SOI Vehicle Program & S5k 4500m ROV

Tuesday, 25th August

HROV as part of the Schmidt Ocean Institute Research Program

Schmidt Ocean Institute was founded to advance the frontiers of ocean research and exploration through innovative technologies, intelligent observation and analysis, and open sharing of information.

Schmidt Ocean Institute core focus areas:

- Commitment to Excellence in Oceanographic Research Operations
- Infrastructure, Platform, and Technology Development for Marine Sciences
- Collaborative Scientific Research aboard Falkor
- Communications, Education, and Outreach Program
- Open Sharing of Information, Data, and Research Outcomes

Infrastructure, Platform, and Technology Development for Marine Sciences

- Robotic research vehicles (HROV, ROV, AUV, ASV, UAV, gliders, etc.)
- Deployable scientific platforms and analytical instruments
- At-sea R&D in technologies and computational algorithms on R/V Falkor and vehicles
- Technology focused R&D projects as part of Falkor cruise program

Long term goal for the HROV Program is to develop a robust full ocean depth robotic vehicle system to support research operations from R/V Falkor

SOI Vehicle Program Overview

Schmidt Ocean Institute is developing a series of three remotely controlled (hybrid) and one autonomous robotic vehicles for use on SOI's research vessel Falkor.

The remotely controlled (hybrid) vehicles will be developed sequentially, with gradually advancing depth and operational capabilities, with the goal to support scientific research throughout the full range of ocean depths, including scientific operations at full ocean depth.

The goal for the first 4500m vehicle development is not to push the boundaries of high risk technology R&D, as will be the case for the subsequent vehicles, but to demonstrate the ability of the SOI engineering team to manage the vehicle development and on schedule delivery before starting higher risk technology R&D.

Overview of the Vehicle Program

Program/S5K Project Planning

Direction provided in Dec 14 to conduct a multi vehicle program with deliverables based on engineering iteration, budget approved late Jan 15, 1st engineers on-board April 15;

- Vehicle 1 – S5K 4500m Conventional Hydraulic Vehicle (COTS)
  - Develop the Team, Culture and prove SOI can deliver its own vehicle.
  - Parallel R&D - PBOF Electronics, Power Supplies, Motor Controllers and Thruster Technology
  - Provides a platform to Falkor to develop & optimise without reliance on rental systems.
- Vehicle 2 – S7K 7000m HROV, battery operated vehicle
  - Develops the knowledge & technologies for FOD
- Vehicle 3 – S11K 11000m HROV, battery operated vehicle
  - Ultimate goal of the program
- SOI AUV – 6000m TBC DOF
  - Companion to the S5K 4500m ROV
  - Development commencing 2015 – SMR
- Inter Vehicle Compatibility Where Possible
- 5+5 year maintenance & upgrade plan

SOI Oceanographic Institution - Technology Development Program

SCHMIDT OCEAN INSTITUTE

Technology Development

Tuesday, 25th August

4500m ROV Project Objectives

The first 4500m rated vehicle will be developed as an ROV and outfitted with a suite of sensors and scientific equipment to support scientific data and sample collection as well as interactive research, experimentation, and technology R&D, including but not limited to:

- physical sample collection and recovery
- seawater characterization,
- acquisition of high quality underwater video, photomosaicing,
- object manipulation, deployment and recovery of equipment,
- seafloor mapping, and surveying, etc.

This vehicle is planned for Factory Acceptance Testing in April 2016 and subsequent Sea Acceptance Testing in summer of 2016.

Science Verification Cruise – Scheduled for November 2016

This vehicle shall employ proven technologies and operational modes, with preference for commercial off-the shelf (COTS) subsystems and components and tethered, surface piloted operation

From the objective statement derived the Operational Requirements which required further augmentation with the Science Mission Requirements.

Science Advisory Group Structure and Purpose

Science Advisory Group (SAG)

- Scientific mission requirements for the Schmidt Ocean Institute 4500m ROV were developed in close coordination with an international group of deep sea researchers and technology developers
- Research Fields represented:
  - Geosciences – 8 experts
  - Marine Biology – 9 experts
  - Microbiology – 8 experts
  - Geochemistry – 7 experts
  - Ocean Technology R&D – 13 experts
- Countries:
  - Australia, Canada, Germany, Japan, Singapore, UK, USA
- Participation:
  - Survey 1 (SMR): 28 experts responded
  - Survey 2 (Instrument Selection): 30 experts responded

Survey 1 & 2: 4500m ROV Science Mission Requirements

Survey 1 - Purpose:

To collect input from the scientific user community on the general operational, scientific surveillance, and research capabilities of a new 4500m ROV.

- Conducted by 28 representatives of the International Deep Ocean Research community who completed the SOI 4500 m ROV Science Mission Requirements Survey (Science Advisory Group)
  - Science Mission;
  - Scientific Sensors;
  - Imaging Systems;
  - Sampling Systems;
  - Seafloor Surveying Systems;
  - Vehicle Instrument Interface;
  - Navigation
- SOI Engineers prioritized the sensors/systems and graded them as Core/Non-Core

Survey 2 - Purpose:

To gather feedback from the international expert user community of scientific ROVs on the scientific instruments and systems presently selected for inclusion into the ROV core design or into the list of its supported add-on instruments based on the input from the previous survey.

- Completed by 25 representatives of the International Deep Ocean Research community over a two week period. Of the original SAG, 17 participated in this survey.
  - Scientific Sensors
  - Imaging Systems
  - Sampling Systems
  - Sonar Systems
  - Vehicle Instrument Interface
  - Navigation
  - Data Annotation Capabilities

S5K 4500m – Core/Non-Core Systems

Core System Sensors
CTD Sensor - Seabird FastCAT CTD Sensor (SBE49)
Pressure Depth Sensor - Paroscientific 8000 Series Submersible Depth Sensor
Oxygen Sensor - Contros Hydroflash O2 Sensor
Add-On System Sensors
Turbidity Sensor - Sea-Point Turbidity Meter (STM/MCBH6M)
Carbon Dioxide Sensor - Contros HydroC CO2
Nitrate Sensor - Seabird DeepSUNA
In-situ Mass Spectrometer - Sea Monitor
High Temperature Water Sensor - TBD
Biomolecular Analyzer - TBD
Redox Potential Sensor - TBD
Fluorometer - TBD

Core Imaging Suite
Situational Video - Sulis-1 4K video camera
HD Science Zoom - Insite Zeus Plus or SULIS 4K 12x Zoom
HD Camera - HD Multi SeaCam 6150
Pan / Tilt / Zoom - Schilling
High Resolution Still Image Capture - Sulis
Full Spectrum LED Lighting - DeepSea Power & Light, Inc. SLS-6150
Video recording system - Triton Technical
Frame Grabber - Greensea Systems
Add-On Imaging Suite
3DHD - TBD
Audio Recording Capability - TBD

Core Sampling System
Water Sampler - Optimized Niskin Design
Add-On Sampling System
Multi-Chamber Suction Sampler – SOI Custom Build
Push Core – SOI Custom Build
Rock Saw / Cutter / Splitter / Core - TBD
Multichamber Insulated Bioboxes (for fragile animals) - TBD

