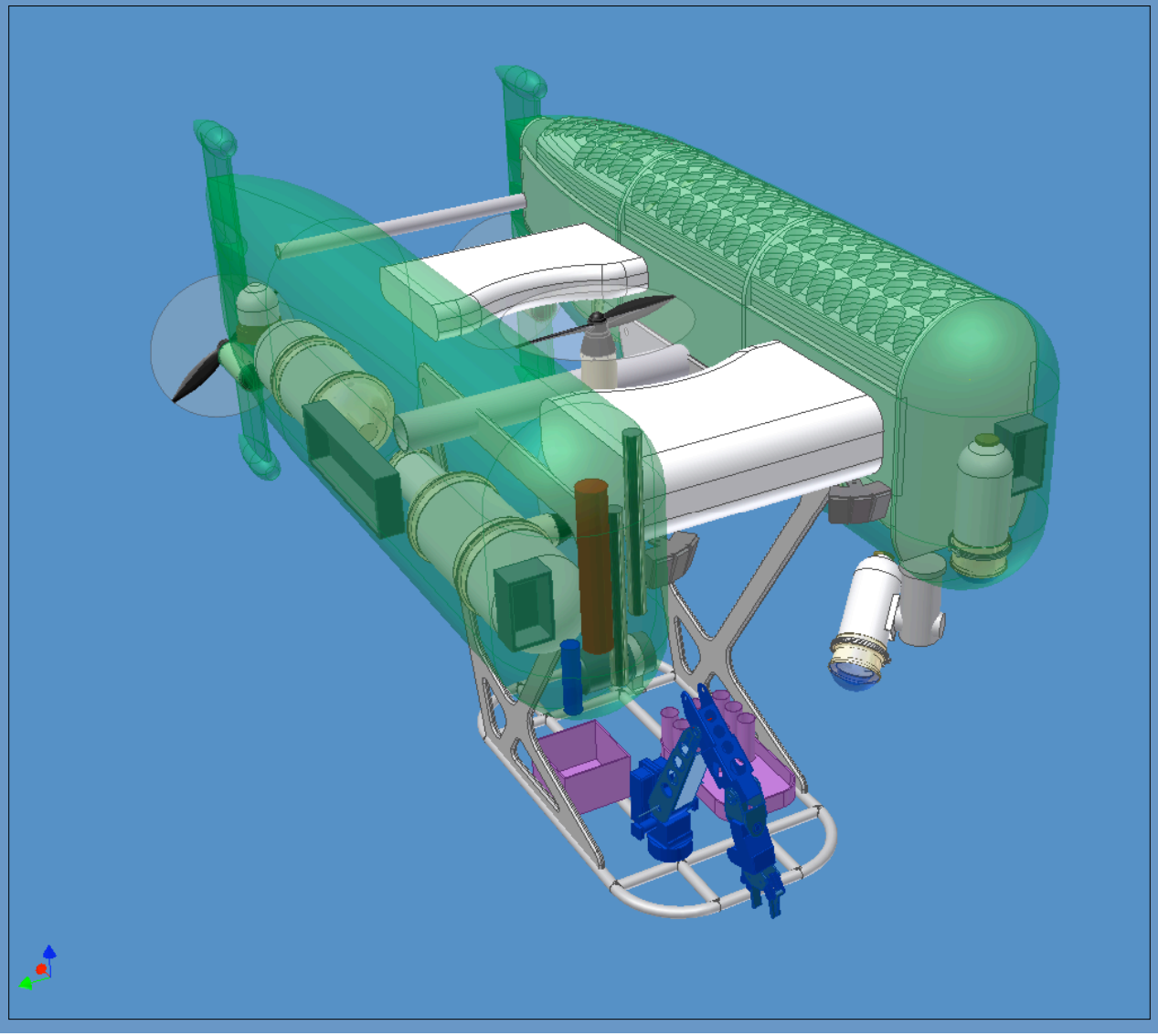
Exploring the Abyss

A Hybrid Vehicle for Working in the Deepest Ocean

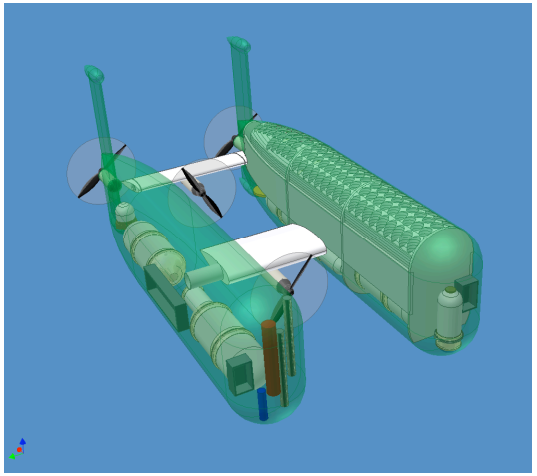


Project Highlights

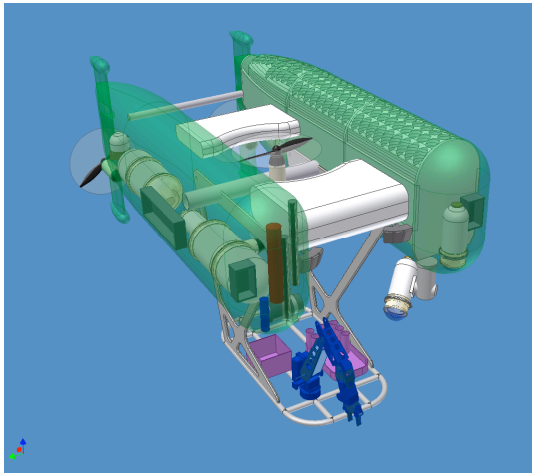
- Computational Fluid Dynamic Modeling of the vehicle complete with the results being incorporated into the final physical layout.
- All ceramic pressure cases have been successfully delivered with initial testing of utility housings to 17,000 psi
- Ceramic floatation sphere production on schedule with delivery completed
- Microfiber tether canister/brake completed and tested using ABE and WHOI pressure test facility
- Deep fiber trials (5000 - 6000M) planned for May on RV Oceanus
- Control computer hardware selection/evaluation underway
- Prototype motor in test
- First article Lithium Ion battery in test
- Prototype Light Emitting Diode components tested on Jason and at pressure
- Power switching electronics complete and in test

What is an HROV?

- A **Hybrid** cross between an AUV and a ROV in a single package
  - AUV for Mapping
  - ROV for Close inspection and manipulation
- New class of vehicle intended to explore the harshest ocean environments though the innovative application of new techniques and materials
- New Class of vehicle intended to offer a more cost effective solution for survey/mapping and direct interaction



