Schmidt Ocean Institute 4,500m ROV Development Survey #2

This report was compiled based on a survey of international deep ocean research community representatives

2015

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Executive Summary

Schmidt Ocean Institute (SOI) is a 501(c)(3) private non-profit operating foundation established in March 2009 to advance oceanographic research, discovery, and knowledge, and catalyze sharing of information about the oceans. SOI is developing a series of advanced undersea robotic research vehicles for use on SOI's research ship *Falkor*. The vehicles will support scientific research throughout the full range of ocean depths, including operations at hadal depths, thereby providing scientists with access to the deepest parts of the ocean. The vehicles will be outfitted with a suite of sensors and scientific equipment to support collection of a broad range of data and samples.

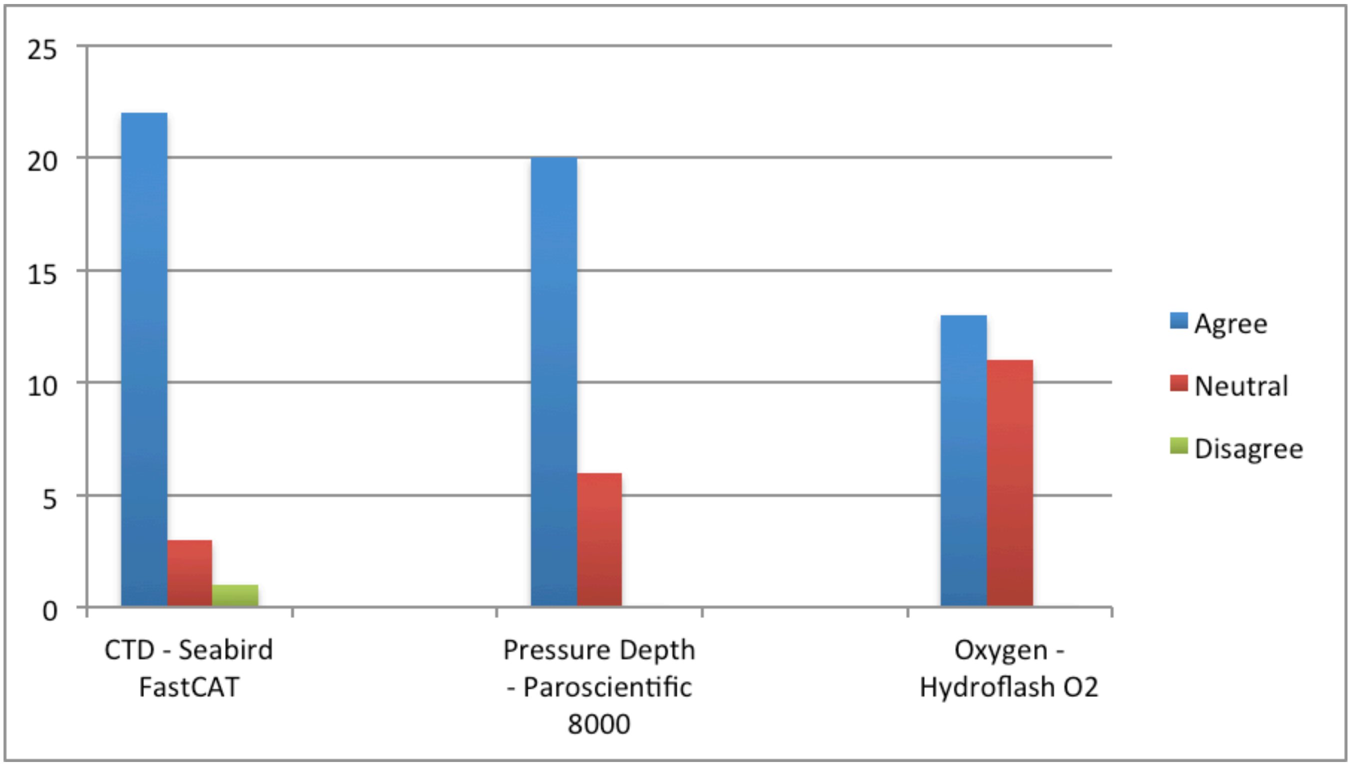
This document outlines the results of an independent survey conducted by SOI to gather feedback from the international expert user community of scientific remotely operated robotic vehicles (ROVs) on the development of the new Schmidt Ocean Institute's 4500m ROV. This survey built upon a previous survey on the science mission requirements for the 4500m ROV to collect input on the specific scientific instruments and systems presently selected for inclusion into the ROV core design and those being considered as add-on instruments. The survey resulted provided responders an opportunity to state whether they agreed, disagreed or had neutral opinions about the equipment selections and provide details supporting their opinions.

The survey was completed by 25 representatives of the international oceanographic research community, all of whom have agreed to have their names shared as the SOI 4500m ROV Science Advisory Group.

Survey Contributors

1. Prof. Douglas Bartlett, University of California, San Diego
2. Dr. William Chadwick, Oregon State University
3. Prof. Mandar Chitre, National University of Singapore
4. Prof. Dr. Mike Coffin, University of Tasmania
5. Dr. Erik Cordes, Temple University
6. Prof. Dr. Colin Devey, GEOMAR, Germany
7. Prof. Gregory Dick, University of Michigan
8. Dr. Vicki Ferrini, Columbia University
9. Prof. Charles Fisher, Portland State University
10. Prof. Peter Girguis, Harvard University
11. Prof. Bruce Howe, University of Hawaii
12. Prof. Kim Juniper, University of Victoria, Canada
13. Dr. Jon Kaye, Gordon and Betty Moore Foundation
14. Dr. Christopher Kelley, University of Hawaii
15. Dr. Deborah Kelley, University of Washington
16. Dr. Tom Kwasnitschka, GEOMAR, Germany
17. Prof. Marvin Lilley, University of Washington
18. Mr. Brian Midson, National Science Foundation
19. Dr. Neil Mitchell, University of Manchester, United Kingdom
20. Dr. Oscar Pizarro, University of Sydney, Australia
21. Dr. Anna-Louise Reysenbach, Portland State University
22. Prof. Oscar Schofield, Rutgers University
23. Prof. Dr. Tina Treude, University of California, Los Angeles
24. Prof. Dr. Cindy Van Dover, Duke University
25. Ms. Zdenka Willis, National Oceanic and Atmospheric Administration

Core Sensor System Responses



Core Sensor System Comments

CTD Sensor - Seabird FastCAT CTD Sensor (SBE49)

Responders generally felt this was an excellent choice. SOI should keep in mind to be aware of any system updates Seabird may develop. SOI should be aware of the fact that there is no ability to add on sensors. Other independent sensors would need to be incorporated to cover DO, transmissivity, fluorescence, etc. Additionally, the ROV heat could contaminate temperature and salinity, so an extra cleanup of data would be needed to look for these kinds of anomalies in the data. The temperature and conductivity sensor should be pumped to make sure they are concurrent and the prevent salinity spikes. It will be important to calibrate the sensor and provide the calibration information as part of the routine data distribution. This is not always done on other similar vehicles and has proven to be problematic with respect to integrating data. One responder recommended that SOI review the Alliance for Coastal Technology database for evaluation test; Scott McClean's (Ocean Networks Canada) national innovative center, and; Michael Jones' (Maritime Alliance), work with San Diego industries.