S5K 4500m – Core/Non-Core Systems cont

Core Sonar System
Forward Looking Imaging and Multibeam Mapping Sonar - M3 Multibeam Echosounder
Singlebeam 360° scanning sonar - Mesotech 1071 Series Sonar Head
Add-On Sonar Systems
Sidescan Sonar - TBD
Magnetometer - TBD
Sub-Bottom Profiler - TBD
Photographic Seafloor 3d/2d Mosaicing - TBD

Core Vehicle Interfaces
RS-232 ports up to 115 Kbps - Core Interface
RS-485/RS-422 ports up to 2.5 Mbps
Ethernet 10/100 Mbps
Time-to-live (TTL) link
3 optical fibers for high speed data transfer
Power 5 VDC, 12 VDC, 24 VDC, and 230 VAC
At least four (4) hydraulic rate valve pack channels
At least two (2) hydraulic servo valve pack channels

Core Navigation Systems
Ring Laser Gyro - Sonardyne Lodestar
Inertial Measurement Unit / Inertial Navigation System (IMU/INS) - Sonardyne Sprint
Ultra-Short Baseline (USBL) Transponder - Sonardyne WMT
Doppler Velocity Log (DVL) - Sonardyne Syrinx
Global Positioning System (GPS) antenna - Iridium XEOS
Add-On Navigation Systems
Acoustic Doppler Current Profiler (ADCP) - TBD

System Constraints

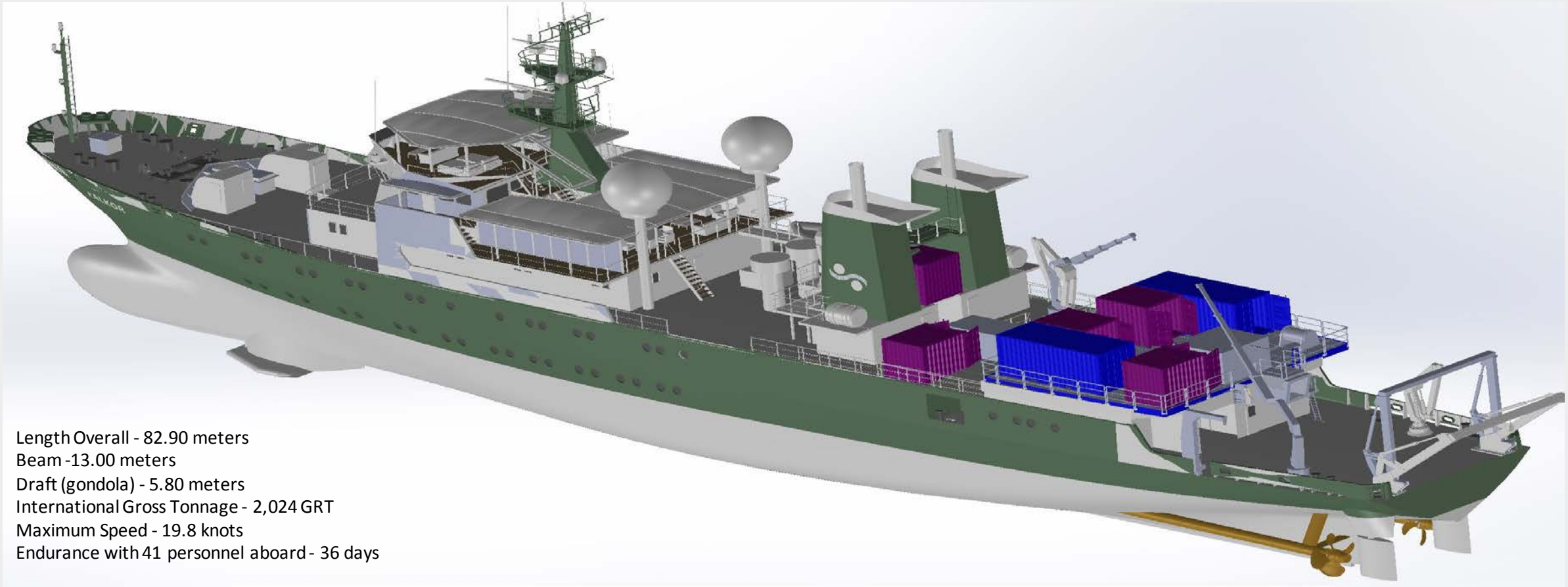
R/V Falkor

- A Frame (4500kg (veh 3200kg & docking head 1300kg))
- Storage Deck Loading (42ton (Winch & Container Weight))
- Staging Bay (hangar 2030mm x 2290mm)
- Dynamic Positioning limited capability (approx 50m watch circle)
- Propulsion and Fan Tail Layout
- Native Power (50Hz 380V)
- Science Control Room