AUV Mode

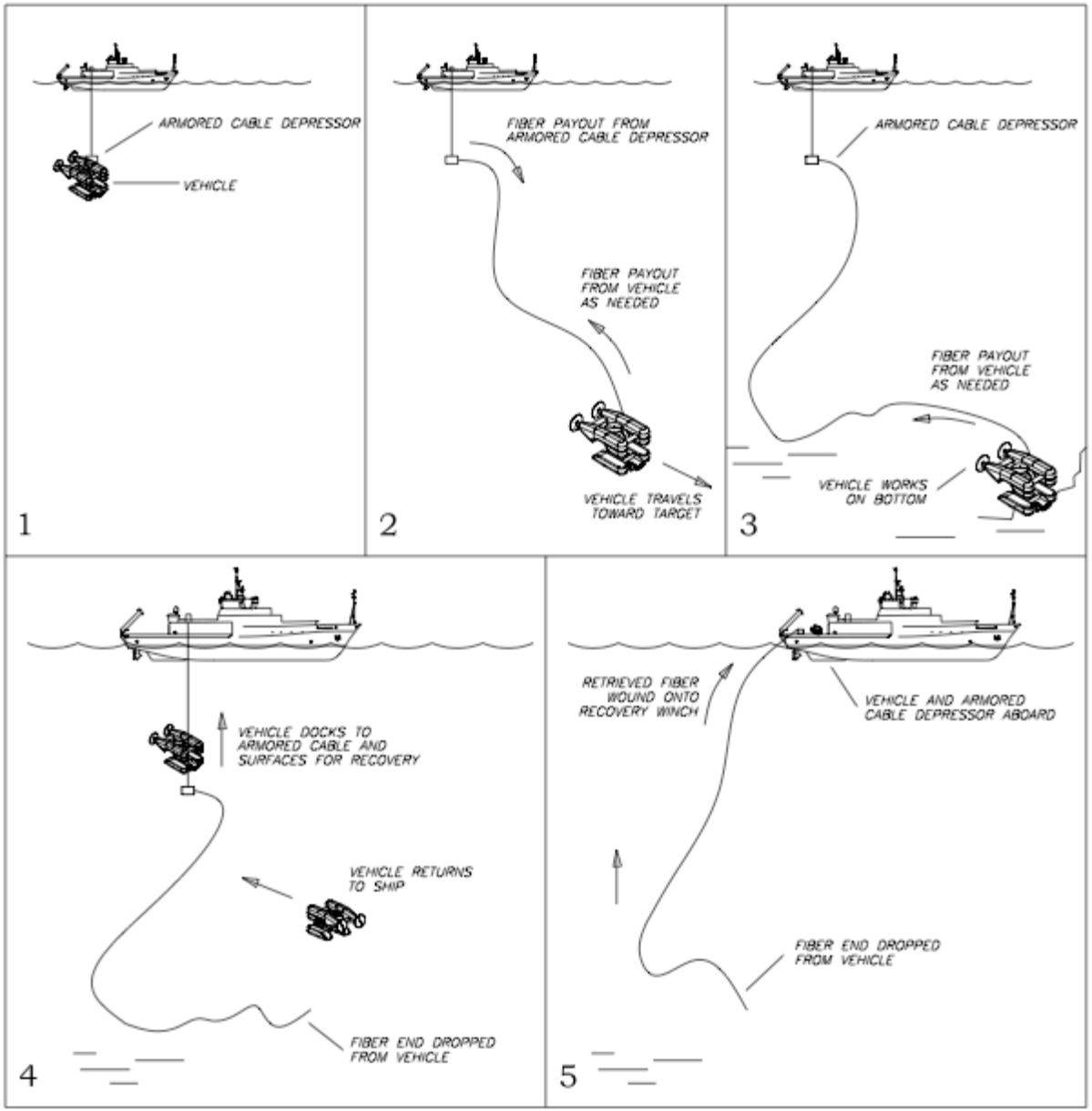


ROV Mode

HROV Operations

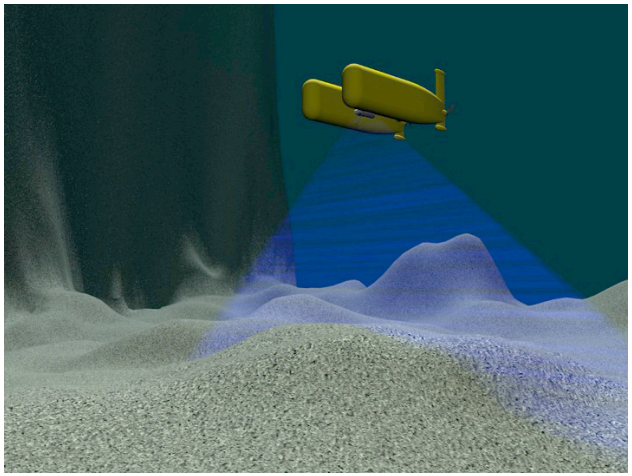
- **Event Response** - Light weight “fly-away”
- **Under Ice Operations** - Large horizontal excursions
- **Margins** - Trenches
- **Marginal Environments** - High latitudes
- **Service and support of Observatories**
- **Public Outreach** - Explore the unknown, Education

HROV Concept of Operations

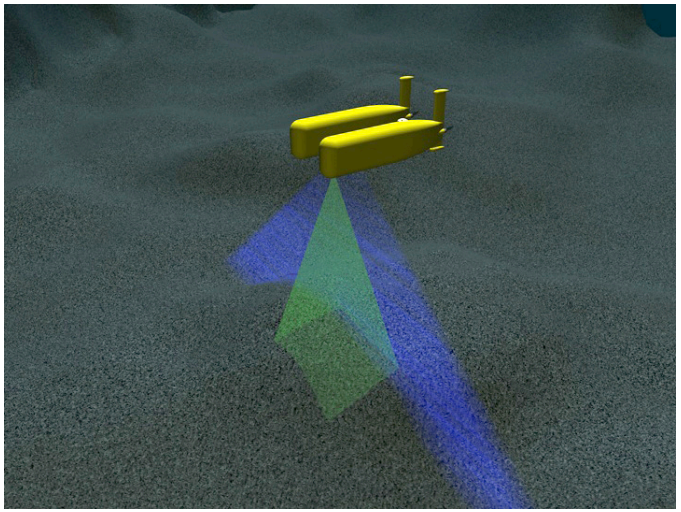


AUV Mode of Operation

High altitude (50M) sonar mapping

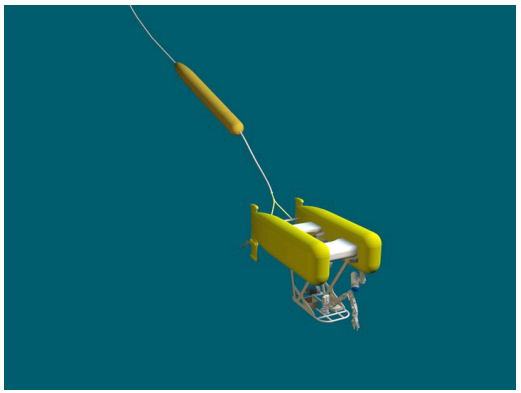


low altitude (10M) digital photograph collection

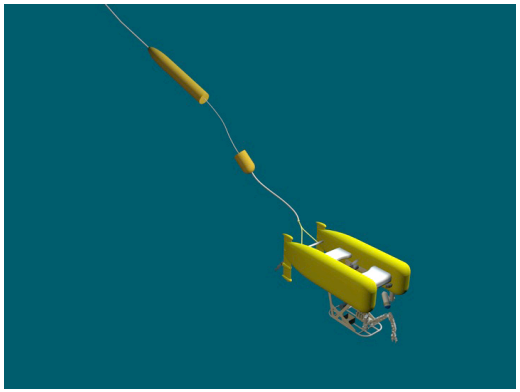


ROV Mode of Operation

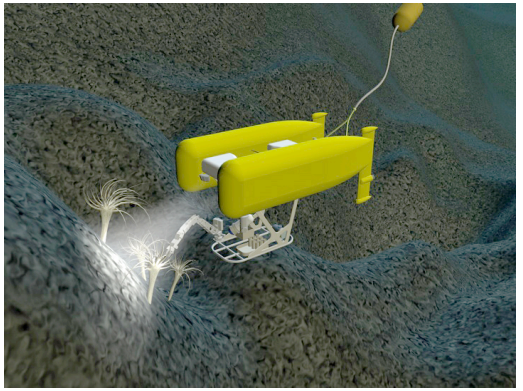
Descent with Depressor and Armored Cable



Release from Depressor
Micro-fiber tether payout

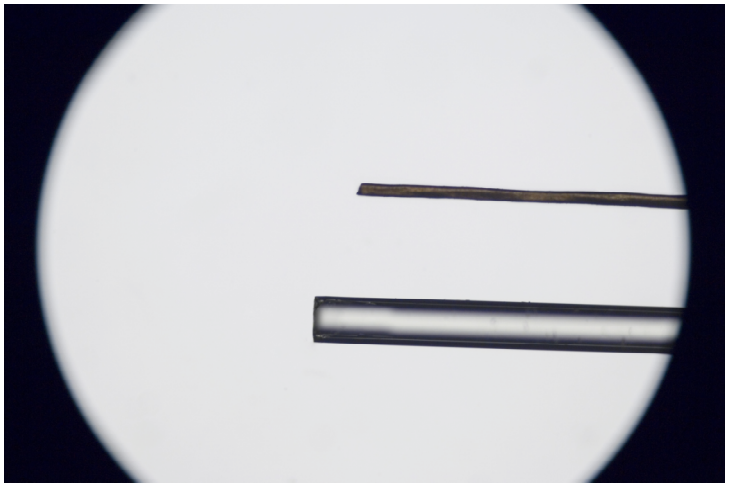


On Bottom collecting samples

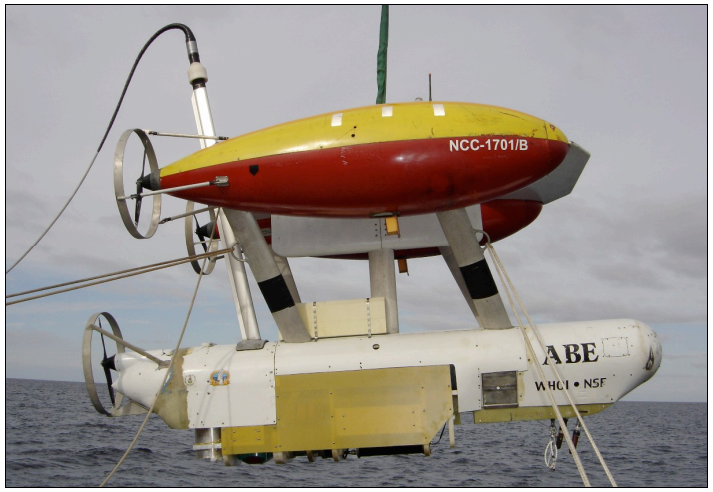


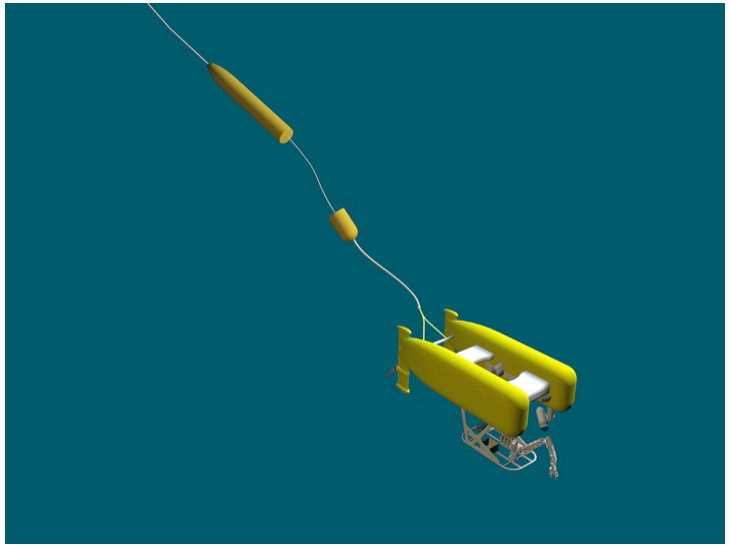
Fiber Optic Micro Cable

- **Size: 0.010 inch diameter, 8lb RBS**
- **Each Canister contains 20km of fiber**
- **20 KM of fiber weights .7 pounds in water.**
- **Tested to 20,000 psi with no optical attenuation.**



