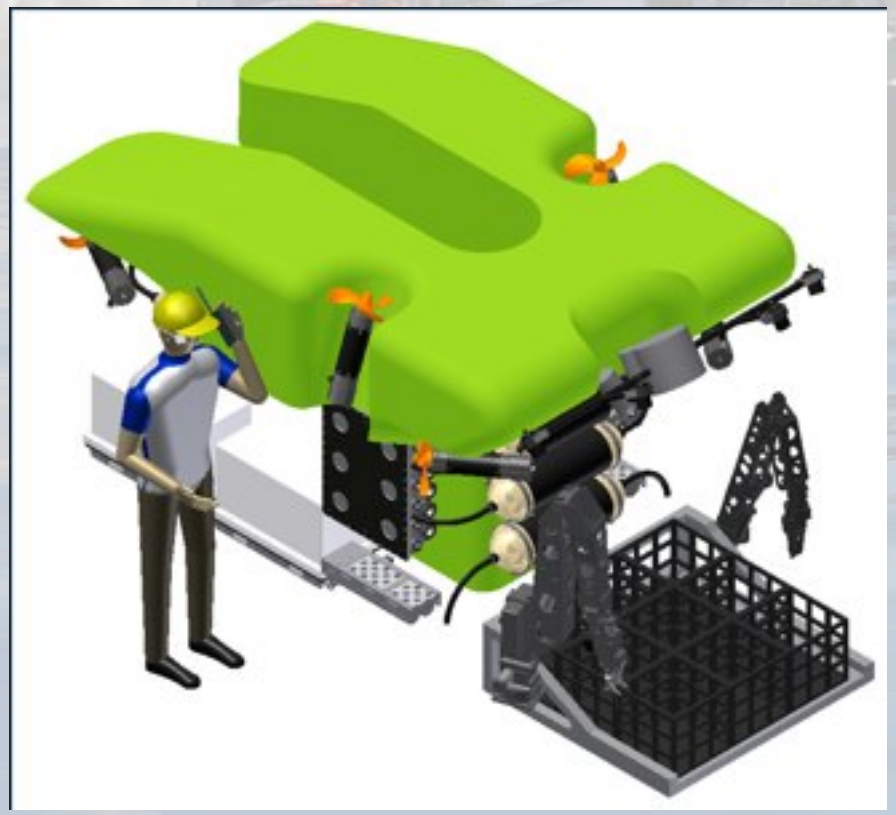
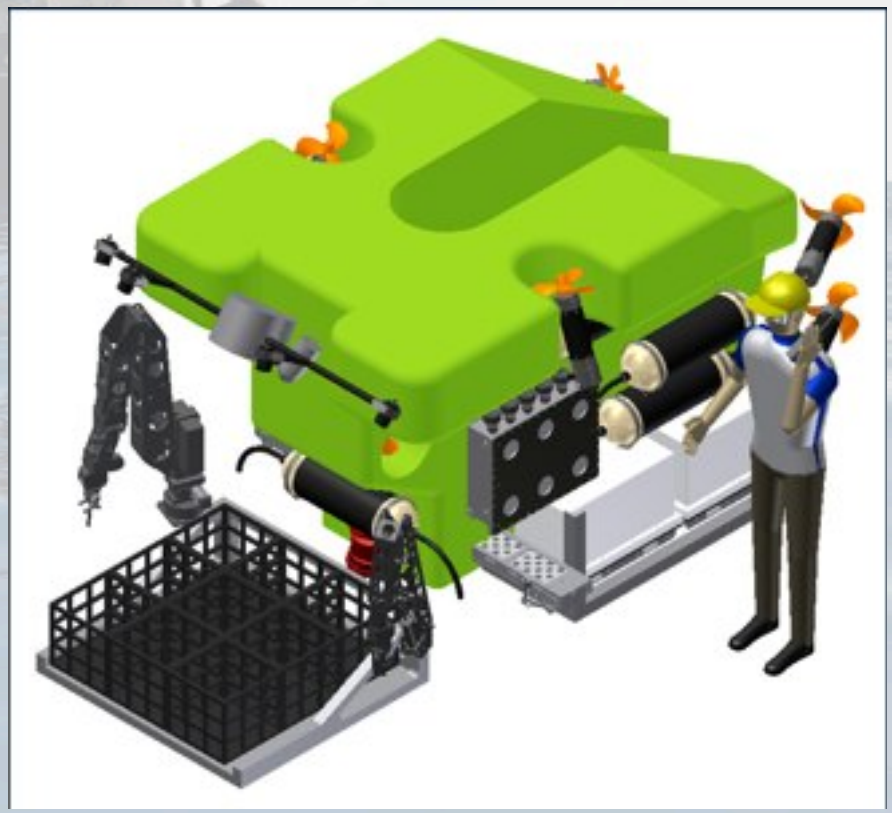