Schedule

- FAT by End April 2016

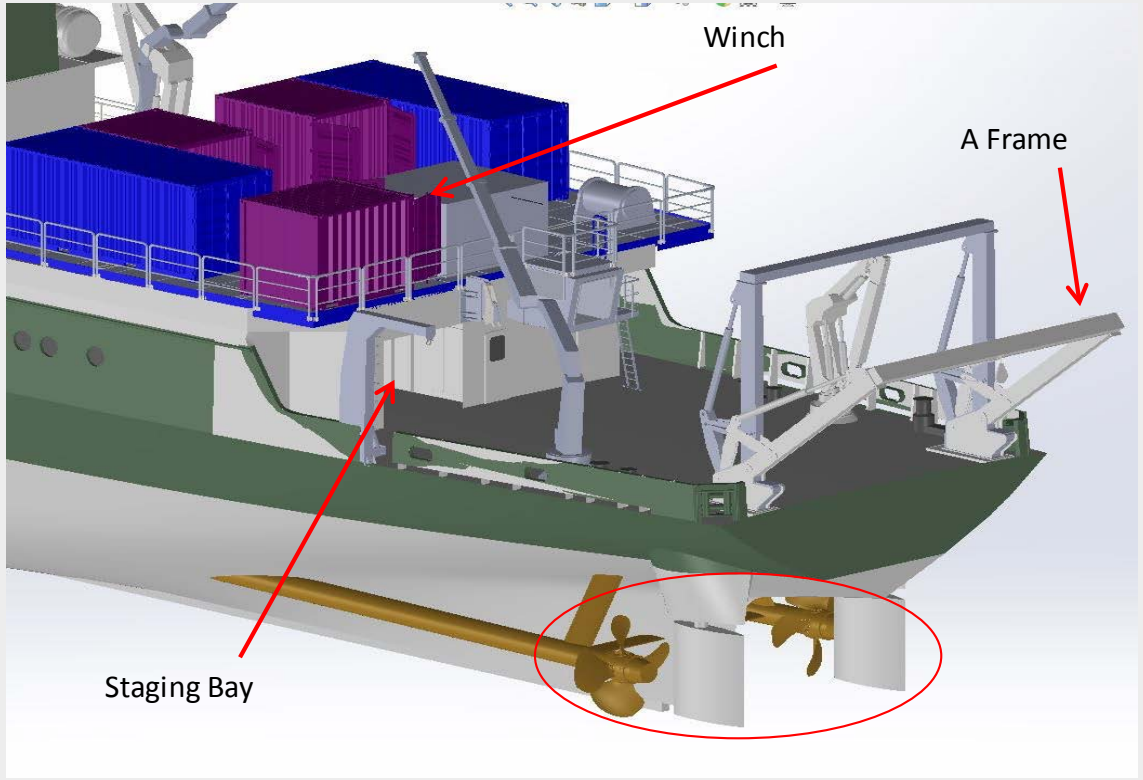
R/V Falkor



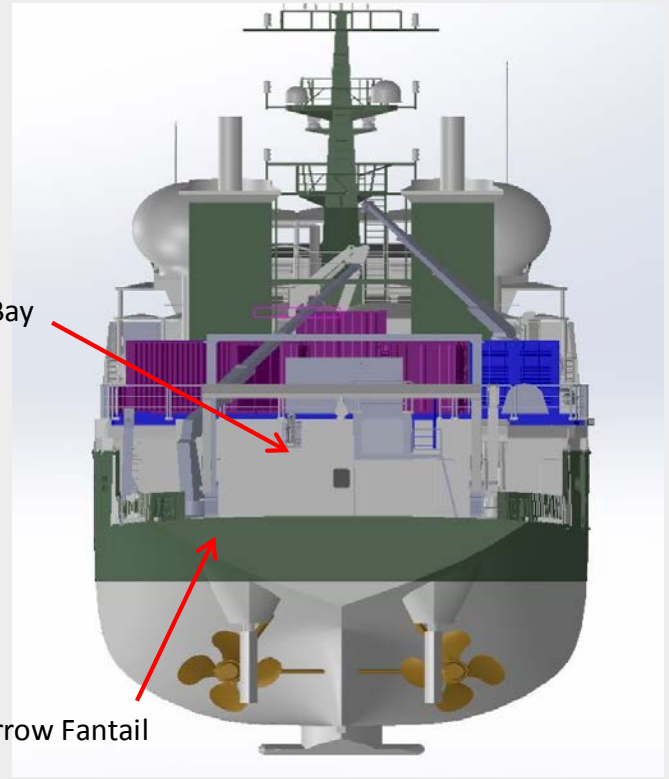
Length Overall - 82.90 meters
Beam -13.00 meters
Draft (gondola) - 5.80 meters
International Gross Tonnage - 2,024 GRT
Maximum Speed - 19.8 knots
Endurance with 41 personnel aboard - 36 days

R/V Falkor cont

Falkor Danger Zones



Falkor Rear View



S5K 4500m – Preliminary Specifications

Single Body Catenary Supported "Live Boat" Configuration

Vehicle Specifications	
Depth Rating	4500m
Speed	3 Knots free run
Payload	100kg minimum
Bollard pull Forward	600kg
Bollard Pull Aft	550kg
Bollard Pull Lateral	3350kg

Hydraulic Specification	
Electric Motor	45hp
Motor Voltage	4150VAC 50hz
Main Pump	Rexroth 100cc
Pressure	207 bar
Flow	131Lpm
Valve Packs	8x Proportional 15Lpm
	8x Solenoid 15Lpm
	6x Servo 60Lpm
Thrusters	4x Sub Atlantic SA300-30
	1x Sub Atlantic SA380-42
Manipulators	2x Schilling Titan 4

Vehicle Dimensions	
Length	2700mm*
Width	1800mm*
Height	1800mm*
Weight in Air	3200kg*

Navigation Sensors	
MRU	Sonardyne Lodestar
DVL	Sonardyne Syrinx 600kHz
Depth	Paroscientific DigiQuartz
USBL	Sonardyne Ranger 2
INS	Sonardyne Sprint

Sonars	
360° Scanning	Kongsberg 1071 - 330kHz
Bathymetric (or)	Kongsberg M3 - 500kHz
Forward Imaging	Kongsberg M3 - 500kHz

Science Sensors - Core	
CTD	SeaBird 49
Dissolved Oxygen	Contros HydroFlash

Science Interfaces	
RS-232	6
RS-485	2
RS-422	2
10/100 Ethernet	2
Gig Ethernet	3
12VDC Switched	4
24VDC Switched	4
Hydraulic	6x Proportional - 15Lpm
	2x Servo - 55Lpm

Physical Sampling Capabilities	
Suction Sampler	8x 6L jars
Core Tubes	Up to 24/dive
Biological Collection	Insulated and Sealed Bioboxes
Storage Tray	1400mmW x 900mmD x 500mmH
Aft Science Bay	1800mmW x 900mmD x 500mmH
Niskins	4x 6L

System Cameras	
Science / Tooling HD	3x 1080p30
Science / Tooling Zoom	1x 1080p30 10x zoom
Tooling SD	3x 480x640
Manipulator Camera	1x 480x640 PAL

Science Zoom Camera (potential)	
Resolution	4130x2160 30fps
Still Capture	20Mp
Field of View	90° Diagonal
Mounting	Pan / Tilt / Extend
Pan / Tilt range	240° Pan, 135° Tilt
Zoom	12x
Dynamic Range	12 Stops

Situational Camera - 4k video and Stills	
Resolution	4130x2160 30fps
Still Capture	12Mp
Field of View	100° Diagonal
Mounting	Bumper Bar - Tilt only
Tilt Range	135° Tilt
Dynamic Range	12 Stops
Strobe	LED - 120,000 lumen

Lighting	
High Output	4x Cathx Aphos 16 LED
	28,000 Lumen
	5700k Color Temp
Medium Output	10x DSPL SLS6150 LED
	11,000 Lumen
	5700k Color temp
Low Output	6x DSPL SLS6130 LED
	6000 Lumen

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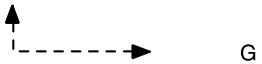
S5K 4500m – Program Organisation



SOI ROV Operations Team

Tuesday, 25th August

The Umbilical

Link between the vehicle and the ship

Requirements

- 4500m vehicle depth rating
- Support for future vehicles (depressor)
- Communications and power (Vehicle & Hotel)
- Strength capacity:
  - Support its own weight at depth
  - Mode 2: Depressor weight at depth
  - Vehicle in air weight
  - Sea state 5 Dynamic Loading

Constraints

- Storage deck capacity/Ship Stability
- Winch capacity
- A-frame capacity

Umbilical Specifications

Umbilical Analysis completed:

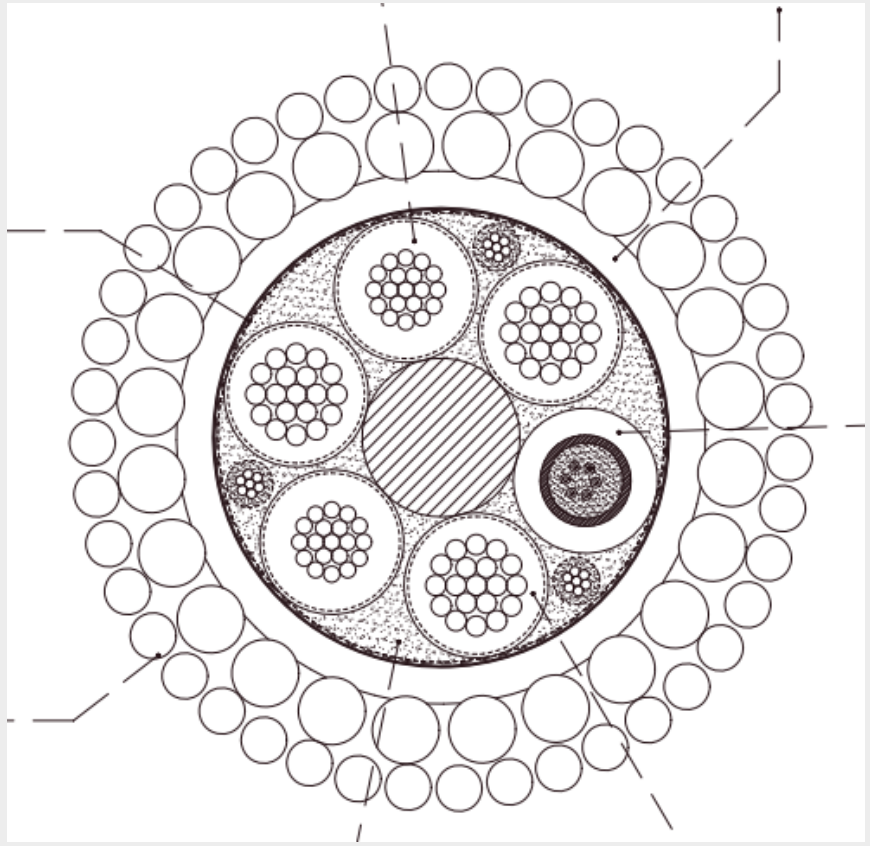
- Manufacturer Selection:
- Propulsion requirements (Vehicle HP):
- Vehicle Electrical Requirements:
- Loading analysis: Completed simultaneously to selection process

Size of umbilical optimized, while meeting operational requirements.

- Minimize Diameter → minimize drag → Minimize HP → Minimize Load on Surface equipment

Recommendation:
(specifications listed which affect overboarding analysis)

- Cortland - 19.1mm diameter cable
- Weight in air: 1,220kg/km (5500m →6,710kg)
- Weight in SW: 920kg/km (4500m →4,140kg)
- Max SWL: 65kN
- Minimum Breaking Load = 200kN
- Max Rotation: 3.3°/m@ SWL (4500m →~12.7 Revolutions)



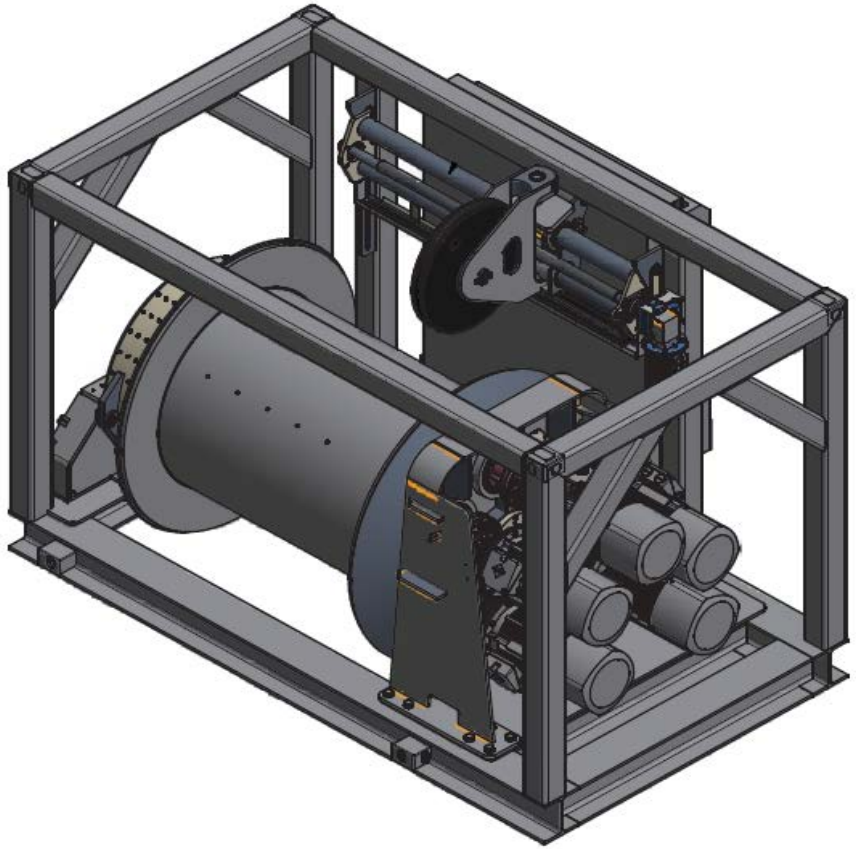
Current Status of Winch Design

Preliminary design of winch determined

- 5x 45kW straight drive electric motors
  - *AHC requirements*
- 10’ container footprint
  - *shipping, and storage deck mounting*
- 24.5MT with 5500m of Umbilical
  - *storage deck strength and stability*
- 450 Peak current draw
  - *Available Power*

Next Steps

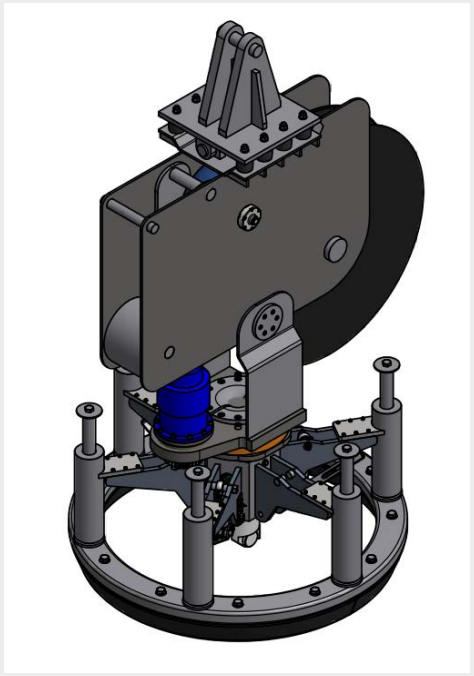
- Design details being refined by SOI/MacArtney
- Detailed design review in house prior to vehicle DDR (Manufacturing timeframe)

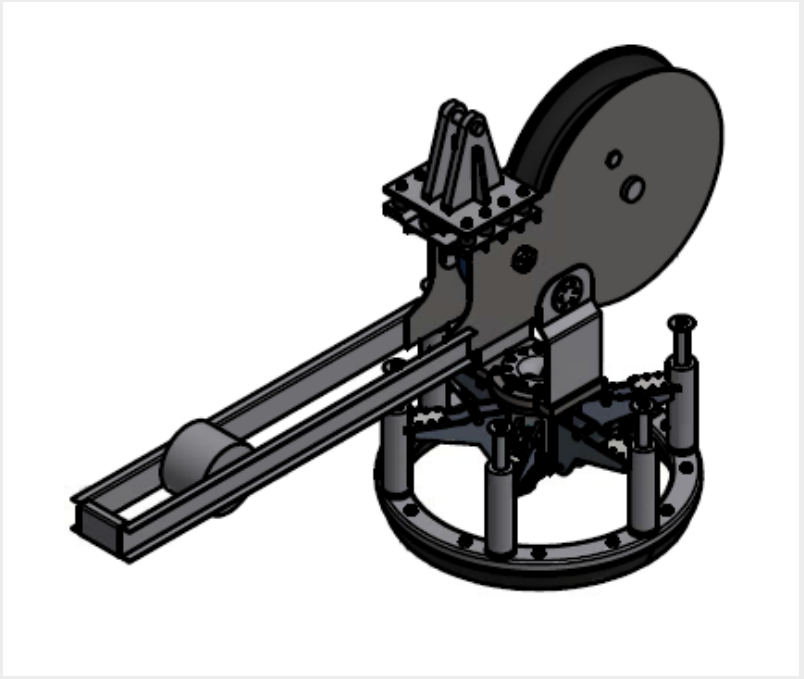


Current Status of Docking Head Design

MacArtney selected as primary vendor.