Micro-Fiber Development Field Trials



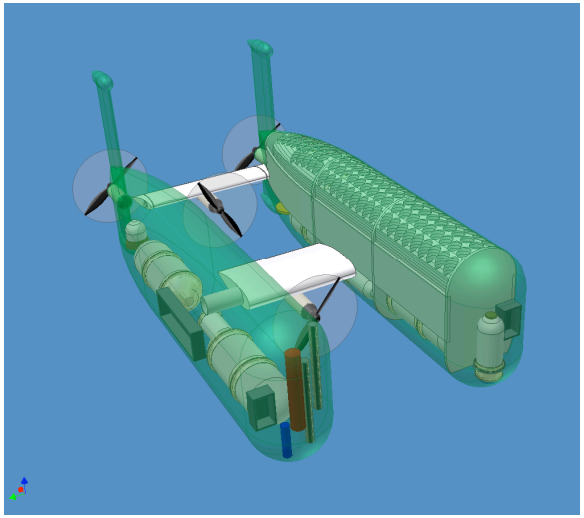


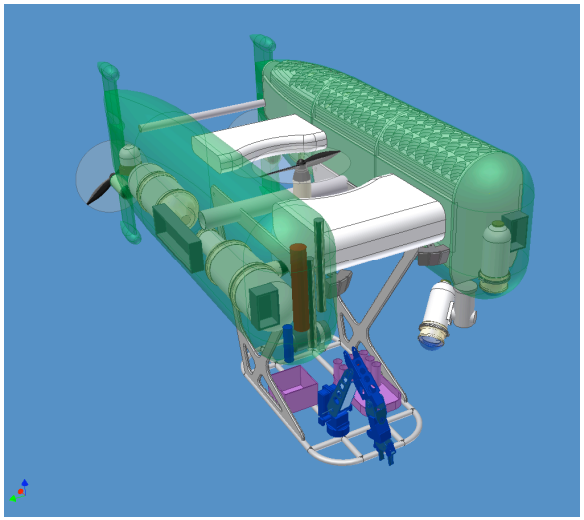
- Initial trials in 2004 deployed elevator with direct connection to the ship
  - Results assisted in selection of fiber
  - Verified modeling
  - Assisted with development of deployment concept

- ABE trials in December 2005
  - Proved concept of remaining connected to vehicle maneuvering on the sea floor (up to 17 hours)
  - Operations from non-DP vessel (SIO New Horizon)
  - Continued development of micro fiber system components

- Depressor deployment (May 2006)
  - Trials of depressor transition
  - Final test of micro-fiber canister/brake assemblies

Summary of Vehicle Mission Profiles





AUV

- Survey speed of up to 3 knots
- 70 KM of coverage (sonar)
- Lower altitude photo coverage at slower speed increases mission duration

ROV

- 4 sample sites (typical)
- Up to 7 KM of transits
- Projected bottom time of 8 hours
- Each sample site assumes high resolution imaging and sample collection

Science Capabilities

- Basic Sensor Suite
  - Two Seabird 49 FastCat CTD's
  - Magnetometer
  - Optical Back Scatter
  - Profiling Sonar
  - Imaging Sonar

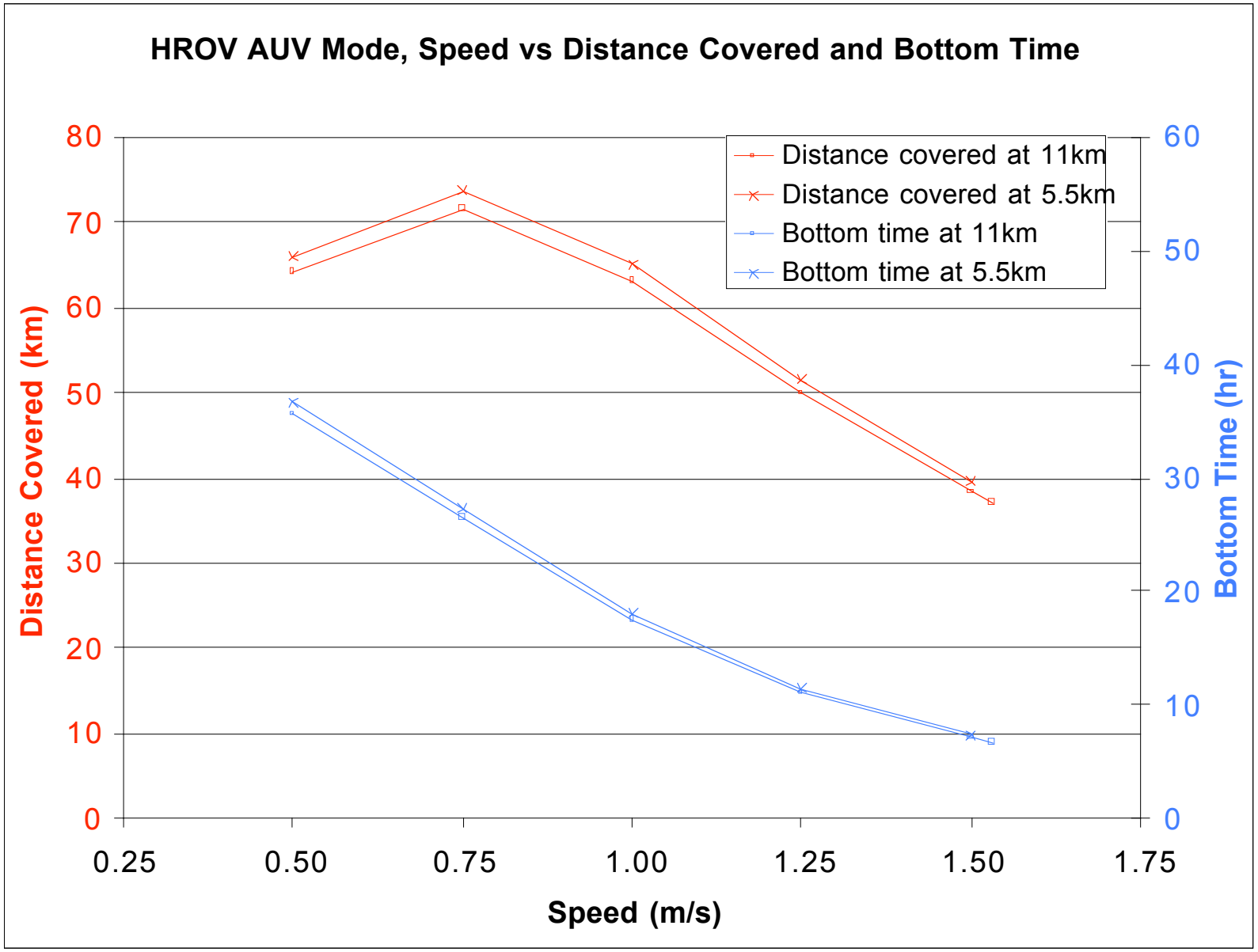
- Additional Capabilities
  - 6 science bus ports distributed between port, stbd, and work package junction boxes.
  - RS-232 x 6
  - One Ethernet
  - Supply voltage nominal 24VDC (48V & 12V configurable), 685 Whr.
  - Up to 4A per channel
  - Available in all vehicle configurations

Mission Profile: Power Use

- Goal:
  - Simulate AUV and ROV missions based on depth and device power consumption with respect to various mission phases
- Results:
  - Reality check of mission durations
  - Review impact of mission depth on mission duration
  - Estimate distance covered with calculated propulsion and vehicle drag values (AUV primarily)
  - Review top power consumers

AUV Mode Mission Phases

Phase	Description
1 - launch-surface	time beginning from the removal of shore power until vehicle is in the water at the time the pin is pulled. estimated at 15 min.
2 - descent/weight drop	time beginning from the pin pull, through free-fall descent to the bottom, and sitting on the descent weight until its release. free-fall descent time is based on descent rate and depth. time on descent weight is estimated at 15 min.
3 - survey	90% of total bottom time from descent release until the survey is complete which thrusters operate at nominal power. 1Hz stills and profiling sonar on.
4 - survey +10%	10% of total bottom time from descent release until the survey is complete which thrusters operate at 10% over nominal power… used to simulate the slight increase in power required to change depth. 1Hz stills and profiling sonar on.
5 - ascent/weight drop	time beginning from the end of survey, during release of ascent weight, and through ascent until on the surface. ascent time is based on ascent rate and depth. release of ascent weight is estimated at 15 min.
6 - recover-surface	time beginning from arrival on surface, through recovery, until shore power is connected. estimated at 30 minutes.