Pressure Depth Sensor - Paroscientific 8000 Submersible Depth Sensor

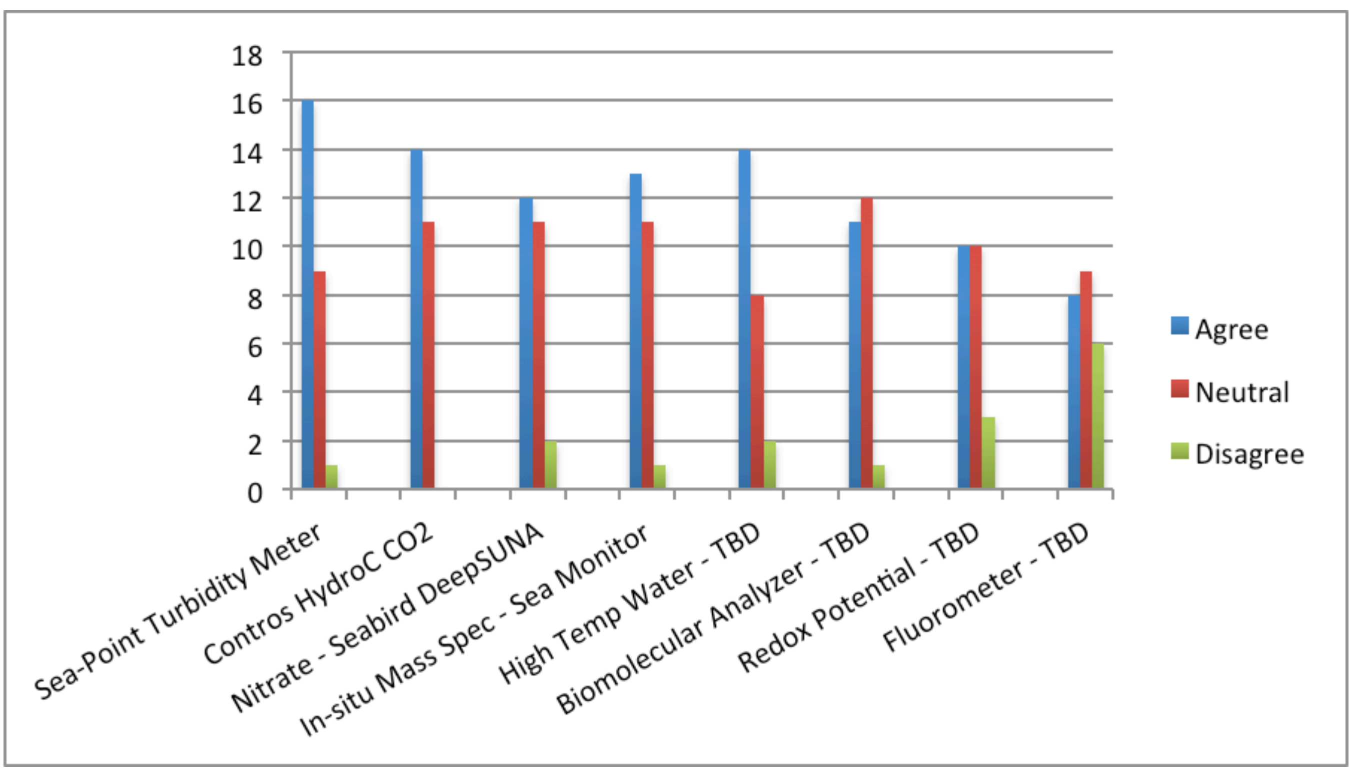
Responders stated this was good, standard, state-of-the-art sensor used on many ROV and AUV. For depth sensors it is important that the community uses the same quality equipment - often on the seafloor if the USBL or LBL is being problematic (multiples, shadowing) you can still make meaningful measurements if you know depths precisely. SOI was suggested to consider using updated system if one is released within the time frame for planning. One responders stated that SOI should be aware that there is a new "nano-resolution" unit that samples to 20 Hz. (same sensor, different firmware). SOI may also want to consider the Paroscientific depth sensor as was used on the Pisces submersibles that their ops team was happy with.

Oxygen Sensor - Contros Hydroflash O2 Sensor

Like all optodes, the response time of this instrument is limited, but reliability and stability are superior to the Clark electrode alternative. For most operations, the slower response time will not be an issue but care are will need to be taken when passing through sharp dissolved oxygen gradients to make sure the instrument has caught up with what is being observed visually.

One responder indicated that they have made comparisons between Seabird and Aanderaa oxygen sensors side-by-side and after years of extensive testing we went back to Seabird because the optodes were not consistently calibrating with each other. Another responder indicated that the listed response time for this unit is three times faster than that listed for Aanderaa's optode; a real improvement in performance. They indicated that consistent calibration will be critical to maintaining reliable readings. SOI was advised to mount two instruments in order to keep track and can confirm that at least one of them is performing adequately.

Add-On Sensor System Responses



Add-On Sensor System Comments

Turbidity Sensor - Sea-Point Turbidity Meter (STM/MCBH6M)

Many responders supported having this as an add-on system. Sensitivity levels were questioned and it was suggested that for deep-ocean sensors the ROV's system spec would need to specify "5-times custom sensitivity" so the range is essentially 0-5 FTU (instead of 0-25 FTU). There are also different gains depending on how it is wired; important for obtaining the highest resolution. One responder questioned whether the sensor will also detect the artificial turbidity (i.e., resuspended particles) the ROV produces itself when close to the ground. The data collected by this and the other systems was suggested to be comparable with those of others systems used by the community. One responder indicated a preference for radiometric sensor that would provide quantity like optical backscatter (allows for a range of calculation opportunities).

Carbon Dioxide Sensor - Contros HydroC CO2

One responder noted the 60 second response time for this system and stated that users will need to be aware of this limitation. Several responders indicated that this system will be useful for many and will probably increase in importance given the CO_2 acidification problematic. Several responders indicated that a pH sensor will also be needed to compliment the utility of this system. It was recommended that SOI consider discussion with Dick Feely of NOAA's PMEL as they have strong expertise in this area.

Nitrate Sensor - Seabird DeepSUNA

Responders provided many unique comments. It was stated that users would need to be aware of the slower response time of this instrument. It was also mentioned that since these sensors are usually biosensors and someone has to take care of the microbes hosted in the sensors SOI should not purchase them but the scientists working with them should. Another indicated that such sensors are far more suited to shallow water investigations, in contrast to the primary mission of this ROV. Finally, one responder said that interesting NO_3 dynamics may occur at hydrothermal vent sites and while this NO_3 sensor appears fine for water column work, as a further add-on possibility SOI may want to consider investigating NO_3 sensors that function at very low NO_3 concentration so as to understand warm diffuse flow mixing habitats.

In-situ Mass Spectrometer - Sea Monitor - TBD

Responders provided several unique comments. SOI was recommended that a robust, reliable instrument is a better choice than a high precision thoroughbred that requires frequent calibration and maintenance at sea and that technical support for it can be significant. Several responders indicated that the system should be capable of determining a wide spectrum of masses. It was noted that most of these systems require a devoted operator who is familiar with the instrument. Someone at SOI would need to be responsible for this. pH data would also be needed to interpret much of the data. Other systems were suggested for consideration, The Girguis lab's underwater mass spec (parts are user-serviceable, keeping the operating costs lower)(system is "open source" and can be built and maintained by a wider variety of operators and scientists). Tim Short's instrument from SRI (http://www.sri.com/newsroom/press-releases/underwater-mass-spec-sri-bluefin)

SOI should also note that Monitor Instruments is embroiled in an IP battle with WHOI over their inlet system.

High Temperature Water Sensor – TBD

One responder stated that this would be good to have in the suite of available systems for the ROV because one can run into hot water unexpectedly on old volcanic seamounts, and even mud volcanoes. Numerous responders stated that it would be critical for hydrothermal vent work and that it should have a range of 0-400°C. Several stated that many groups could build this to order, but that SOI should plan ahead to avoid delay issues.

Biomolecular Analyzer - TBD

Responders were overwhelmingly in support of this being an add-on system as the technology is very immature. It was noted that investigators who would ask for such a system would likely already have one. This equipment would be for specific and limited use and may not be something SOI would want to invest in for such limited use.

Redox Potential Sensor - TBD

The responders agreed that this is an important and powerful tool for hydrothermal vent research. Some indicated that it would be beneficial for SOI to have this sensor available for projects when needed. Other responders shared that there are proven sensors that can be borrowed, in some cases for the cost of coauthorship, that would be beneficial for SOI to obtain when needed. For example, Koichi's eH sensor or Ed Bakers ORP sensor (analog and digital).