Single-body launch and recovery requirement is the primary driver for the arrangement

# Concept of Operations

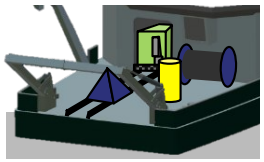
N11-90-002
Rev B

## PRE-CRUISE

Mission Planning
- Identify science objectives.
- Choose operational mode and configure vehicle.
- Prepare dive plan.

Mobilize vehicle on ship if not already on board.
Perform Pre-Cruise Maintenance

## AT-SEA OPERATIONS



Vehicle stored in hangar.
- Moved back and forth from LARS via track system.
- Working space on all sides of vehicle.

Depressor and winch stored on deck.
A-frame mounted Launch and Recovery System (LARS).

*24 hour operations*

### Surface Interval

Perform maintenance and re-configure vehicle as needed for next mission.
Conduct post-dive debrief and pre-dive brief for next dive.
Max 8 hours on surface between dives.

## POST-CRUISE

Deliver data package.
Demobilize vehicle if desired.
- Every 18 months: Perform overhaul maintenance.

### OUTREACH & COMMUNICATIONS

Interactive live broadcasts & video feed to public, classrooms, shore-side investigators, data distribution and publication, etc.

**Topside Control & Data Management**
Communications, Navigation, Tracking
Data post-processing

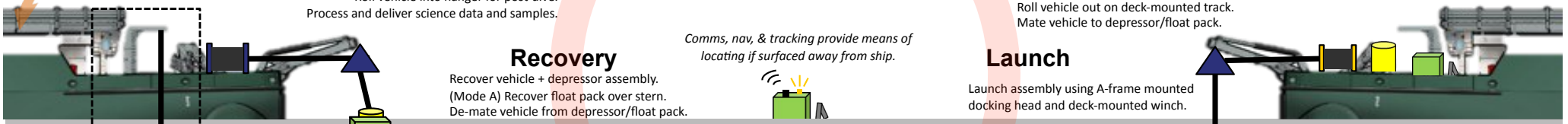
### Post-Dive

Roll vehicle into hanger for post-dive.
Process and deliver science data and samples.

### Pre-Dive

Configure vehicle and begin pre-dive in hangar:
- (Mode 1) Fiber stack for depressor & float-pack terminated in lab space.
- (Mode 2) Optical modems setup.
- (Mode 3) EOM cable connected directly to vehicle.

Prepare depressor on deck.
Roll vehicle out on deck-mounted track.
Mate vehicle to depressor/float pack.



*Comms, nav, & tracking provide means of locating if surfaced away from ship.*

### Recovery

Recover vehicle + depressor assembly.
(Mode A) Recover float pack over stern.
De-mate vehicle from depressor/float pack.

*Float Pack - Mode A only*

### Launch

Launch assembly using A-frame mounted docking head and deck-mounted winch.

*Default single body launch and recovery.*

*Vehicle may also be separately deployed and recovered using J-Frame.*

### Ascent

Re-position ship near ascending vehicle.
Re-launch depressor to ~2000-m depth.
Execute subsea docking of vehicle to depressor.

### Descent

Vehicle + depressor passively sinks to desired depth (mode dependent).
Drive vehicle away from depressor.
(Mode A) Separate float pack and begin fiber payout.

### Execute Mission

*8 hours bottom time at 11 km*

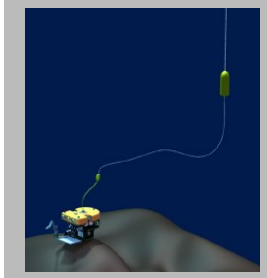
Upon commanded or auto-abort:
- (Mode A) Break fiber.
- Adjust ballast for positive buoyancy.
- Begin ascent.