HROV AUV Mode, Speed vs Distance Covered and Bottom Time
Distance covered at 11km
Distance covered at 5.5km
Bottom time at 11km
Bottom time at 5.5km
Distance Covered (km)
Bottom Time (hr)
Speed (m/s)
0
10
20
30
40
50
60
70
80
0.25
0.50
0.75
1.00
1.25
1.50
1.75

AUV Mode Top Power Consumers

29.5 hr mission, 17.5 hr on the bottom

11000 m depth **1.0m/s, 1hz vid survey + profile**			
auv_pd03			
2006_02_16_auv03			
subtotal	**rank**	**power consumed (%)**	**equipment**
	1	56.5%	thrusters
72.4%	2	16.0%	actuators
77.5%	3	5.1%	cpu
80.6%	4	3.1%	profile sonar
83.2%	5	2.6%	phins INS
85.8%	6	2.6%	doppler

ROV Mode Mission Phases

Phase	Description
1 - launch-surface	time beginning from the removal of shore power until vehicle is in the water at the time the pin is pulled. estimated at 15 min.
2 - descent/weight drop	time beginning from the pin pull, through free-fall descent to the bottom, and sitting on the descent weight until its release. free-fall descent time is based on descent rate and depth. time on descent weight is estimated at 15 min.
3 - transit	total time spent transiting between worksites. **fwd LED 1 Hz, task LED off, imagining sonar on**. see next slide.
4 - survey	total time spent surveying worksites. **fwd LED 2 Hz, task LED off, imagining sonar on.** see next slide.
5 - sample, low power	total time spent sampling at nominal hydraulic power. **fwd LED 30 Hz, task LED on, imagining sonar off.** see next slide.
6 - sample, high power	total time spent sampling at maximum hydraulic power. **fwd LED 30 Hz, task LED on, imagining sonar off.** see next slide.
7 - sampling position adjustment	total time spent adjusting vehicle position during sampling. **fwd LED 10 Hz, task LED on, imagining sonar off.** see next slide.
8 - ascent/weight drop	time beginning from the end of survey, during release of ascent weight, and through ascent until on the surface. ascent time is based on ascent rate and depth. release of ascent weight is estimated at 15 min.
9 - recover-surface	time beginning from arrival on surface, through recovery, until shore power is connected. estimated at 30 minutes.

ROV Mode Top Power Consumers

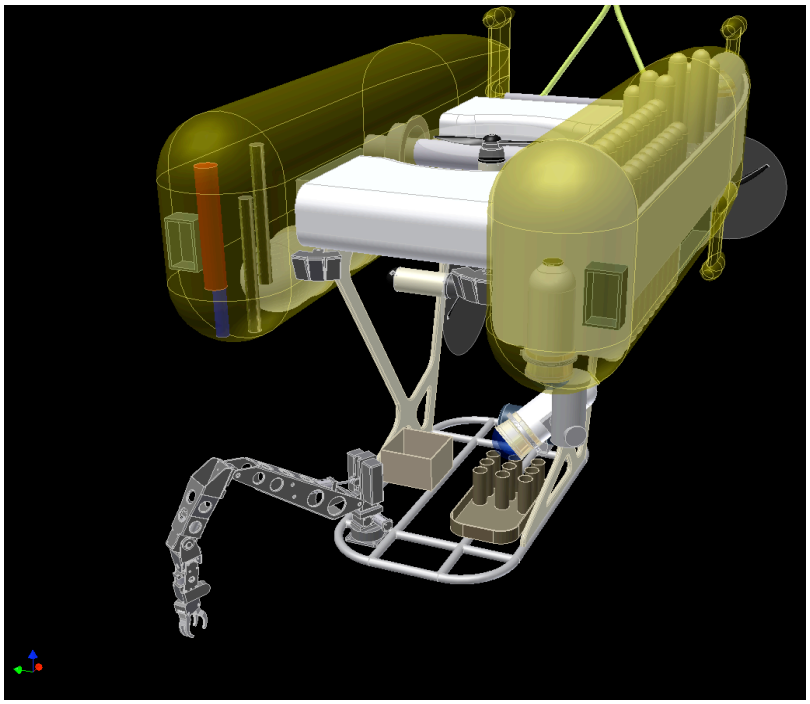
11000 m depth **100% hpu power, average ascent/descent**			
rov_pd07			
2006_02_17_rov06			
subtotal	**rank**	**power consumed (%)**	**equipment**
	1	25.0%	thr aft or vertical
39.1%	2	14.1%	thr port
53.2%	2	14.1%	thr stbd
65.9%	3	12.7%	hpu
74.5%	4	8.6%	thr fwd or lateral
78.7%	5	4.2%	fwd LED
82.4%	6	3.7%	cpu 1
84.4%	7	2.0%	fiber transceiver
86.3%	8	1.9%	phins
88.1%	9	1.9%	doppler
89.3%	10	1.1%	ethernet switch

- 21.4 hr mission, 6.8 hr on the bottom
- 61.8% thruster total
- 100% HPU power level
- Lights and cameras on per phase requirements

HROV Sampling Capabilities

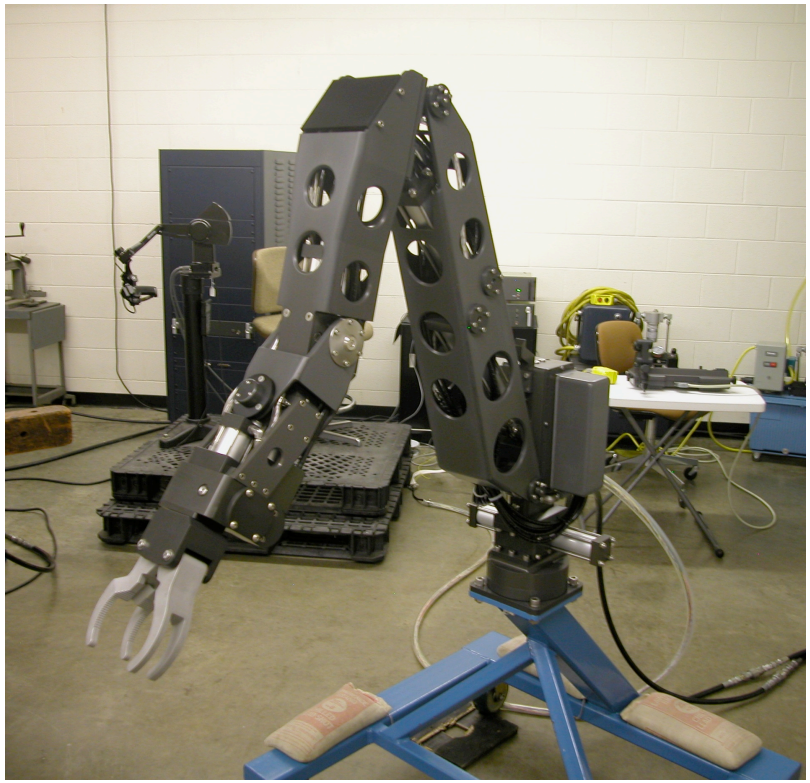
- Push coring
- Heat-flow probe – e.g. the Alvin probe.
- Geotechnical/Geochemical sensors –pore pressure in sediments
- Rock sampling/drilling
- Biological sampling – small suction samplers, nets and “bio boxes”
- Water sampling

HROV Workspace



- Manipulator work package suspended from the core vehicle structure
- Flexible sample storage facilities will reside within the frame of the ROV work package
- Pan and tilt will be on the opposite side of the manipulator for good visibility of the workspace
- Will have 2 utility cameras used to see into the frame and sample storage facilities
- Workspace optimized through the use of CAD
- Much of this development is based on lessons learn with the Alvin, Jason I and Jason II systems

HROV Manipulator Specifications



- Hydraulically powered
- 6 Degree of field, 7-function, Master/Slave
- Horizontal reach 66” with minimum lift capacity of 30 pounds
- Grip closure force (controllable) 0-100 lbf
- Delivery scheduled for June 8th.
- Development of a highly efficient adaptive hydraulic power system
- Auxiliary output for science payloads

Main Housings

Mechanical Characteristics

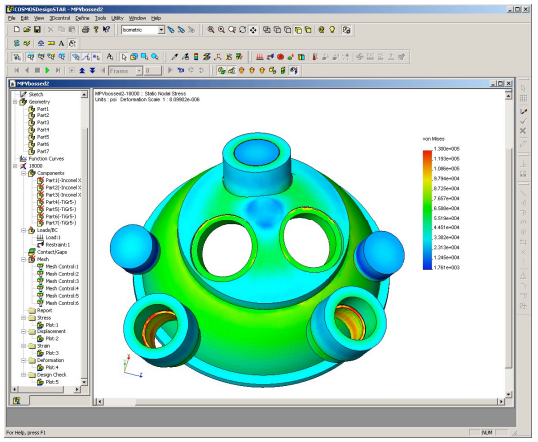
•Alumina Ceramic/Grade 5 titanium construction based on SPAWAR design guidelines

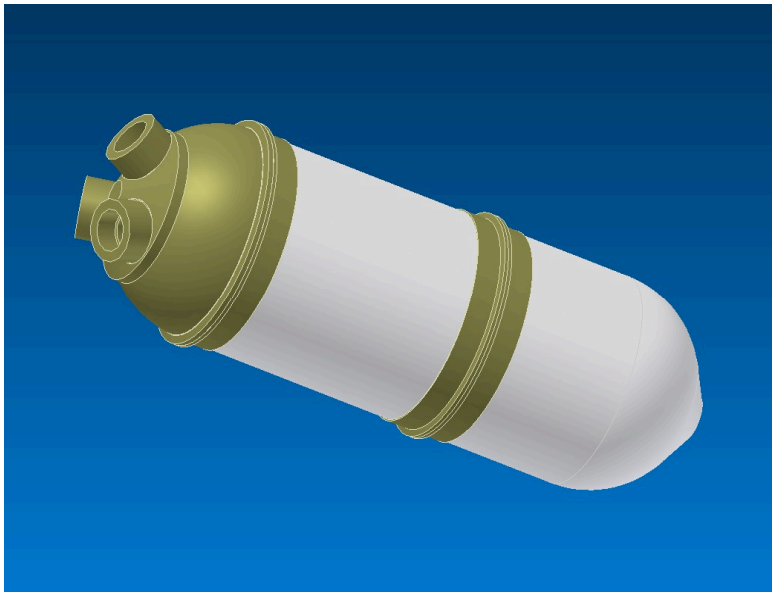
• 4 Housings - 2 for batteries and 2 for electronics

•135 lbs buoyant in water

• Comparable Ti vessel: 300 lbs air weight and 80 lbs negative in water, yielding a savings of 215 pounds.