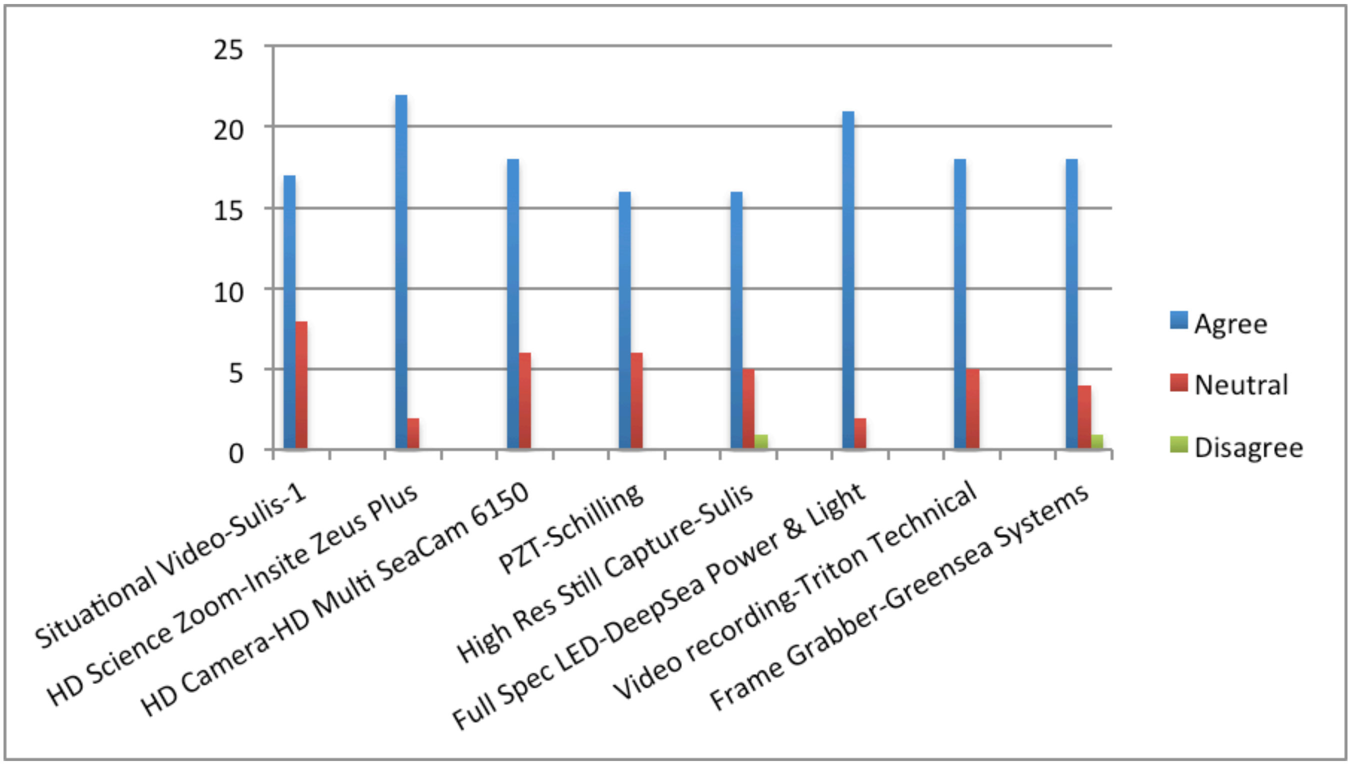
Fluorometer - TBD

Responders were mixed on the utility of this sensor. They agreed on value for midwater work but generally believed that the vehicles primary purpose would be for research deeper than this sensor's utility. One indicated that SOI would have two requests for this - one for export productivity of phytoplankton (CDOM), and one for hydrocarbons (Aquatraka) and that there will be much higher demand for CDOM. Some responders found the sensor to be a useful addition and stated that it would be an ideal add-on system. One indicated that having something like Wetlabs' ecopuck permanently mounted is worth considering, given the small size and low power requirements.

General Comments on Add-On Scientific Sensing Systems

A few responders commented that SOI should consider a pH sensor as part of the ROVs systems. One suggested that some of the add-on sensors are very effective when used on in survey mode and are well (better?) suited to AUVs. One responder strongly urged SOI to consider how the entire sensor data suite would be linked to video and navigation files. One responder suggested that SOI pick a standard suite of sensors to minimize the interfaces and utilize adaptive sampling using a standard set of equipment to gather unplanned parameters as the opportunity comes up.

Core Imaging System Responses



Core Imaging System Comments

Situational Video – Sulis-1 4K video camera

Responders were generally supportive of the system selected and commented that the higher the resolution the better. A responder stated that this system is an excellent choice and that it will set the bar for scientific submersibles for the next several years. The newness of the system led one responder to question the systems operational experience and what its actual performance and reliability are. One commented that they found the systems potential very high but would appreciate the company providing more specifications and file formats and storage sizes needed. One stated that having a fixed wide-angle lens is a good choice. Another stated that it should be mounted on a tilt head to change from downward to frontal surveys without surfacing.

HD Science Zoom - Insite Zeus Plus

Responders were overwhelming supportive of this choice and several stated that having zoom capability was essential. One responder stated that with its interlaced video output, the Zeus is not standard any more. It is time for manufacturer to offer a different imager, which may be a refit that later. Another responder suggested that the system should be mounted on the pan/tilt head to increase its usefulness.

HD Camera - HD Multi SeaCam 6150

Responders were supportive of this camera choice. Several questioned where the system would be mounted. One suggested that multiple Insite cameras might be a better option.

Pan / Tilt / Zoom - Schilling 101-3686-2

Many responders commented that this capability would be critical for the ROV's imaging systems. Several stated they would have appreciated greater details on the system's specifications.

High Resolution Still Image Capture - Sulis

Responders provided general comments regarding this system. One indicated that they would like a text plate insert that would show up through the video and could be removed subsequently for other purposes. One indicated that this was an excellent choice and would set the standard for future submersibles. Another indicated that HD digital still can be poor quality (as the HD videos promised high quality stills, but the systems used by the Hercules and little Hercules, and jason II all produce low quality still images). Some responders felt that a standalone camera would be unnecessary because the quality would be similar to that taken from the 4K video frame grab.

Full Spectrum LED Lighting - DeepSea Power & Light, Inc. SLS-6150

The responders all felt that full spectrum LED lighting was essential and many stated this system was a good choice. One commented that the lighting arrangement should be flexible to allow it to be rearranged when needed. One questioned whether or not the lighting spectrum and intensity would be controllable. One questioned what illumination would be provided for the still imagery.

Video recording system - Triton Technical

Responders were supportive of this capability and were pleased with the multi format and codec options. One questioned the manufactures ability to meet the challenges of broadcasting (live). They suggested that SOI also consider a video engineer station such as on the Okeanos Explorer and involving a systems provider of mobile broadcasting solutions.

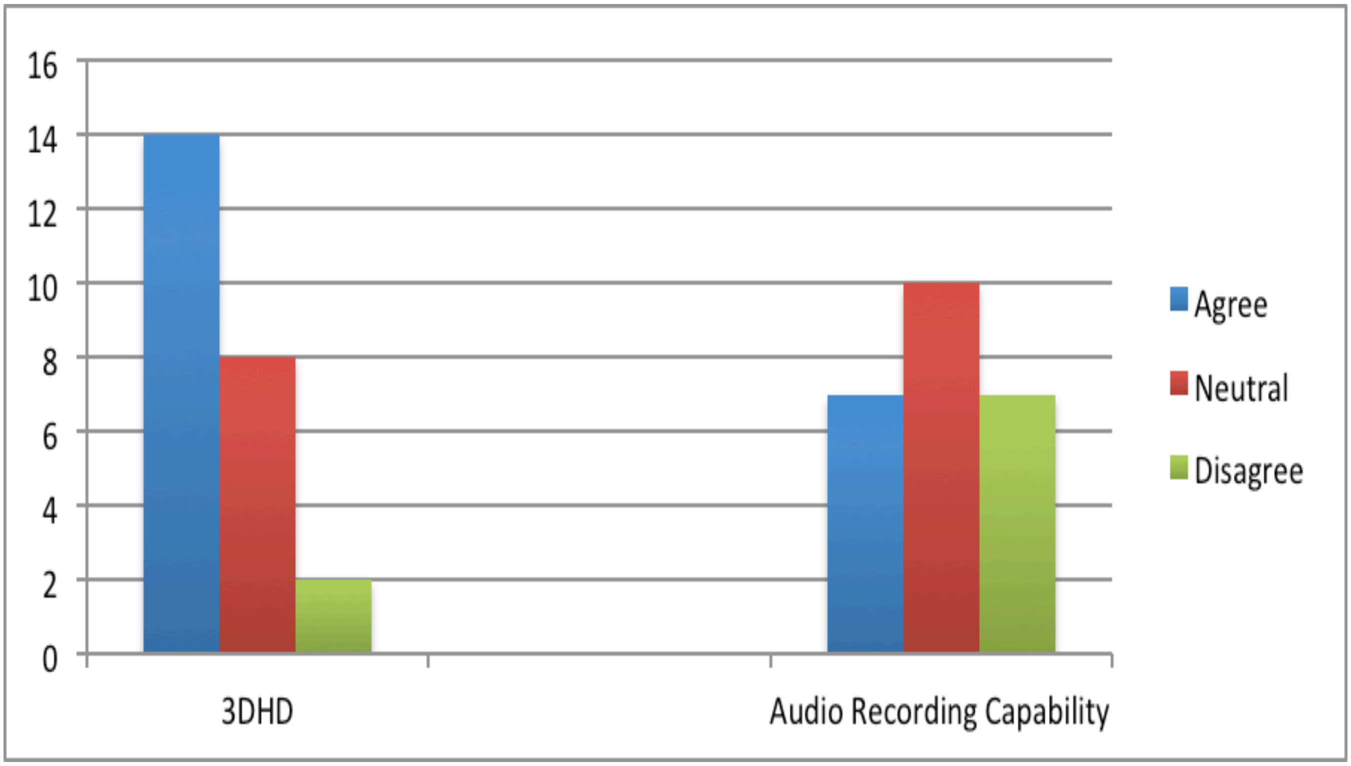
Frame Grabber - Greensea Systems

Many responders stated that this was a useful and essential tool. Several questioned why this particular system was needed because it should be part of the Sulis system. One responder stated that frame grabs from an HD camera are only OK because they pixilate quickly when enlarged and are not suitable for many of the uses that high quality digital still images are needed for.

General Comments on Core Imaging Systems

Responders provided several unique comments on the core imaging systems. One stated that it would be important (crucial for the sulis and Zeus) to have orientation sensors attached to the cameras. Another indicated that the selections made were all good choices and went on to state that it was unclear what real-time image annotation (logging) would be possible or how still and moving image records will be linked to navigation data. One responder stated concern with the final ability to obtain close up and high quality digital still images of biological specimens for identification, or for any purpose that requires very high quality still images. One questioned where there are thermal over-rides on lights (operating in air). SOI was suggest to consider a focus group for each sensor type in consideration to gather technical input and/or host an industry day- based on an RFI - so it can determine best sensor. Finally, a responder noted that cameras are likely to continue to evolve quickly (and more quickly than most other subsystems) so SOI should consider designing for flexibility and ease of upgrading the imaging systems.