Haul in on depressor and recover.

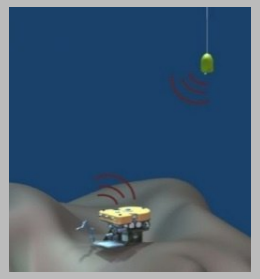
*Telemetry to/from vehicle according to Mode A, B, C, or D configuration.*

Explore.
Collect samples.
Record video and images.
Make bathymetric maps.
Interact with lander.
Etc.

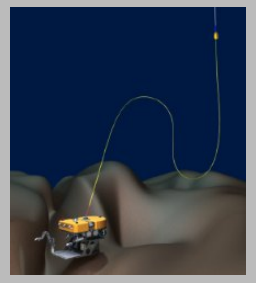
*400 lb total payload capacity*
*~ 100-200 lb sample basket payload*



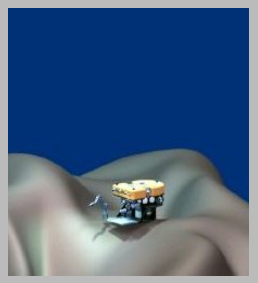
*Mode A*



*Mode B*



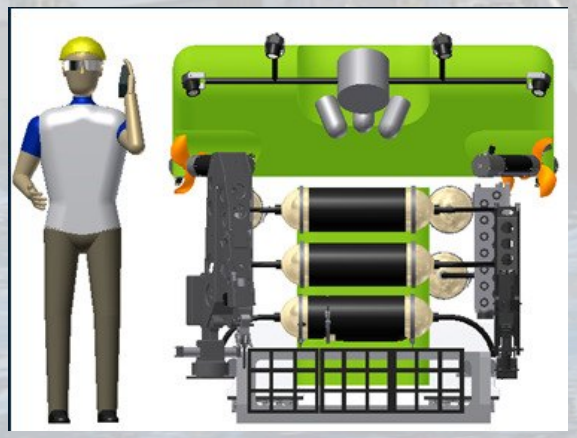
*Mode C*

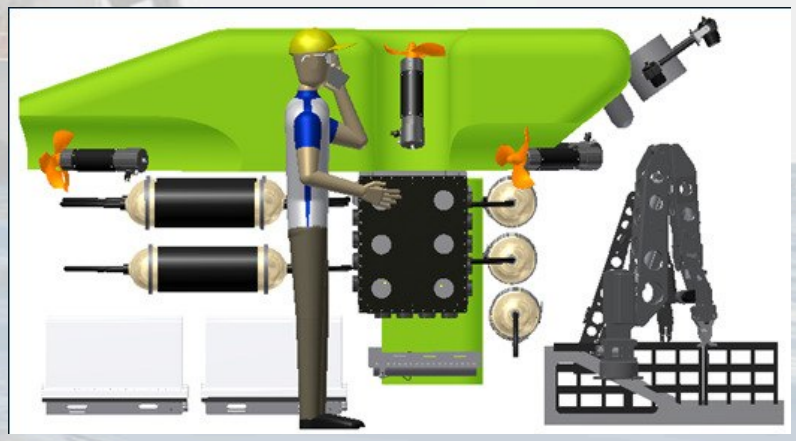


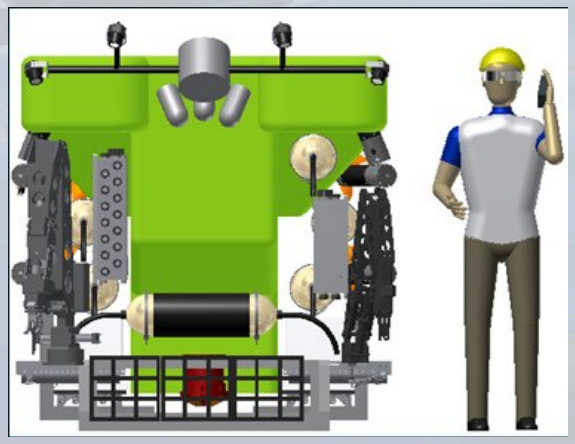
*Mode D*

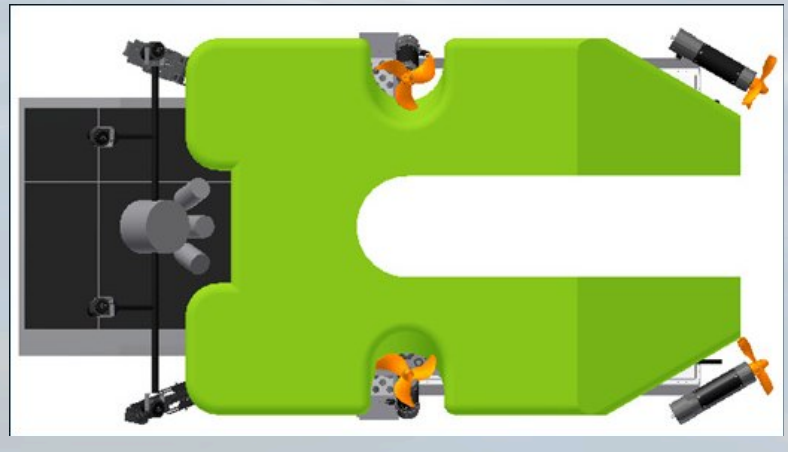
# Preliminary Arrangement (pending review)

HROV Frame:
**Al** and **Ti** considered for primary load path members, lightweight plastics and composites for secondary vehicle structure