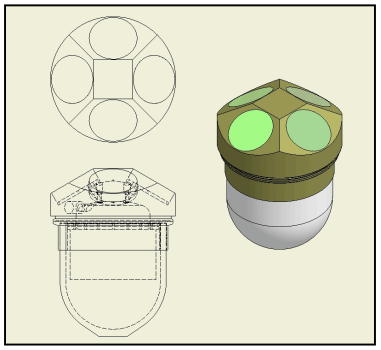
• Total in-water weight savings of approximately 730 lbs!

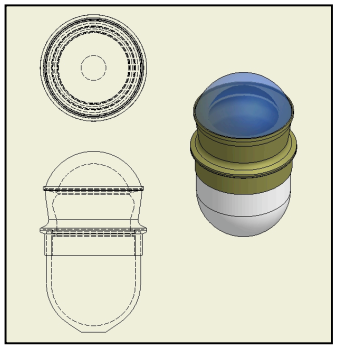




Utility Housings

Versatile packaging for electronics outside of the main pressure vessel





List of Instruments

1) Doppler
2) GPS/ Iridium beacon and LBL
3) Altimeter and Pressure transducer
4) Digital still camera
5) Motion camera
6) High altitude digital camera

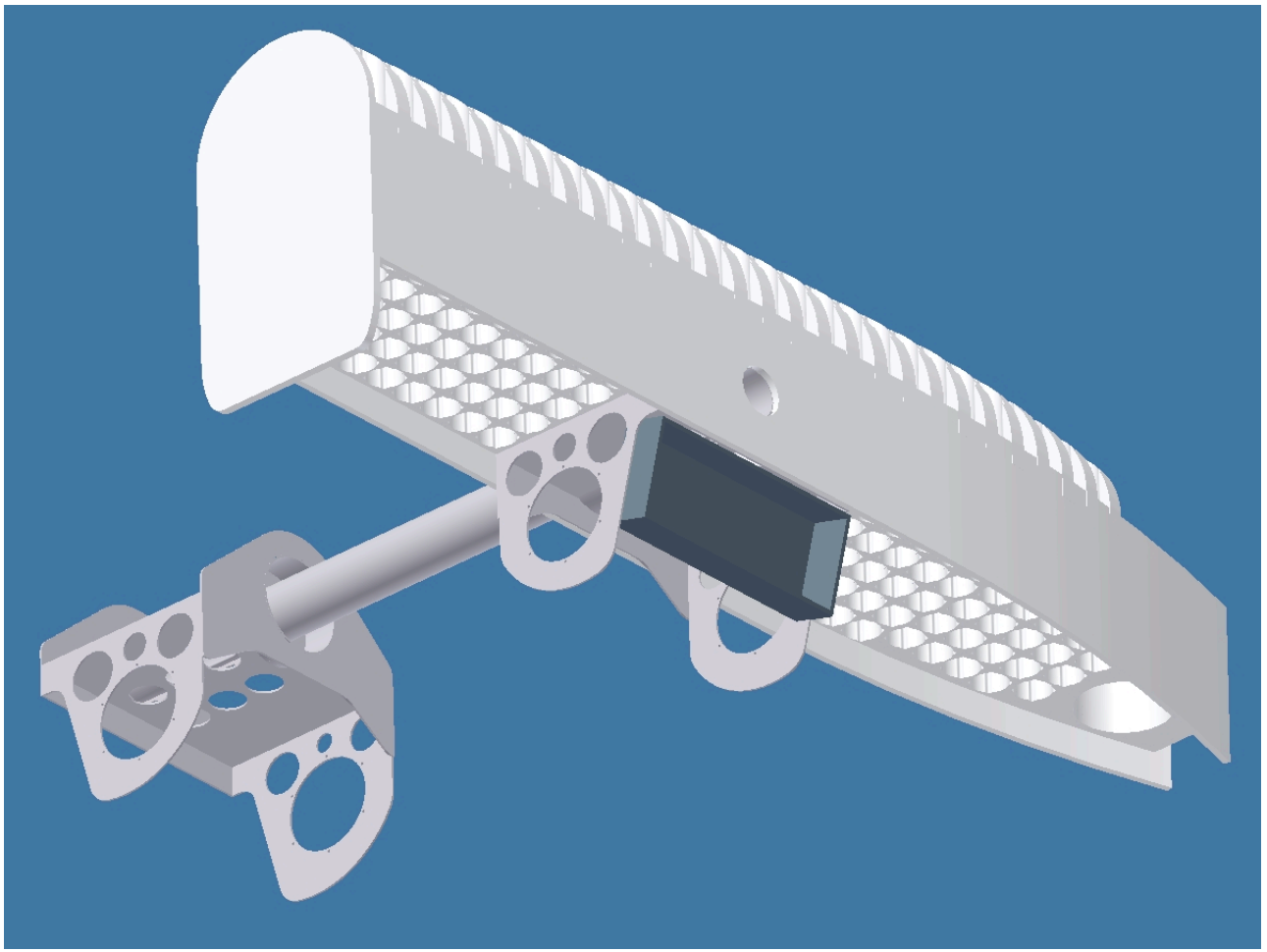
27 lbs air weight

2 lbs buoyant water weight

Ceramic Floatation

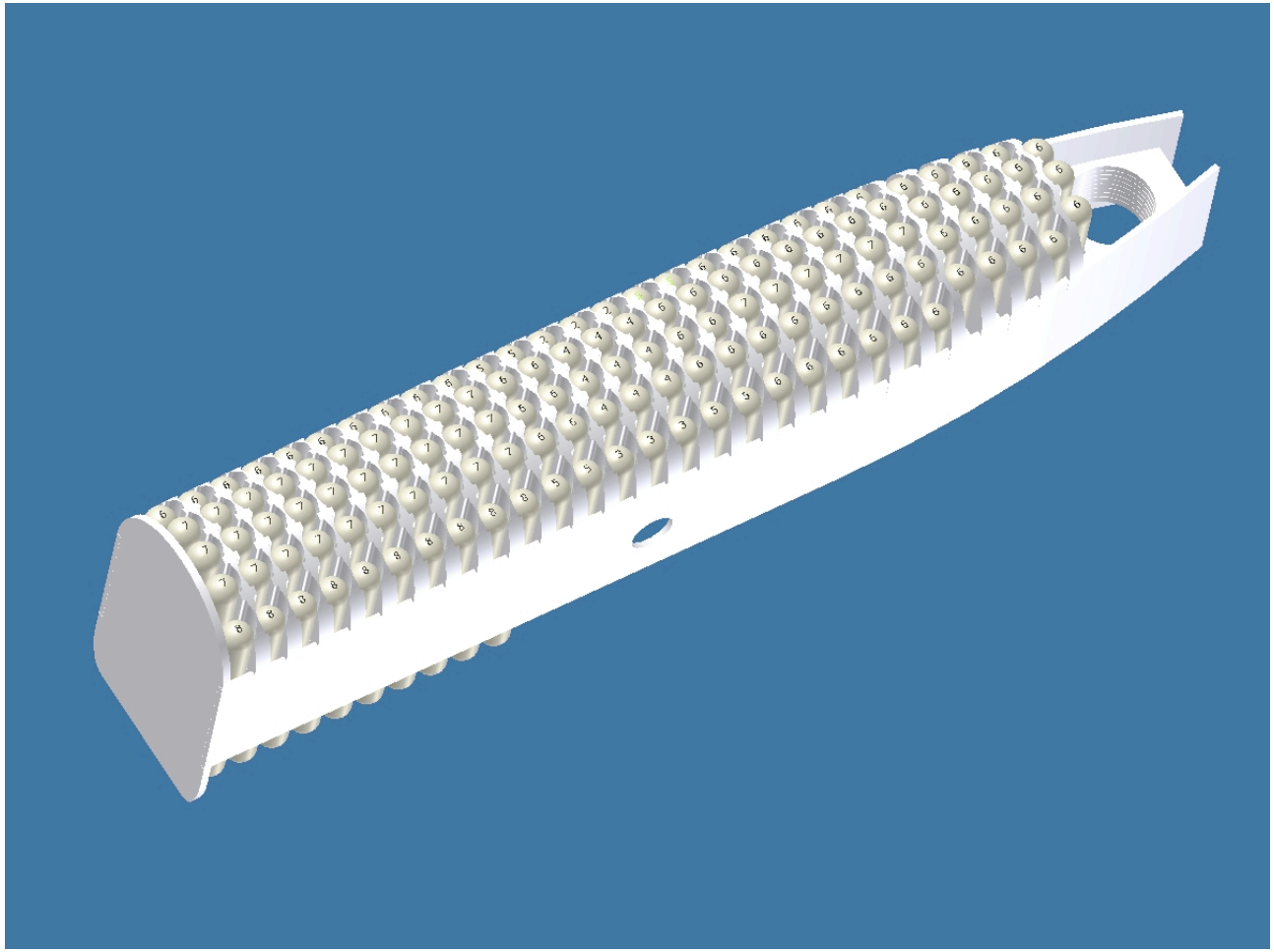
- Traditional syntactic foam for 11,000 meters has a S.G of .68
- 3.5 inch dia. alumina ceramic spheres have a S.G of .37
- Collapse pressure in excess of 30,000 psi (close to a 2X safety factor for HROV)