Add-On Imaging System Responses



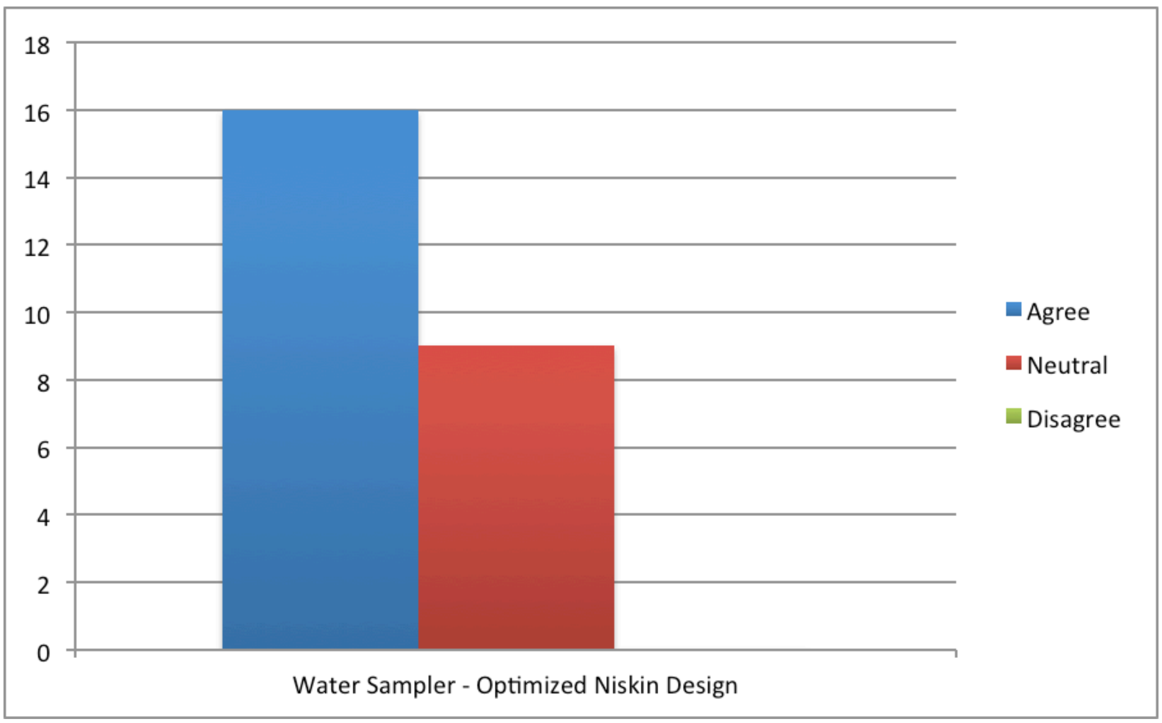
Add-On Imaging System Comments

3DHD Video – TBD
Most responders felt this system could be valuable but should be an add-on when needed. Many described trouble with disappointing visuals. Some found great utility for outreach and possibly for science as well with georeferencing included.

Audio Recording Capability – TBD
Responders had numerous unique comments regarding this capability. They fell into two categories, those relating to ambient noise recording and those related to shipboard audio commentary capabilities for researchers. One responder noted that the ROV should include a microphone in one of the housings to estimate noise levels generated by the vehicle. Another felt audio recording under water was mostly not necessary. Another indicated that it would be a very specialist sensor, which would not need to be on board all the time. One supportive

responder felt that audio would give another sense to the operators - the operational soundscape (bi-aural) though if hydraulics is loud it may not be worth it. Another stated that being able to record sounds while in the water would be of immense potential benefits to many missions and that audio recording is not an expensive capability, nor does it drain too much of battery or occupy too much space. One responder emphasized the science plan of the International Quiet Ocean Experiment, the soundscape of the ocean is a huge and beckoning frontier and that many first-order discoveries await. Several responders indicated that their experience has been that audio comments by those participating in ROV dives are an essential and valuable component of the real-time annotation of video records. Another stated that audio is sometimes the only record one has of context for an observation or sampling selection and that having it is low cost, high-reward. One responder advised that from an engineering perspective, the power spectrum showing machinery lines could be an indicator of health or not.

Core Sampling System Responses

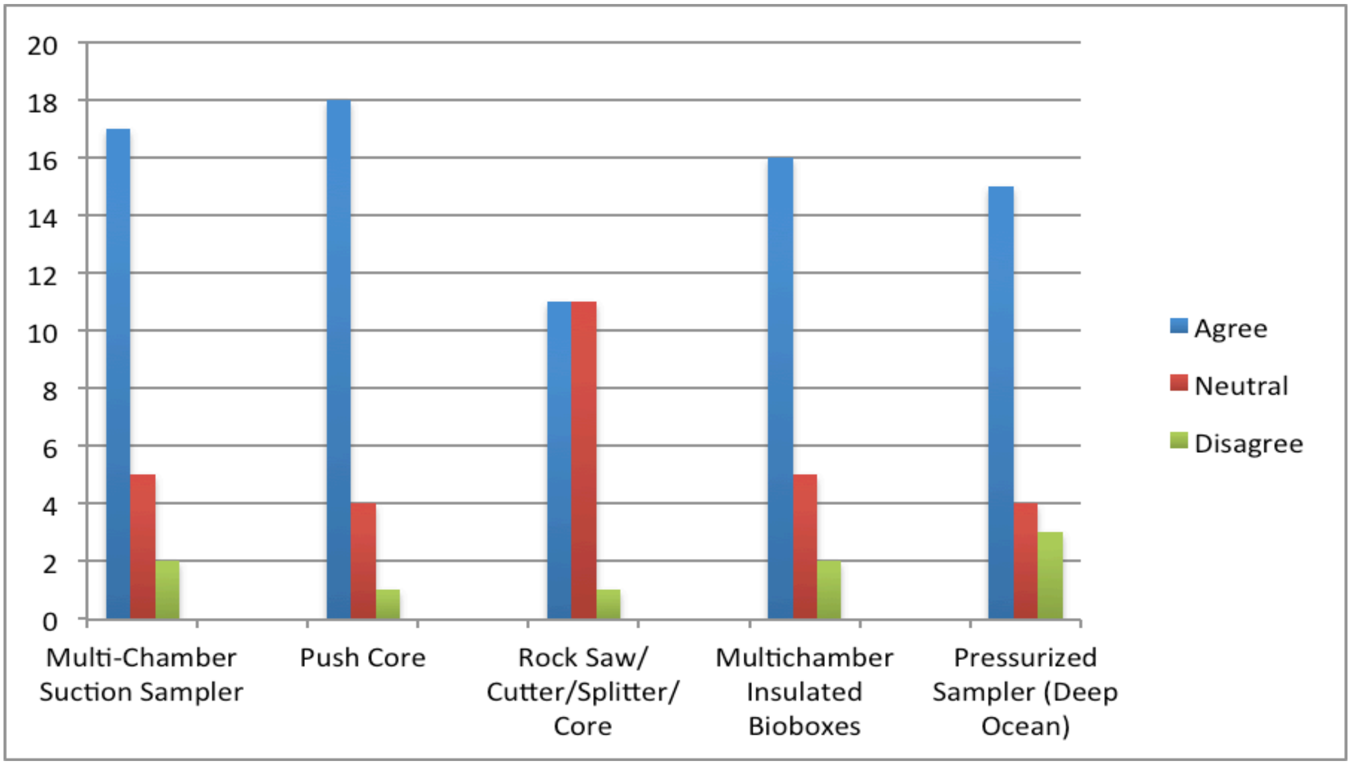


Core Sampling System Responses

Water Sampler - Optimized Niskin Design

The large majority of responders felt that this would be a standard piece of core equipment. One stated that they get big fairly easily and should be placed where they are not in the way of other things. Another advised locating it on brow, swing arms, and hand held for optimal sampling. A few felt this equipment could be optional partly because small volume, specific samplers tend to be preferred.

Add-On Sampling System Responses



Add-On Sampling System Comments

Multi-Chamber Suction Sampler – Custom

Several responders stated that this should be a core part of the ROV systems. Others agreed that it would be good as an add-on to ensure space/weight needs are met for projects that don't make use of it. A responder suggested the system used by ROPOS as a good balance between size and capability. A suggestion was made to consider a retractable hose like on the MBARI Doc Ricketts ROV. One responder commented that the system should be designed not to be clogged by rocks and gravel while collecting biological samples. One responder commented that a multi chamber would be better.

Push Core - Custom

Many responders stated that this is a very useful system and standard for many types of research so it should be considered as core. One suggested that a capacity for 4-6 cores (various diameters with possible core-catcher capability) per dive would be ideal. Another stated that these should be mounted on swing arms or something like that to avoid fouling the front of the ROV with handles etc. One responder commented that an innovative modification that would be useful for culturing, biochemistry and physiology and perhaps gene expression studies would be to have a temperature buffered quiver system that would ensure that samples get back to the ship at the in situ temperatures.