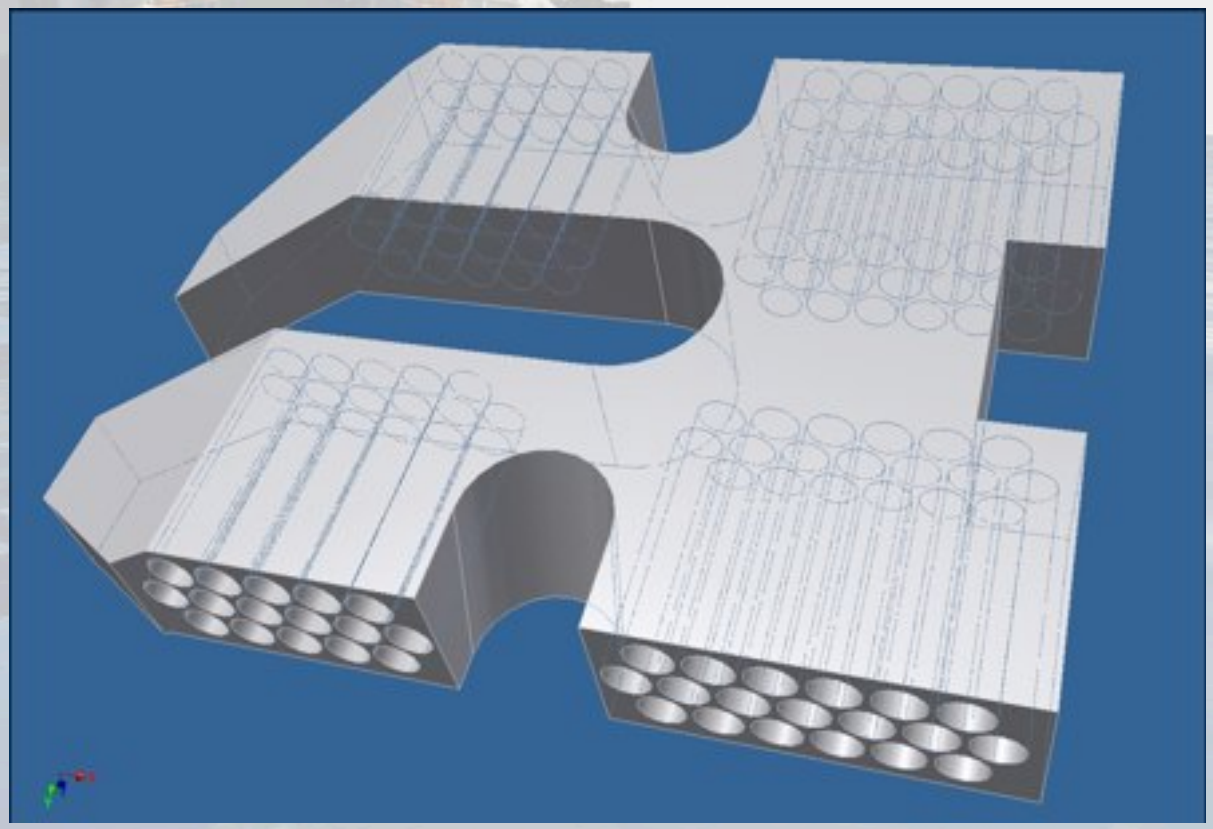






# Flotation Concept

- Combination of syntactic foam and ceramic spheres in thwartships sphere tube matrix
  - Foam density 609-673 kg/$m^3$ (38-42 PCF)
  - Ceramic sphere density 336 kg/ $m^3$ (21 PCF)



# HROV Design Features

- **Ballast System** comprised of the ascent and descent weight releases with triple redundancy
- Six Nereus-style **Utility Pressure Housings** with penetrators
- **Electrical Distribution System** leverages the Nereid Core design
- Pressure Balanced Oil Filled (PBOF) **Lithium Ion Battery Modules** and **Battery Management System**
- Pressure Balanced Oil Filled (PBOF) **Direct Drive Thrusters** and **Motor Controllers**
- In-hull **Command & Control** hardware and software that implements ROV and AUV functionality
- Designed to use **Small Diameter Tether** in light tether mode

# HROV Operational Capabilities

- Four **Operational and Telemetry Modes:**
  - Piloted via **expendable fiber** to 11 km
  - Piloted via **optical comms** to 6 km
  - Piloted via **light tether** to 6 km
  - Untethered (Acoustic comms) to 11 km (AUV)
- **Reconfiguration between modes** at sea will take 6 hours for 2 people
- Optimized for the prevalence of ROV operations, expected **range of autonomous transit** is at least 20 km
- **Vertical transit time** to or from 11 km no greater than 8 hours
- **Maximum required surface interval** between dives is 8 hours
- Per year, HROV will support up to 30 dives to 3000-m, 30 dives to 6000-m, and 60 dives to 11000-m.

# HROV Sensor Capabilities (pending reviews)

- **Bathymetry, backscatter, water column:** Reson 7125 AUV 3 Multibeam Echo Sounder (6km)