Vehicle Core



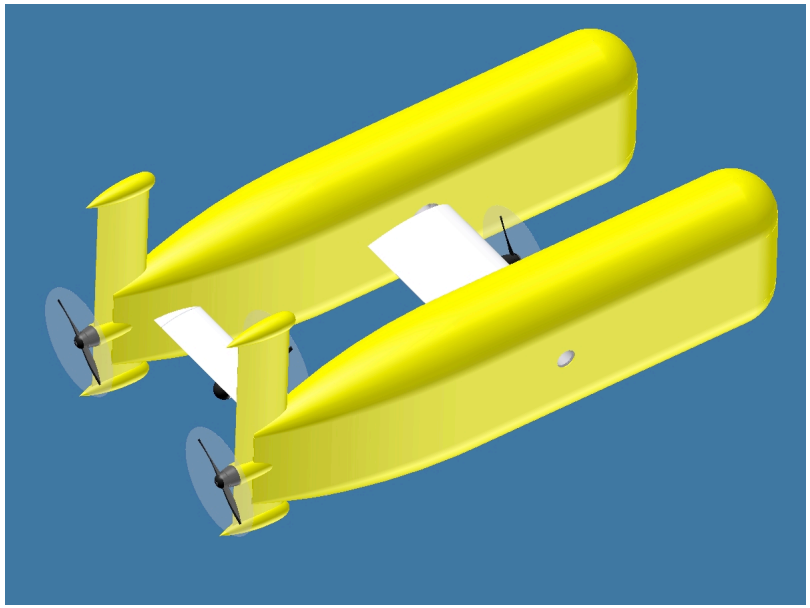
Main Structural Elements welded metallic cross structure
Polyethylene hull core/flotation matrix

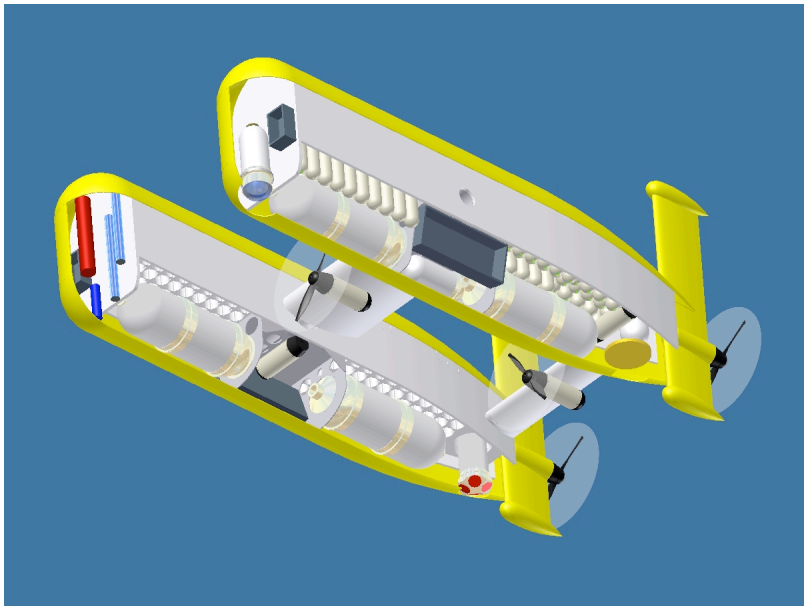
Flotation



750 jacketed ceramic spheres arranged within hull structure

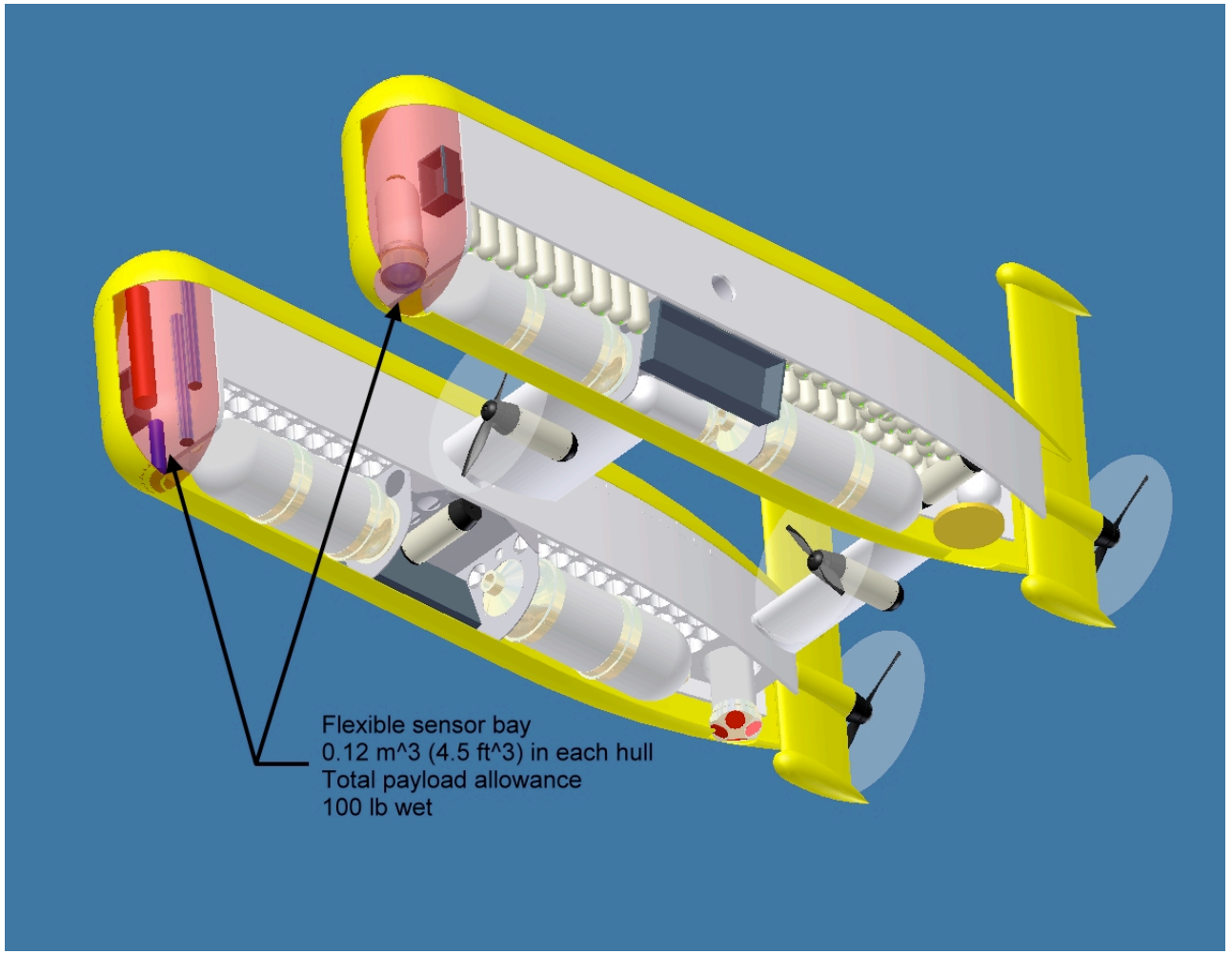
AUV Configuration





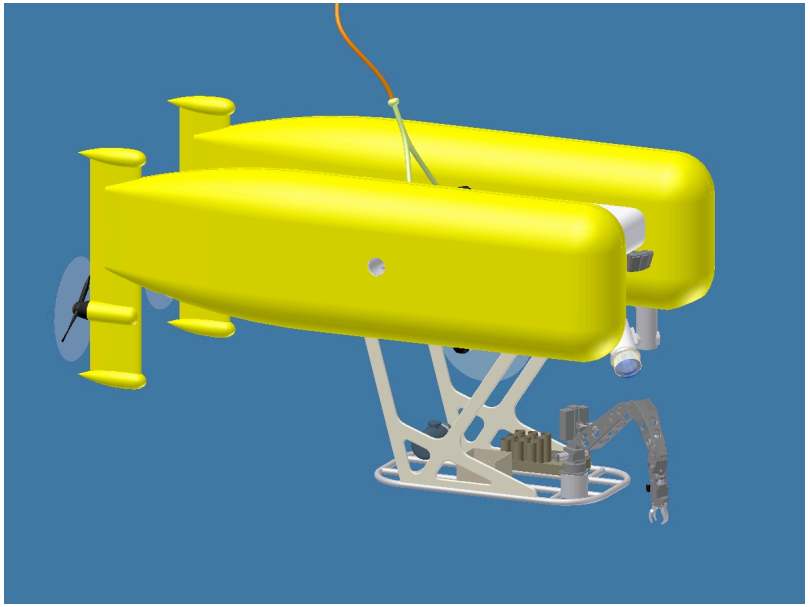
Payload Allowance
100 lb wet wt in forward bays
6 inches aft of vehicle nose