Rock Saw / Cutter / Splitter / Core – TBD

Responder comments regarding this system were mixed. Several agreed that it was specialized equipment that they would appreciate having and felt it would be ideal as an add-on since it may rarely be used. One indicated that it would be great to have but a big resource regarding human time and specialized training and suggested holding off until user demand warrants. A responder pointed out that there is already one of these at WHOI (that works very well), and has rarely been requested/used. Another stated that there are commercial, hydraulic chain saws capable of cutting through rocks that are available if needed.

Multichamber Insulated Bioboxes (for fragile animals) – TBD

The responders overwhelmingly agreed that this should be a **core** part of the ROVs available systems. They all noted that it is critical for biological operations (one stated that they hold rocks too). Two recommendations were made for systems to consider, the newest bioboxes made by the OET group for the 2015 field season and the ROV Hercules' starboard side biobox.

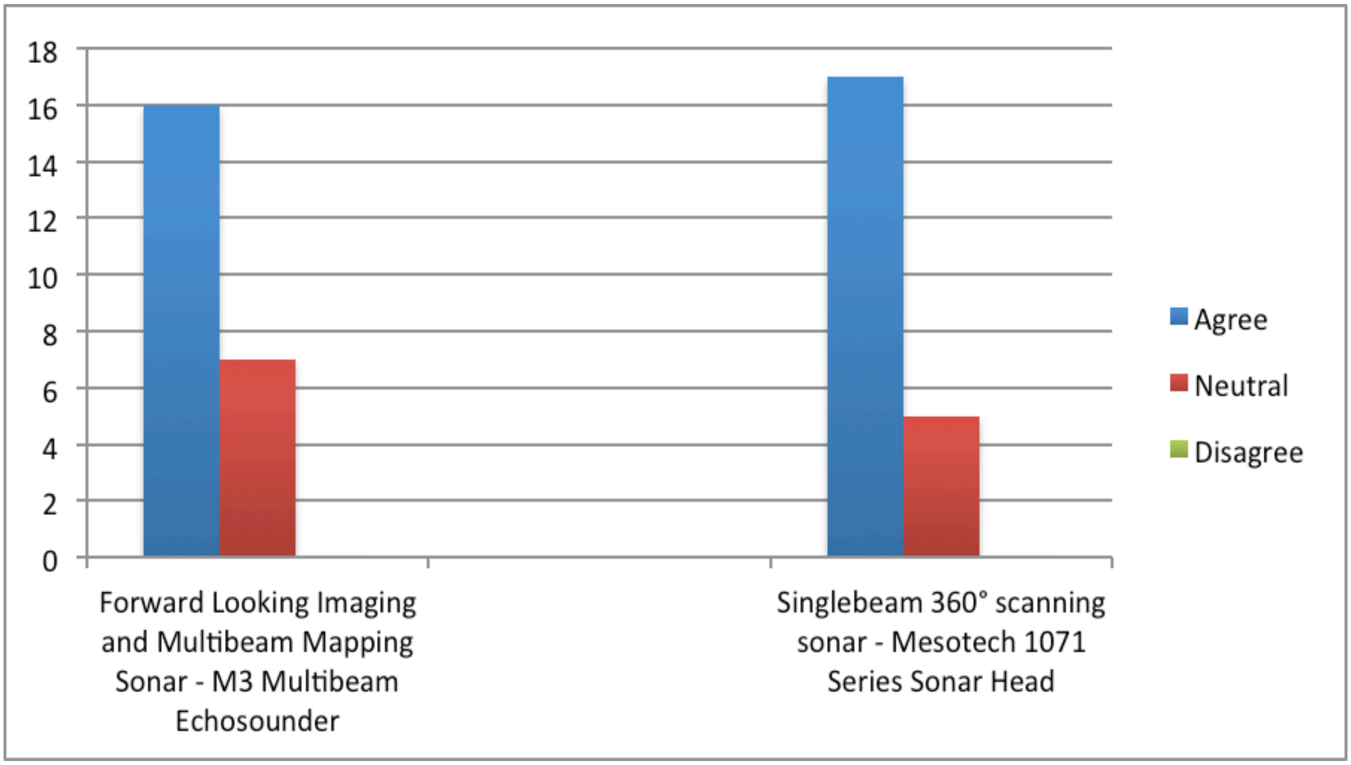
Pressurized Sampler for Deep Ocean – TBD

The majority of responders stated that this equipment would only have value for specific questions and should be user supplied. Several indicated that the system would require pressure vessels that it can mate to and possibly high pressure tanks on board once samples were brought up. One responder believes the use of pressurized samplers will become more and more important as time goes on and noted that it is very important that samples come back cold as well as pressurized. Some responders felt the technology needs to mature because the risk of using it based on current technology is too high for the value it provides.

General Comments on add-On Sampling System

- Bioboxes, pushcores, slurp need not go on every mission, so in this sense they are not 'core' to the vehicle...but I expect they will be heavily used. Bioboxes are used on every biology dive, but I surmise that because they are not 'core' on some ROVs, they may be poorly maintained.
- I expect researchers would have specific demands for multichamber or even pressurized boxes or bring their own so postponing this is a good idea.
- I would make sure push core and suction sampler are "shadow core equipment" - I cannot imaging any sampling deployment of the ROV not wanting to have that equipment on board. Make sure its inclusion in a dive does not mean excluding any other important core sensor (e.g. that there is enough space to include the suction corer on the vehicle without having to dismantle the sampling basket).
- I think there should be some add-on samplers available specifically for hydrothermal vent fluid sampling, like titanium "major samplers" and perhaps titanium "gas-tight samplers".
- I do not see samplers for hydrothermal fluids - IGT bottles or major samplers would be useful for seep-vent researchers.

Core Sonar System Responses



Core Sonar System Comments

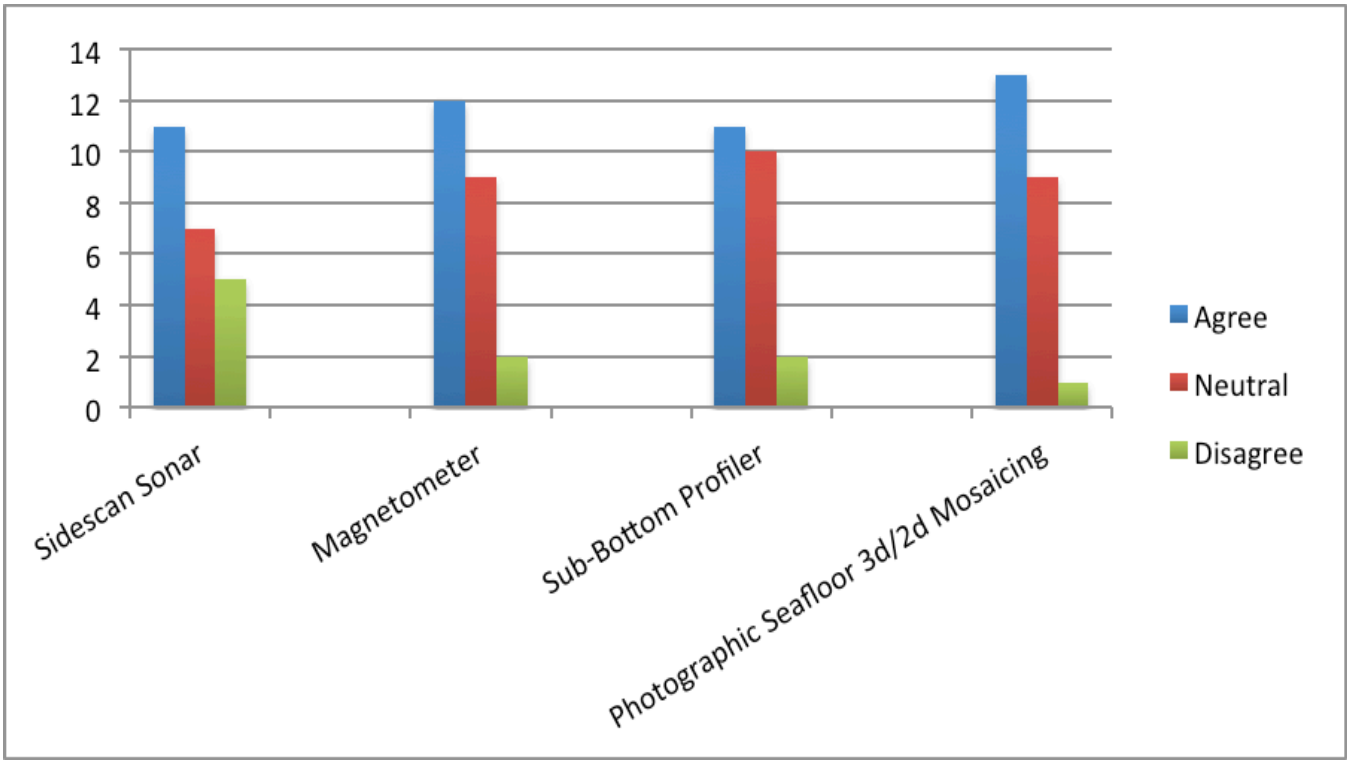
Forward Looking Imaging and Multibeam Mapping Sonar - M3 Multibeam Echosounder

Responders were generally positive with this system and the manufacturer selected. Comments included that multibeam with ability to collect water column data is critical for high resolution mapping and for locating bubble plumes and other water column features. Some questioned whether the SOI staff would be able to support it. It was noted that the manufacturer only claims 4000 m depth capability and pointed out that it is possible to negotiate an extension to 4500 m. A few questioned the purpose of a forward looking sonar. Other systems recommended were Sound Metrics Didson imaging sonar, the Tritech Gemini multibeam sonar, and the BlueView imaging sonar. A few responders asked what the intended use of this unit is, pilot assistance, mapping, obstacle avoidance, etc.?