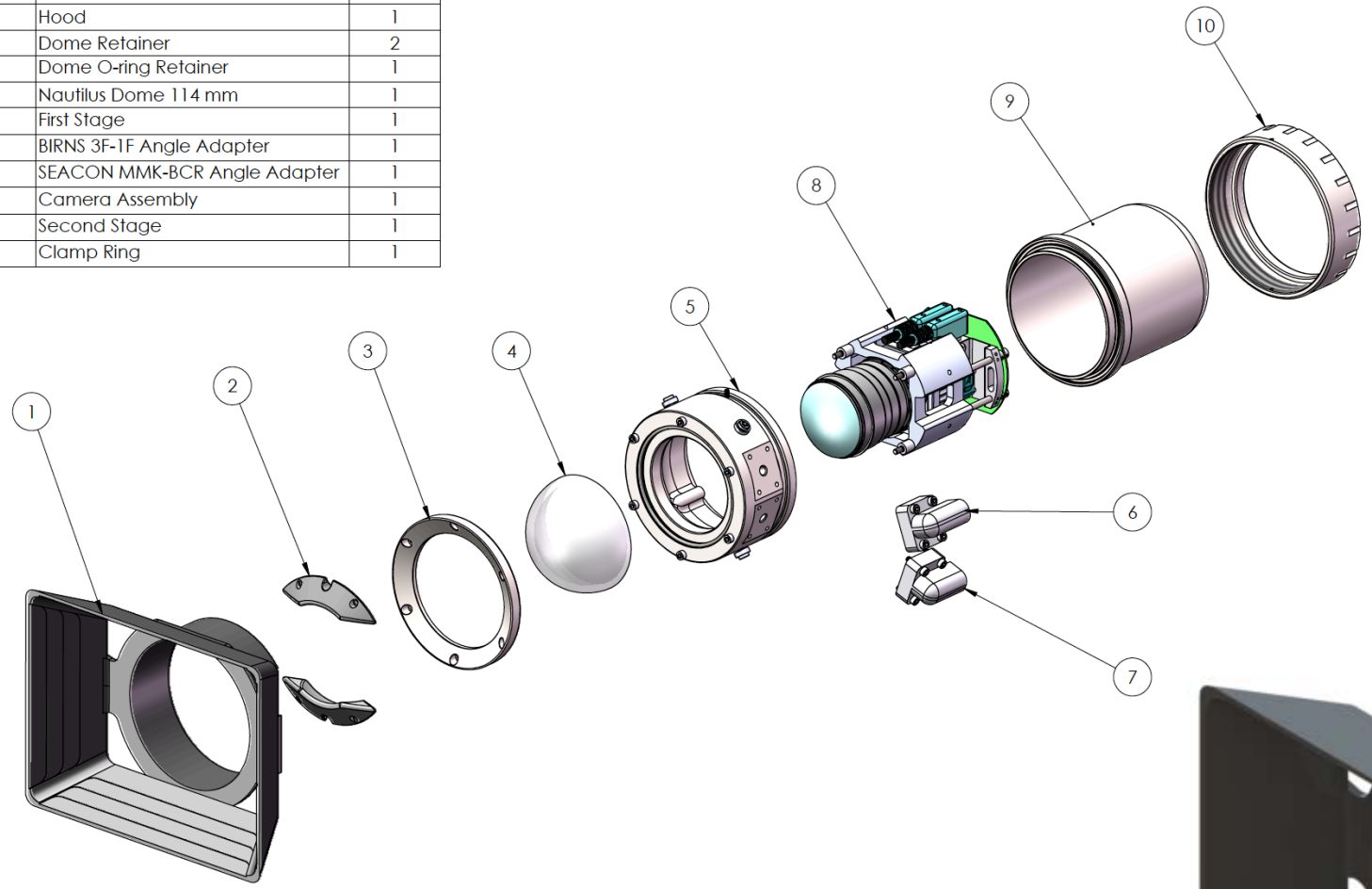
→ **Complete system**: A-frame, Winch, Docking Head, Umbilical Termination





3 iterations of preliminary design

ITEM NO.	PART NUMBER	QTY.
1	Hood	1
2	Dome Retainer	2
3	Dome O-ring Retainer	1
4	Nautilus Dome 114 mm	1
5	First Stage	1
6	BIRNS 3F-1F Angle Adapter	1
7	SEACON MMK-BCR Angle Adapter	1
8	Camera Assembly	1
9	Second Stage	1
10	Clamp Ring	1



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S5K 4500m Scientific Camera

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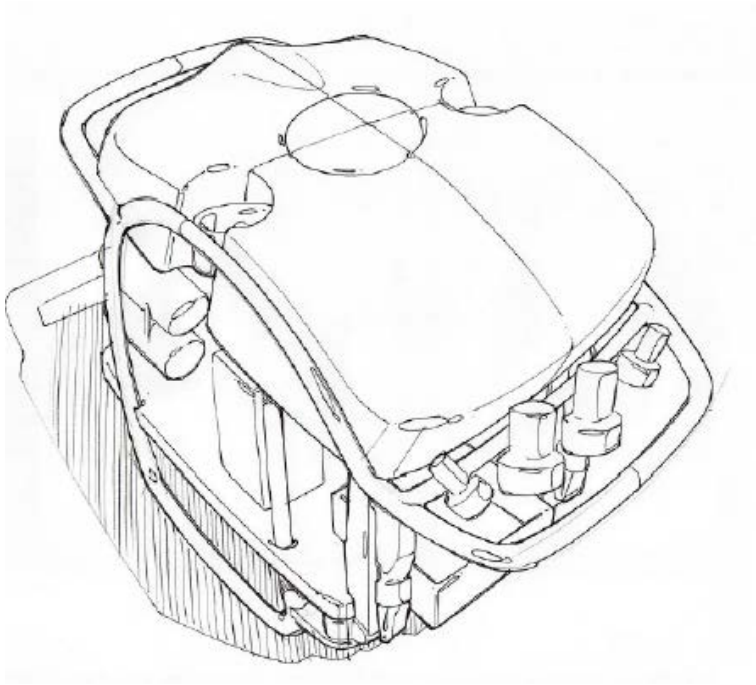