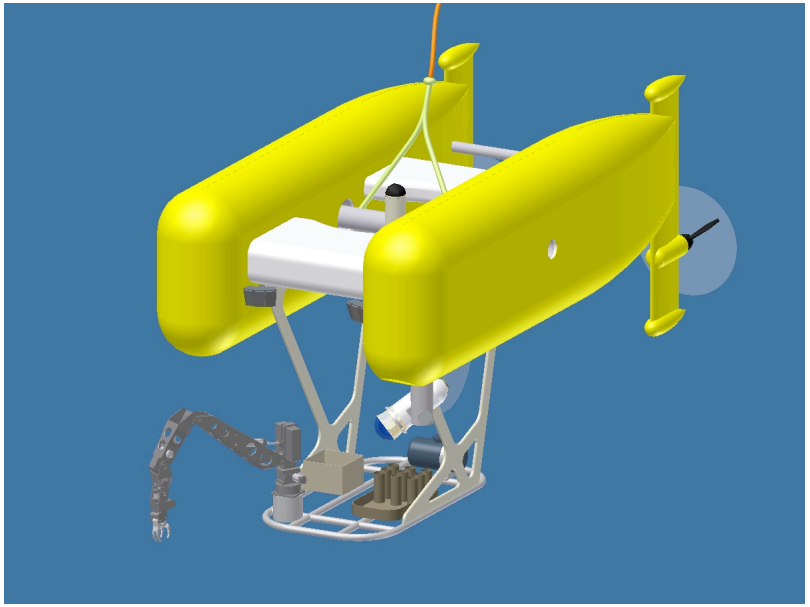
AUV Configuration



Skins removed to show internal configuration

ROV Configuration



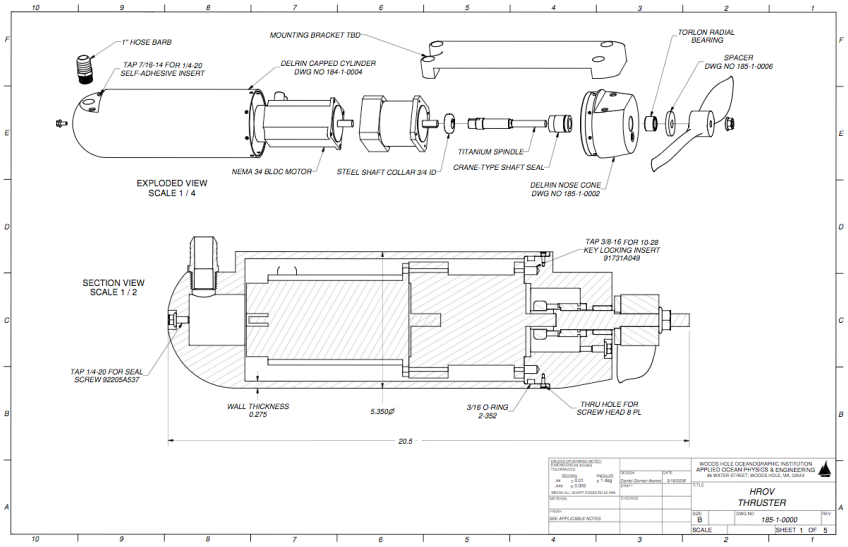


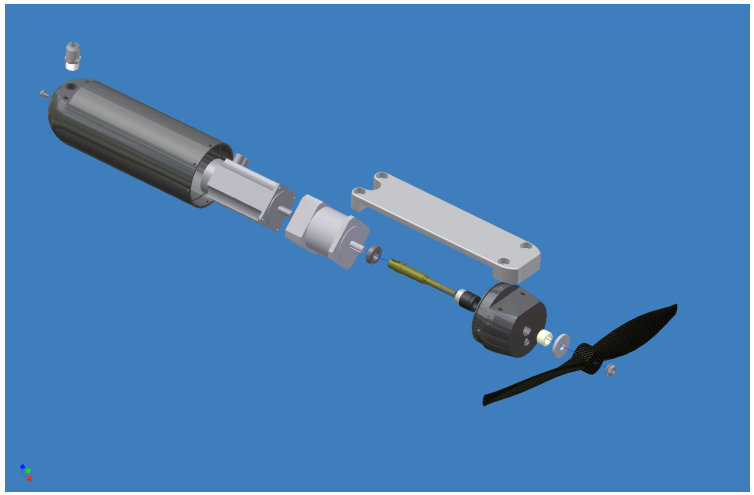
Payload Allowance
150 lb wet wt
In sample storage area
25 inches aft of vehicle nose

Propulsion Thruster

Permanent magnet brushless DC motor.

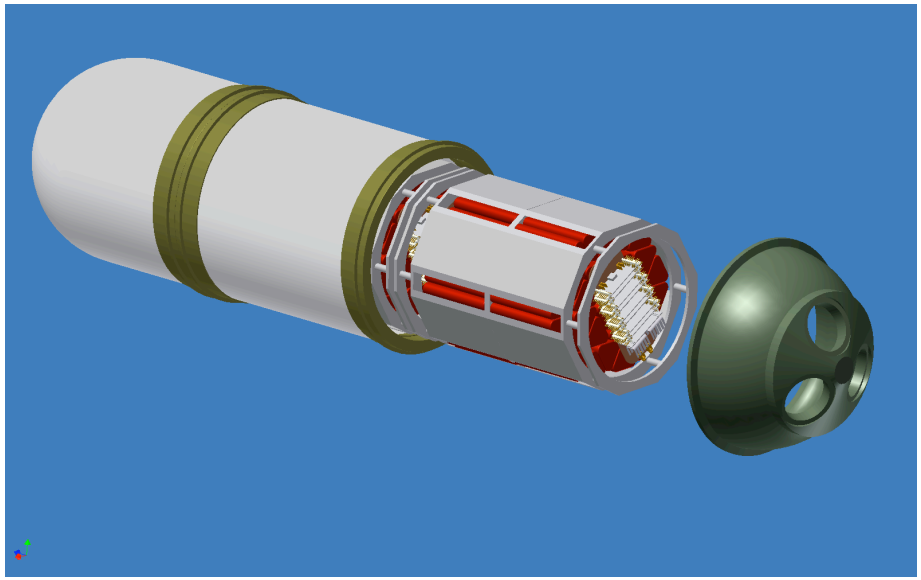
- Power Input: 750 Watts
- Weight: 6.3kg
- Thrust: 230N (51lbs)
- RPM: 200

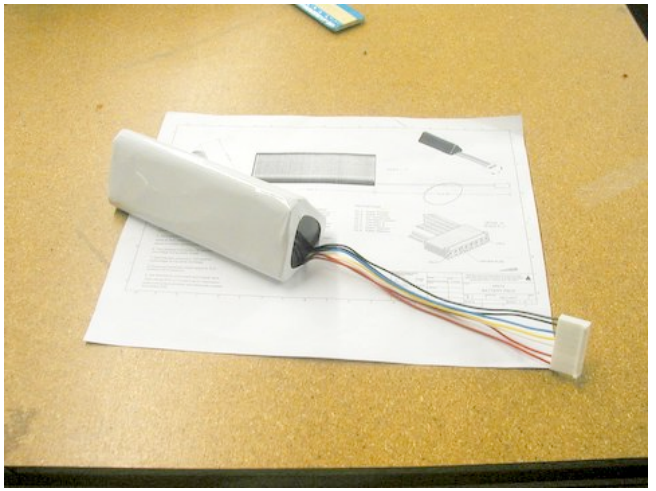




Lithium Ion Batteries

- 18 KWh total capacity
- 50 volt buss, 3KW charge/discharge
- 270 lbs weight
- Formal hazard analysis complete with external review
- First article battery in house undergoing test prior to U.N. testing



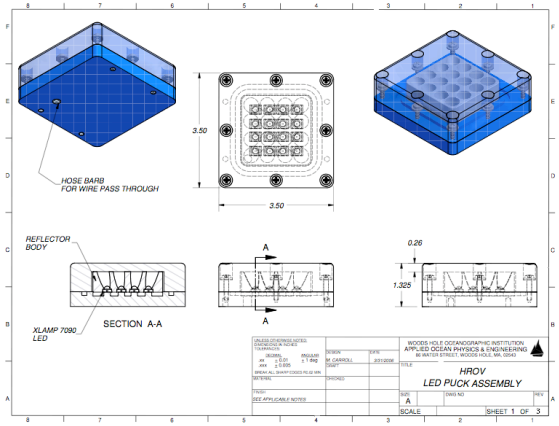


HROV Lighting Requirements

- Strobe capability
- Low power consumption
- Pressure tolerant
- Uniform illumination field