Singlebeam 360° scanning sonar - Mesotech 1071 Series Sonar Head

Responders stated that this is an appropriate core piece of equipment. Several questioned whether it would be redundant to the M3 system and if they frequencies my interfere.

Add-On Sonar System Responses



Add-On Sonar System Comments

Sidescan Sonar – TBD

Responders provided mixed opinions regarding this system. Some felt the instrument could be helpful for tracking activity on the sides of the vechicle and to allow the ROV to conduct mapping work. Other responders felt this system was better suited to dedicated AUV's. One indicated that downlooking systems are better.

Magnetometer – TBD

Many responders agreed with this as an add on instrument. Some indicated that if the system was needed it should be user supplied. One responder stated that some teams do good work with an onboard magnetometer, but it is not "plug and play" technology, especially in terms of data reduction. So I think the choice is right - if you have a project which needs magnetometry there will be experts to interpret it and fitting a magnetometer to the vehicle on a needs basis should not be too difficult assuming you have the available ports. One responder cautioned that interference from the magnetic metal on the vehicle could be problematic and recommending discussing the issue with Maurice Tivey (WHOI).

Sub-Bottom Profiler - TBD

Responders provided mixed opinions regarding this system. Some felt that it provides an important capability, but only for some applications and that it would be an appropriate add-on. Others felt that it would be more appropriate for an AUV. One responder stated that it is a natural companion to the multi-beam echosounder and should be included as a core system.

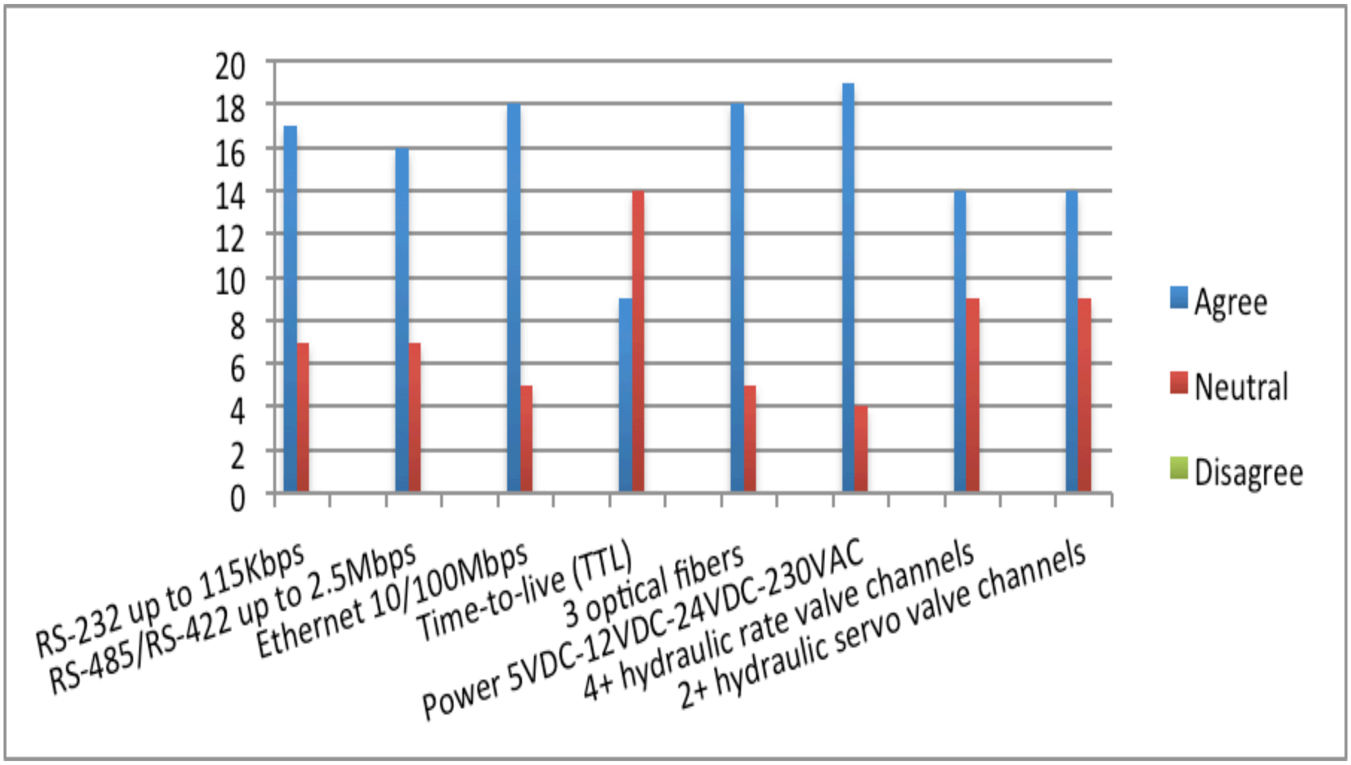
Photographic Seafloor 3d/2d Mosaicking - TBD

All responders indicated this would be a valuable addition to the vehicles capability. One stated that this ability would be amazing if it were routine, reliable, and automated as much as possible. Some indicated that this system should be an add-on and users requiring such a data product may best do it. Some indicated that this should be considered part of the core imaging suite and that many of the systems already selected would be capable of supporting it. A few indicated that this work would be better done by AUVs.

Comments on Add-On Seafloor Surveying Systems

- I have used hi-res multibeam, sub-bottom profiles, and photomosaics (or photo analysis) together - very powerful for science, habitat mapping.
- The mentioned acoustic sensors may work better on an AUV then an ROV. Provided the Sulis camera works to specification, it allows high resolution optical surveys.
- Have you considered purchasing two sulis Cameras in order to create a stereo system, not for viewing but for photogrammetric surveying?
- I think you left out all the right things - either because ROV time should be used for human intervention studies and mapping is not one of those things humans need to be involved in or because the sensor data need expert interpretation before being useful
- Downlooking mutlibeam would be much more important than fwd looking.
- Those instruments described above as not selected should be considered for an AUV survey system to support SOI missions.
- I think the ROV should have an add-on down-looking multibeam sonar system for making high-resolution maps of the seafloor. This has become a critical ingredient for geologic mapping of the seafloor. I would rank this way above a sidescan sonar, for example. High-resolution bathymetry is collected most efficiently with an AUV, but ROVs are also capable of collecting good quality data, and if you don't have an AUV on board, it's the next best thing.
- Definitely need the option to conduct down-looking photomosaicking transects--hence need for good telemetry system also.
- Some systems are much better suited for wide-ranging AUVs than for pinpoint ROVs.

Core Vehicle Interface Responses



Core Vehicle Interface Comments

RS-232 ports up to 115 Kbps
Responders indicated that this would be absolutely critical and essential for user-supplied legacy sensors linked to Windows.

RS-485/RS-422 ports up to 2.5 Mbps
Responders stated that these are critical and there should be at least one or two to support user-supplied legacy sensors linked to AppleOS.

Ethernet 10/100 Mbps
Responders indicated that this would be important to support advanced instruments. Recommendations were made to consider power over ethernet PoE, IEEE-1588 precise timing protocol, pressure tolerant ethernet/rs232/etc, and GigE.

Time-to-live (TTL) link
One responder indicated that uniform time stamping of data from all sensors is essential.

3 optical fibers for high speed data transfer
Responders were very supportive of providing this interface and agreed that high speed data transfer would be critical and that they are good for video. One indicated that both full raw fiber access, as well as separate wavelengths would be beneficial.

Power 5 VDC, 12 VDC, 24 VDC, and 230 VAC

The responders felt that this covers the most commonly used voltages. Some recommendations were to add 48 V because it is the observatory standard and stepdown converter to 120 VAC. One responder questioned whether 115 and/or 230 VAC were needed.

Hydraulic rate functions

All responders indicated that they would make use of hydraulic tools and that at least four would be good. One stated they would prefer eight.