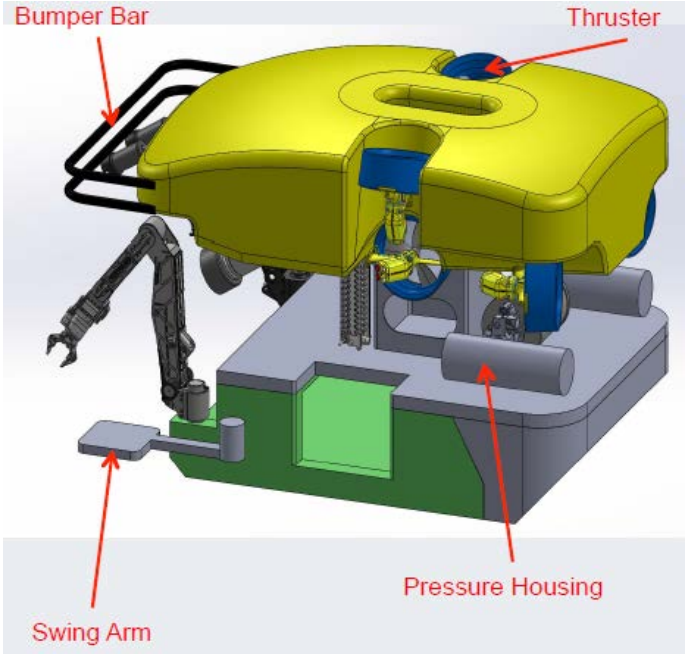

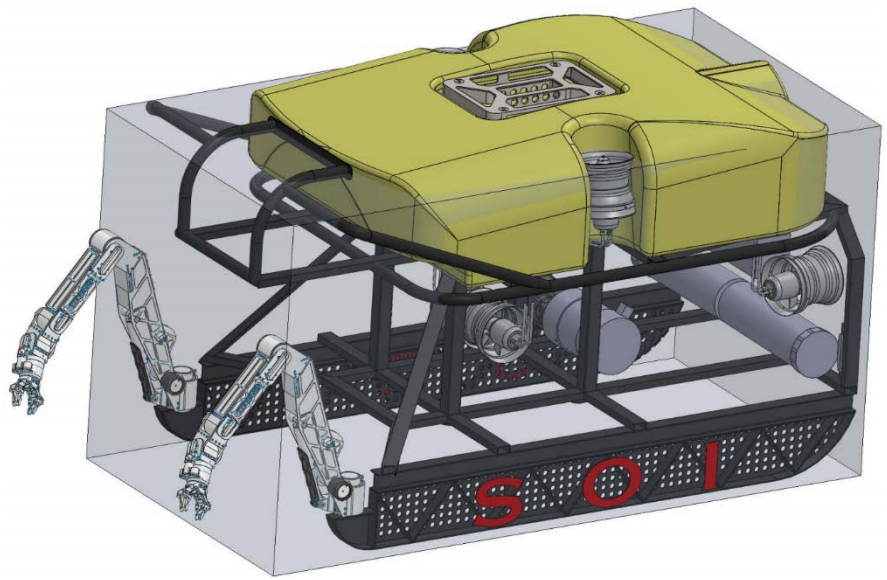

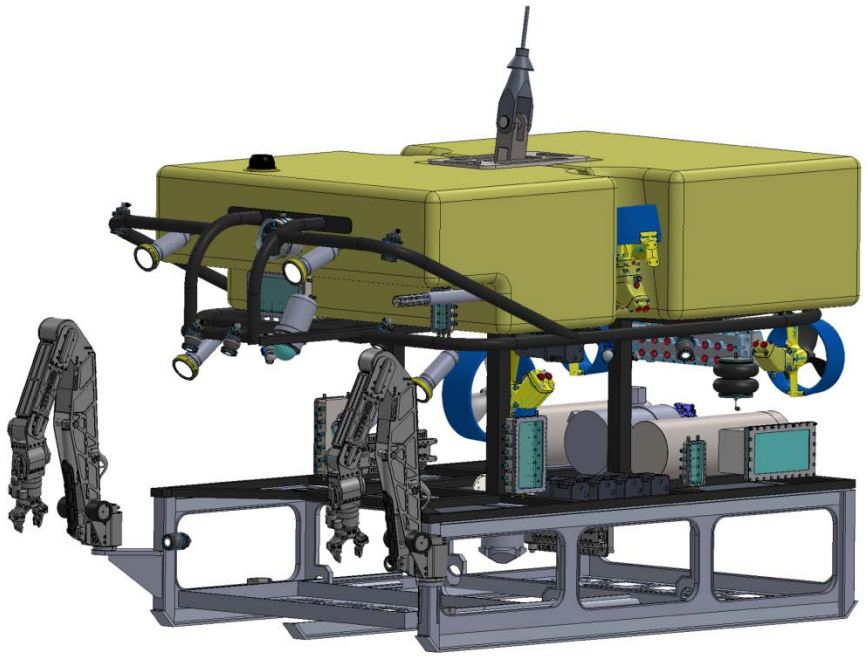

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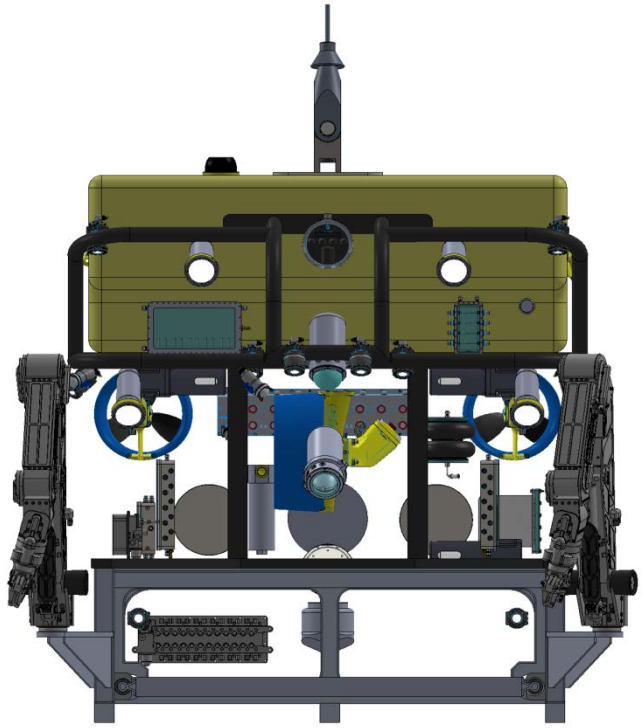
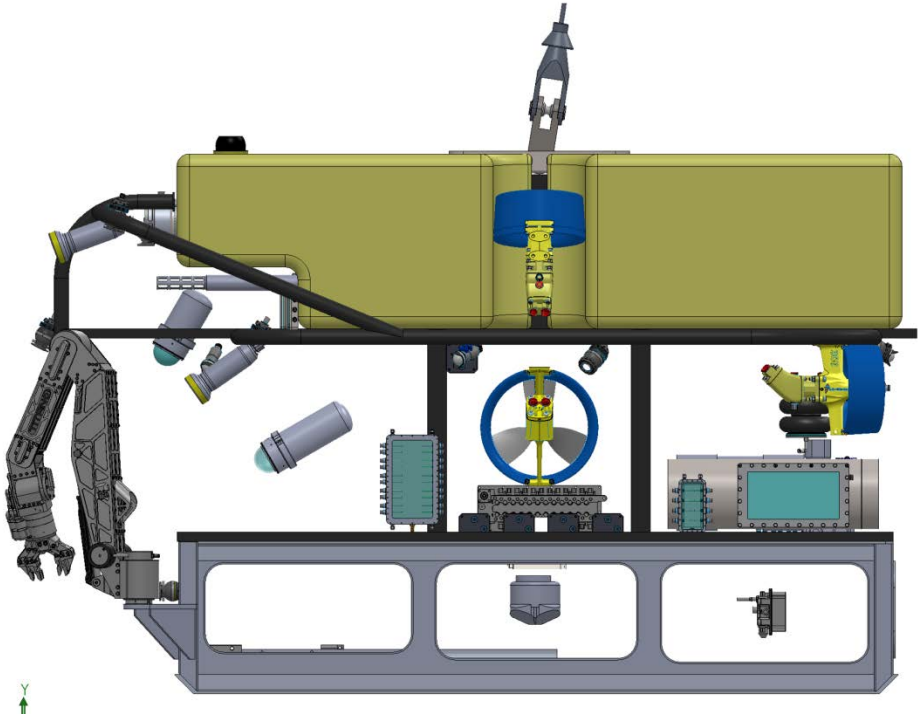
S5K 4500m ROV Evolution