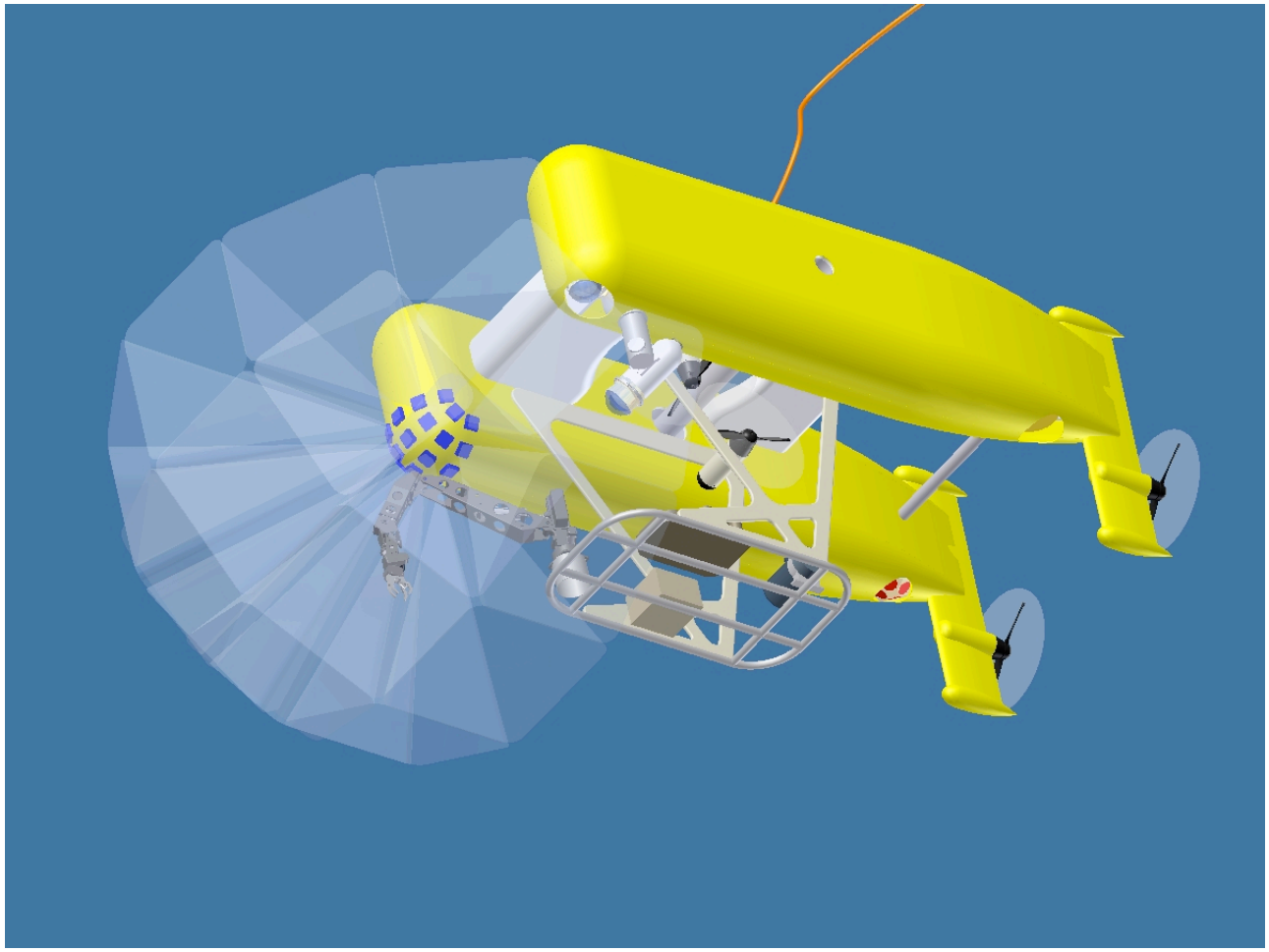
Two Task Dependent Arrays

- One downward looking, survey array
  - 56 element
  - 500nm (blue/green)
  - Range 5m to 20m (optimally 10m)



- Two forward looking, task arrays
  - 20 elements
  - Broad spectrum for close up color and video
  - Range 1m to 5m
  - Electronically aimable array coupled with camera motion

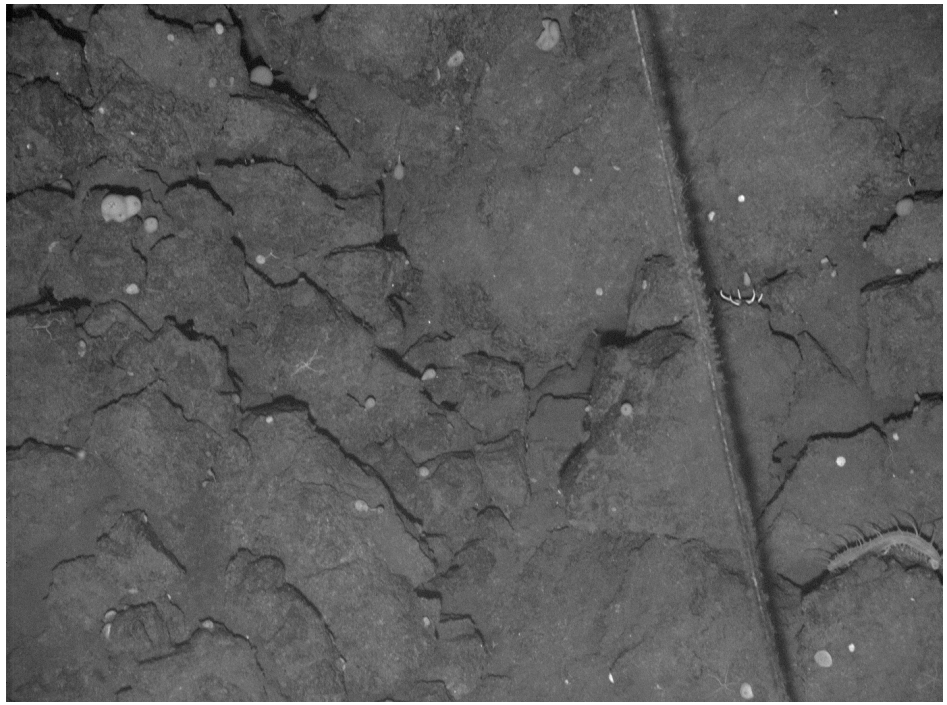
ROV Configuration



Segmented imaging array lighting coverage

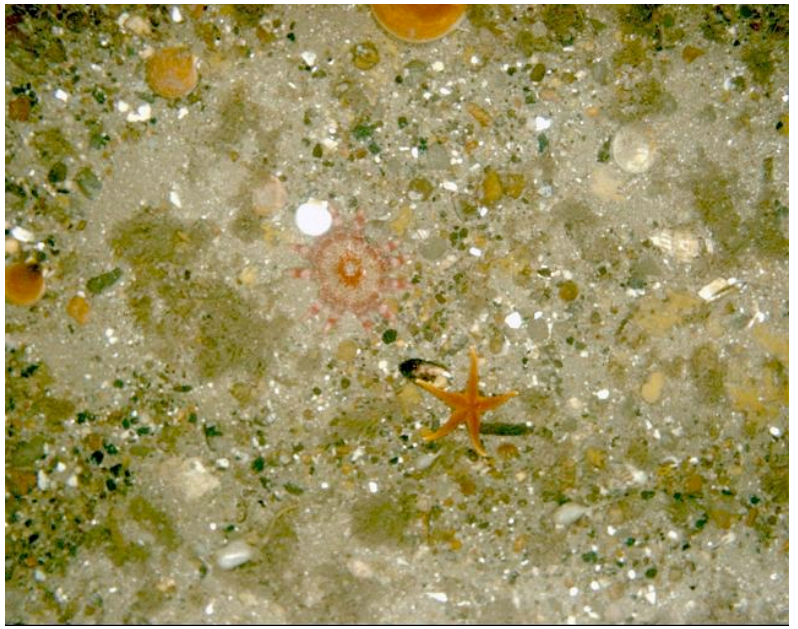
Cameras AUV Mission

- Single, down-looking grey-scale imager
- Domed utility housing
- Extension to color requires white-light strobe,new camera module
- Software tested in prototype form on ABE



ROV Mode

- Single imager for piloting, still cameras
  - Capable of 30 Hz, actual update driven by mission requirements
  - Remote zoom, focus
  - Optics in conjunction with Insite Pacific
- Two utility cameras (single chip, composite, Insite)
- All cameras sync'd—can view one utility camera at a time, driving strobes
- All cameras capable of operating at less than frame rate—strobe sync



HROV Potential Names!

- Aiolos
- Shad-EV
- Project Clearwater
- Oceanota
- Homarus
- PIC'S Sounder
- Nessie
- Jacques
- Reason
- Harv
- Ryujin
- Audrey
- Megalops
- Siren
- Nereus
- DORI
- DRACOS
- Chameleon
- Corsair
- Pueo
- CERES

Summary

- This is a unique, high risk project to develop new technology allowing cost effective access to unexplored areas of the ocean
- HROV technology will have important implications and feed forward into other oceanographic systems
  - Micro-fiber tether
  - Ceramics
  - High capacity energy storage
  - Efficient (autonomous) manipulation
  - Integrated lighting and imaging systems
- Exploration of the final 4,500 meters of the ocean and under ice environments **will** result in new discoveries