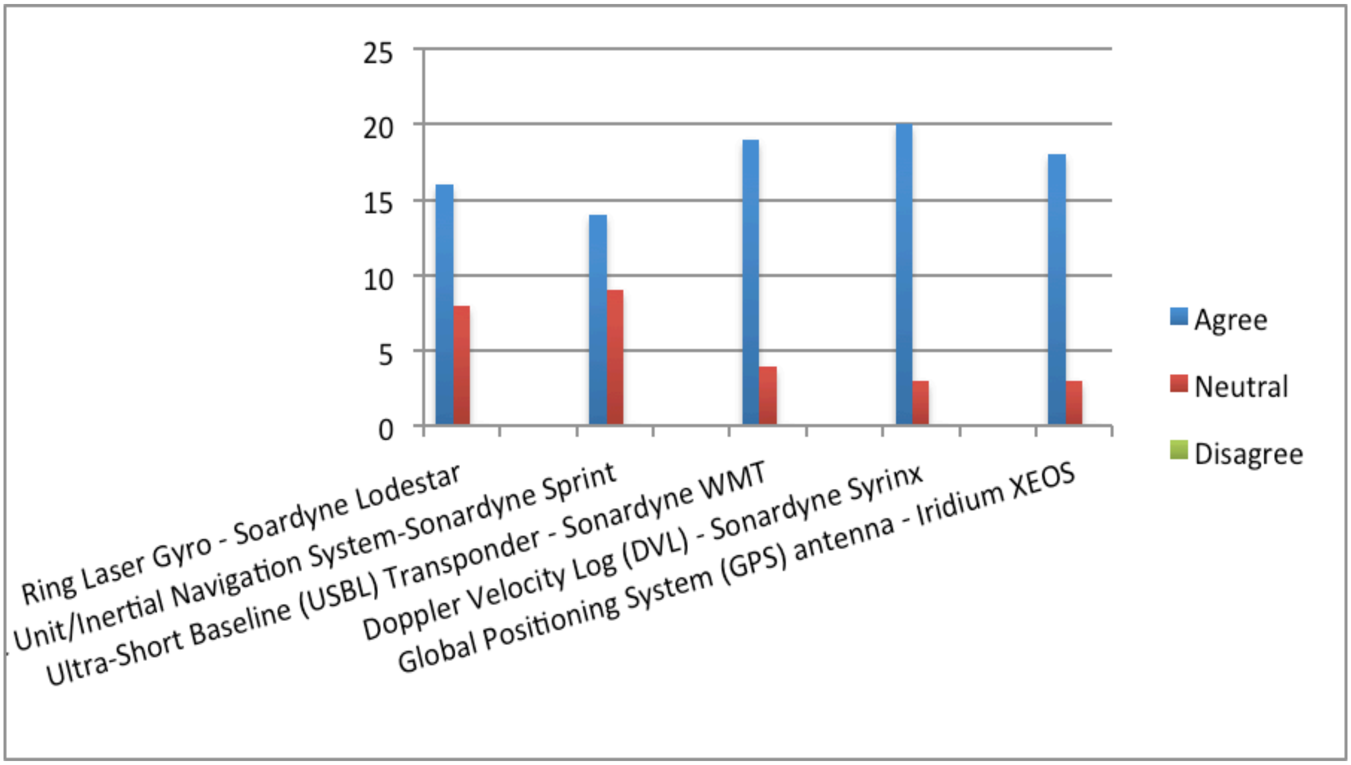
Hydraulic servo functions - Comments

Responders indicated that their opinions mirrored their opinions for Hydraulic Rate Functions, above.

Comments on Core Vehicle Interfaces

- This broad range of interfaces will provide great flexibility for adding tools and sensors provided by users or future SOI acquisitions.
- I expect the technology has improved a lot - our older experience with fibre optics was not so good as a cable failure in the earlier systems would lead to major problems. Presumably those issues have been fixed though.
- Redundancy and over-availability of interfaces make the vehicle somewhat future-proof, but then again I could have said that of every laptop, mobile phone or even high-pressure water cleaner I ever possessed
- Consider providing observatory interfaces - NeptuneCanada/MARS/RSN/ACO, etc. so the ROV can plug into an instrument for testing it, or plug into an observatory to test its port. One would like to think standardization is coming.
- Make precise time distribution explicit - IEEE1588, pulse-per-second, ascii time strings, IRIGB etc. Provision to attached instruments, to observatories for checking, etc.
- I question whether AC ports are needed, as they have high power requirements.

Core Navigation System Responses



Core Navigation System Comments

Ring Laser Gyro - Soardyne Lodestar

Reviewers provided mixed opinions for this system. A few indicated that it seemed essential. Others suggested that SOI should hold off on this until it is requested. One responder stated that integrating multiple Sonardyne instruments may be a relevant reason to make this selection.

Inertial Measurement Unit / Inertial Navigation System (IMU/INS) – Sonardyne Sprint

Responders generally agreed that this system is essential. One indicated that USBL and DVL were of greater importance. Another responder suggested that there are some good, less expensive options available. On responder note that as an "off the shelf' solution it offers a good path to using the whole suite of navigation sensors.

A responder commented that one thing to consider is how flexible this system is if you eventually would like to incorporate other types of observations. For example, terrain-relative navigation capabilities or Simultaneous Localization and Mapping with sonars or cameras (reducing drift be recognizing the same features in the environment). While not critical with high end navigation instruments, for long enough dives the internal consistency of the tracks will be only as good as the USBL without the ability to recognize the environment.

Ultra-Short Baseline (USBL) Transponder - Sonardyne WMT

The majority of responders indicated that this would be essential and that Sonardyne is an excellent choice. Recommendations were to get extra beacons, make sure the one on the ROV operates in responder mode and can be controlled from above and consider including acoustic modem functionality (in case the ROV operates near other untethered assets).

Doppler Velocity Log (DVL) - Sonardyne Syrinx

Responders indicated that this would be essential. One stated that it may be worth considering how much know-how is built into the software drivers and operators' experience using RDI DVLs. RDI DVL can be upgraded to offer ADCP functionality (interleaving bottom lock and water column pings). This may be relevant to some users and could save installing a separate down looking ADCP.

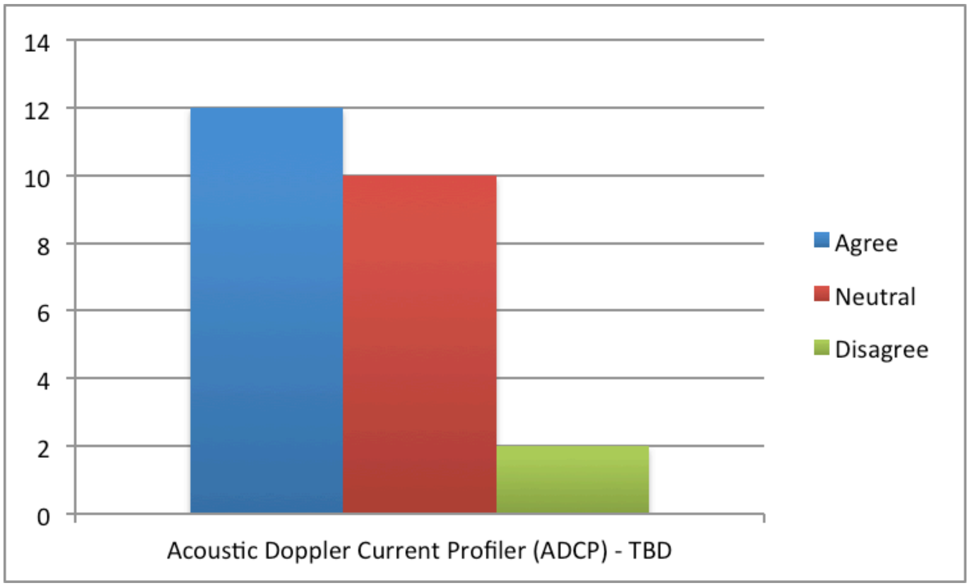
Global Positioning System (GPS) antenna - Iridium XEOS

Responders generally agreed that this would be valuable as an emergency locator beacon on the surface but that iridium real time comms/location would also be needed. One stated that the lat/lon would not be available on the vehicle, which is sensible given that it is a tethered platform. SOI would need to make sure to get good answers on maturity and reliability of the unit (i.e. how many have they made and how often do they fail). One suggestion was to consider a simple animal tracking Argos tags can offer a cheap and robust backup.

Comments on Core Navigation Systems

- It does make sense to purchase an integrated navigation solution from a single vendor as proposed. Make sure the raw components of the navigation will be logged as well for post processing. Does sonardyne offer a postprocessing software? The real time results still can obviously be improved as the document illustrates.
- All great choices. How will navigation data be integrated with video and sensor records? Will there be a real-time logging/annotation system that will do this integration?
- I am not so familiar with Sonardyne systems, though the proposal certainly is very promising. Attitude data will be critical for the quality of the multibeam data, once merged with the sounding data. I did not get a sense of how exactly the time data are passed between these different instruments or recorded - this can be important because a small clock delay (latency) leads to offset in the different sensor data in processing.
- Roll accuracy can be important (otherwise the processed data will show a ripple effect in the outermost beams of the multibeam) - I'm glad to see a high accuracy is quoted for this system.
- Important points are to get the best INS you can for the vehicle - they are so intimately integrated into chassis and software that changing them out later is very difficult, and underwater your navigation can never be too good. I note you have not included homing beacons in your set of core equipment - finding stuff repeatedly on the seafloor can be much easier with such beacons.
- USBL+INS+DVL is needed. Only question is how much to invest in the INS now vs later.
- Need altimeter!!! hover mode.
- Dynamic positioning with DVL etc.