S5K 4500m ROV – Vehicle Current Layout

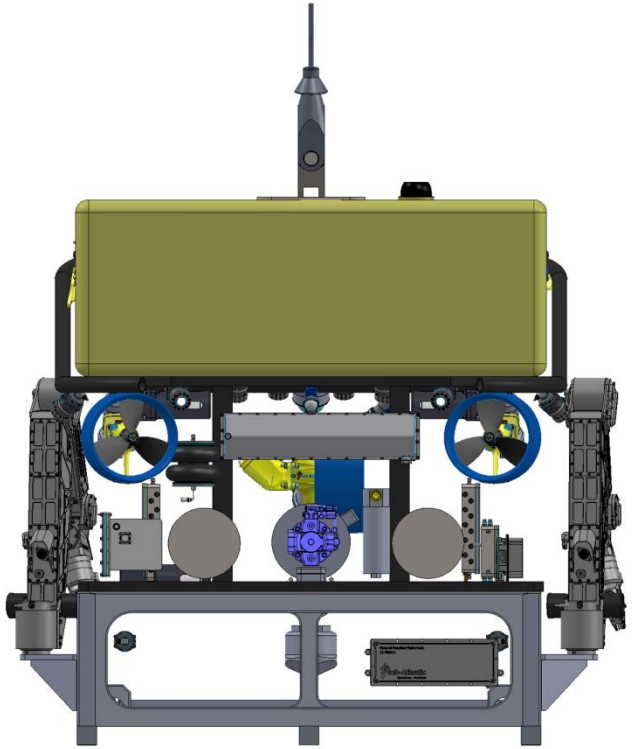
Front View

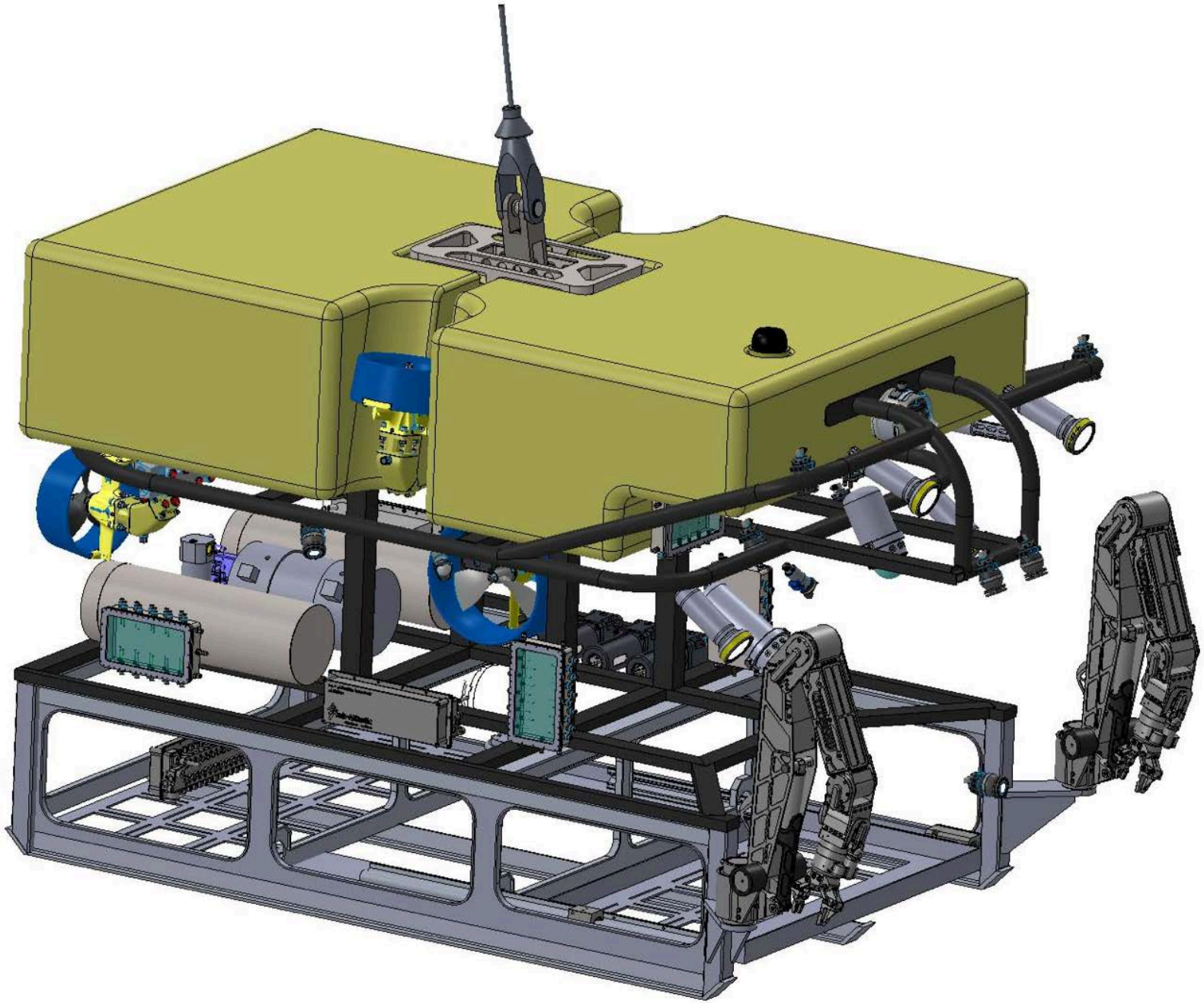


Side View



Back View





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S5K 4500m Functional

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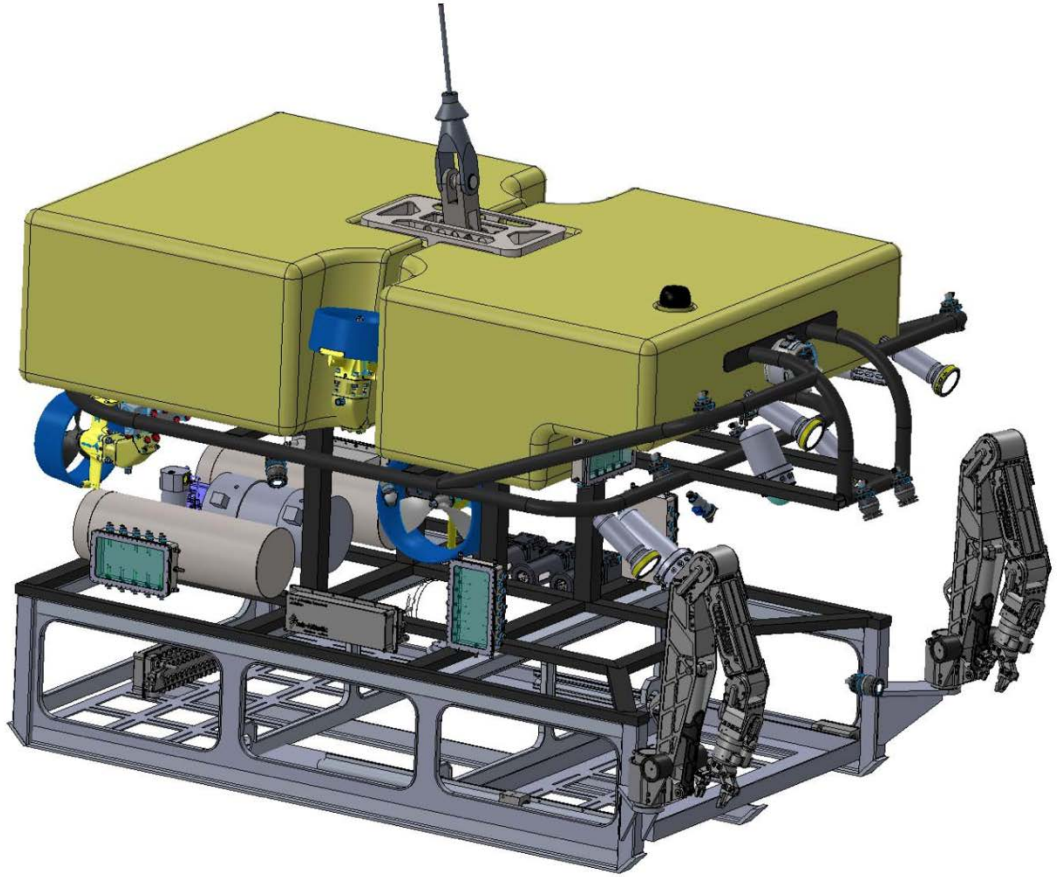

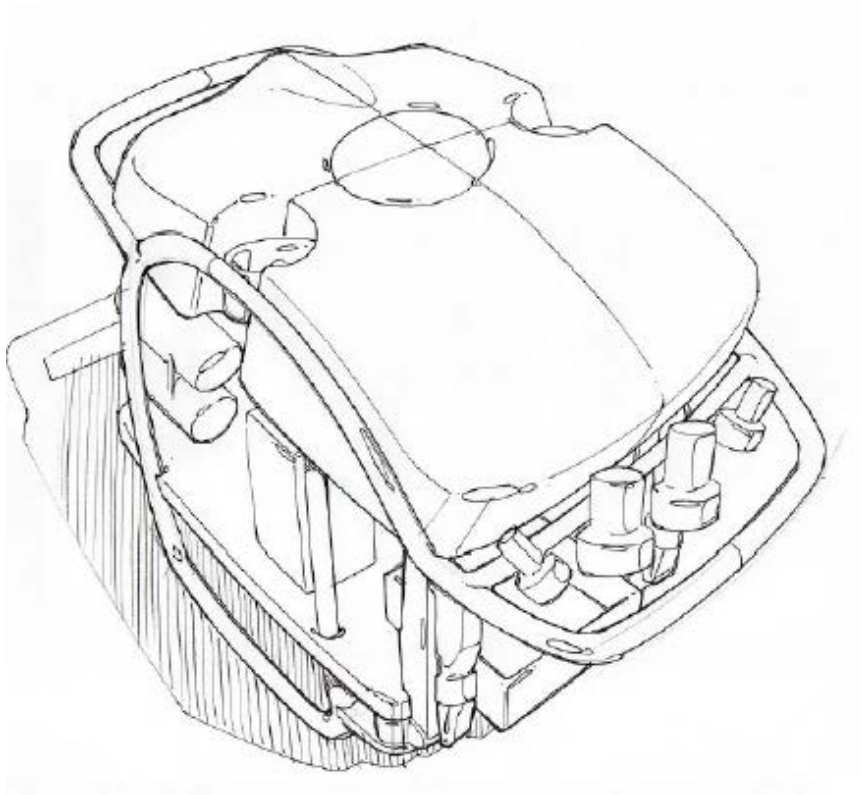

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S5K 4500m Function vs Form

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Progression as at 24 August 15

- Major System in design or contract:
  - Floatation Foam - Trelleborg
  - Winch - MacArtney
  - Docking Head - MacArtney
  - Umbilical – Cortland
  - Manipulators – Schilling T4 (2)
  - Imaging - SULIS
  - Cmd & Ctrl, Power & Telemetry - GSS
  - Power Distribution Unit (PDU) – Tinitron (TBC)
  - Machinery Vans – Silhoutte Steel (TBC)
  - Hydraulics & Propulsion – SOI
  - Electrical Systems Architecture – SOI
  - GA - SOI
- Design Status:
  - **Concept Design Review (CDR) May 2015**
  - Preliminary Design Review (PDR) 2-4 September 2015
  - Detailed Design Review (DDR) 17-18 Dec 15
    - Winch DDR Oct 2015
    - Docking Head DDR Oct 2015
    - Machinery Vans DDR Oct 2015

- Sub System Manufacturer Testing:
  - Floatation Foam FAT Jan 16
  - Winch – FAT Dec 2015