- **Interferometric bathymetry, sub-bottom profiles, sidescan:** Edgetech 2205m (11km)
- **3-axis magnetic flux:** Applied Physics Systems APS-1520 magnetometer (11km)
- **Color video:** 3DHD, panoramic, and UHD PZT cameras (11 km)
- **Color photographs:** WHOI/Insight Pacific Digital Still Camera with Strobe (6km)
- **Turbidity:** TBD, probably Seapoint Optical Backscatter sensor (>6km)
- **Dissolved oxygen:** Aandara Optode 4330-fastfoil (11km)

# HROV Sensor Capabilities (pending reviews)

- **Conductivity, temperature, depth:** Seabird SBE-49 (11km)
- **Sound Velocity Probe:** TBD, probably Reson (>6km)
- **Redox potential:** PMEL ORP Eh Probe (>6km)
- **Vehicle position:** Ixea PHINS-3 6-degree-of-freedom Inertial Navigation Sensor (internal, 11km)
- **Vehicle velocities, water currents, altitude:** RDI or ROWE Doppler Velocity Log, TBD (11km)
- **Altitude over sea floor, backup altimetry:** TBD, probably Novatech (11km)
- **Pressure depth sensors:** TBD, probably Paroscientific (11km)
- **Vehicle position on surface:** TBD, Iridium, AIS (11km)

# HROV Sampling Capabilities (pending reviews)

- **Payload Weight**: 180 kg
- 1x 7-function Kraft **primary manipulator** arm (11km)
- 1x 6-function Schilling **secondary manipulator** arm (11km)
- 8x 6.4 cm dia **sediment cores** (11km)
- 2x 30.5 cm x 30.5 cm 30.5 cm UHMW polyethylene **biobox** (11 km)
- 1x multi-chamber **slurp system** (11km)
- 5x 2-liter **Niskin bottles** (11km)
- **Mid-water column** observations and sampling
- The vehicle will accommodate add-on scientific systems via ethernet, RS-232, RS-485, RS-422, serial, and analog interfaces and 5000 WHr of battery power at up to 80V and 100W per channel.

# Questions?