  - Docking Head – FAT Dec 2015
  - Umbilical – FAT Dec 2015
  - Manipulators – FAT Dec 2015
  - Power Distribution Unit (PDU) – FAT TBC
  - Machinery Vans – FAT TBC
- System Integration & Testing:
  - FAT (Hayward) 1-15 April 2016
  - Tank Testing (MBARI) 16-30 April 2016
  - Winch SAT , 4 – 7 July 16
  - SAT 1 (Engineering), 12 – 30 July 16
  - SAT 2 (Engineering Confirmation) 1-14 Aug 16
  - SVC 18-29 Nov 16

S5K 4500m ROV - Conclusion

Budget

- Currently on track and as the design matures expect to remain budget +.

Design

- Currently meeting SAG's SMR & Operational requirements
- Currently on schedule overall some minor areas lagging behind:
  - Machinery Vans (critical for PDU)
  - General Arrangement (function over form)
  - Testing (development of a comprehensive test plan)
  - Manning (Development & approval of operations team)

Schedule

- Currently on track no foreseen delays.
  - Integration is an unknown (schedule buffer incorporated)

Risks

- Staffing – inherent weakness with small staff and may generate burnout.
- Vendors – Need to monitor closely to identify those unlikely to deliver
- Integration – Unknown problems arising but being managed by detailed interface controls

S5K 4500m ROV - Questions

Questions

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