Add-On Navigation System Responses



Add-On Navigation System Comments

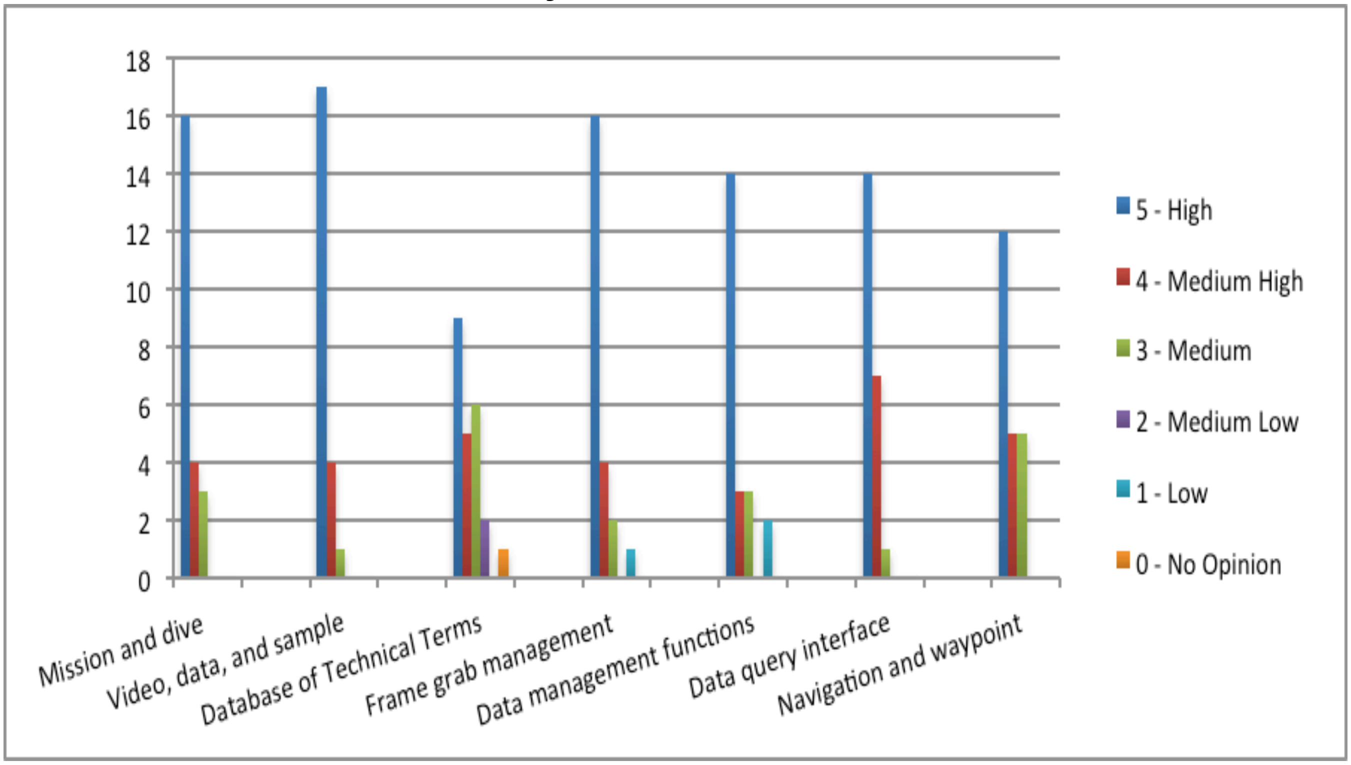
Acoustic Doppler Current Profiler (ADCP)

Responders provided mixed opinions of this system particularly with respect to its value in addition to the Syrinx DVL. One responder stated that ADCP measurements from moving platforms with limited attitude control are, at best, challenging to perform. Another suggested discussing with the DVL manufacturer to see if you can get ADCP capacity. Another responder stated that they were unsure about the Sonardyne DVL but RDI DVLs can be upgraded to include an ADCP mode (could be used in for down-looking). A responder suggested that this data will become a science priority quickly and the system should be in the initial ROV design. Another state that in searching for hydrothermal venting, current direction is the single important piece of information that is almost always missing.

Comments on Add-On Navigation Systems

- I would not regard an ADCP as a navigation instrument, it is a scientific sensor. In order to conduct precise midwater studies, it may be essential for the DVL to have water column tracking capabilities.
- Make sure the sonardyne usbl can also work with long baseline beacons if available, ideally from multiple manufacturers.
- Good nav display needed – GreenSeas possibly

ROV Data Annotation System Comments



Comments on mission and dive annotation capabilities

- Annotation is critical for post mission analysis, especially if that analysis is undertaken by individuals not involved in the real-time effort.
- Yes, this is an essential, integrating component of the software that supports dive operations. A capability for real-time audio and text annotation, and text editing are important. Users should also be able to add new annotations to the archive after the cruise.
- Should be a standard part of what SOI collects from the science party.
- This is always a can of worms - but needed. Can be applied to the other rov systems as well.
- Absolutely critical -- must be integrated with HD resolution frame grabs. The database should be accessible in real-time to at least all members of shipboard party, if not via telepresence.
- I don't know if this is tied into a similar system for ship operations, but something similar to this is also needed for ship ops, not just ROV operations.
- Metadata needs standardization
- Automated metadata about the conditions of the dive is as critical as the data
- This kind of system has been tricky to try to implement such that it is useful, not burdensome and is adopted by the broad community. It is extremely important, and is a great place where SOI can make a substantive contribution with respect to not only developing/implementing a system, but also by establishing guidelines and workflows.
- YES! This is one of the areas that the SOI can really help the community.
- Making metadata easier to capture, which includes ease of editing / making corrections, is tremendously important.
- An ROV dive produces an incredible amount of data and in my experience capturing as much as possible on the fly is extremely valuable. It is a formidable task to review all the video post-cruise.

Comments on video, data, and sample annotation capabilities

- Important, though the annotation is only as good as the knowledge of the annotator; some kind of quality control might be needed.
- Consider implementing a touch screen, maybe have a number of mobile devices so multi user entries are possible. A mission specific web guide could be implemented and configured out of a toolbox prior to the dive.
- We should be able to make notes to films and pictures.
- Make this audio annotation with voice-to-text conversion. When you are watching ROV images you can talk but you cannot type. The person sitting in conventional ROV situations with the keyboard on their lap is the person who will get the least out of the dive! Occupied submersibles use audio recording systems for just this reason.
- This is incredibly useful and I typically have my own system is a useful version is not available and linked to the video in real time.
- In my opinion, its all about the product, which is much more than just the video but also includes the data you extract from the video as well as the data from the sensors. This is high priority if you want your data to be accessed and used as quickly and widely as possible.
- Absolutely critical. Must have the ability to manipulate and co-register this information easily.
- Ideally logging system could tie to low-resolution video, allowing easy search functions that would then tie into high res versions.
- In real time is the best way to do this. Implementation has been questionable, in my opinion, and board accessibility of the metadata has been challenging, but can be easily handled with the right tools and services.
- YES! This is one of the areas that the SOI can really help the community.
- Video is an insufficiently exploited data type, in no small part due to the size of files, inability to "search," etc. I encourage efforts devoted to facilitating use of video.

Comments on knowledge database functionality

- Seems useful to develop a uniform language, but I would recommend against too stringent a requirement for language to conform to norms - dehumanizing observations has advantages and disadvantages.
- There is no standard for such a knowledgebase (there should be). Likely, every project will generate or introduce its own suite of keywords. A knowledgebase should be optional and expandable, but definitely available through a shorebased mirror so teams can work and expand it independently of a cruise, or well before.
- Need to keep this simple, and adaptable to mission requirements of individual users.
- I hadn't thought about this, but it may turn out to be useful to ensure uniformity the SOI's data. By analogy, the IODP, following earlier ODP and DSDP, have developed a sophisticated set of descriptors for the on-board archiving of cores and downhole logging data (http://iodp.org/scientific-publications - e.g., see the ODP publications).
- Would be a high priority if I thought it actually worked. But the same term means different things to different people (especially researchers!) so this type of "ideal tagging" is often less than effective.
- This is very helpful to keep the video annotation process consistent from cruise to cruise and PI to PI.

- Standardized language, perhaps drop-down based, will aid with database formulation and utilization.
- Cuts down on the clutter of different people doing things their own way, each absolutely certain their way is best. Standardizing the input terms is definitely a good idea.
- If such tags are used, they should be editable, so they can be tailored to each particular cruise. Or there should be some combination of tags that you don't change and others that you can create for specific needs.
- Significant funds are utilized to collect these data and without a database to tie terms directly to video, it is not searchable and looses much of its value.
- It seems to me that this could be provided by individual users/experts rather than integrated into a knowledge database
- These, together with chemical and physical terms, are essential for both cross-disciplinary and public communication.
- Anything that will make the previous two tasks easier and more likely to be adopted and utilized effectively is, in my opinion, worthwhile and high priority.
- In the long run, a standardized representation will add value to the collection of data sets the ROV acquires by making it easier to ask new questions that go across multiple cruises (with different purposes originally).
- This is a huge undertaking and well outside the scope of SOI. Ontologies already exist. I strongly advise SOI to explore what is already going on in the community before pursuing this task. Please don't reinvent the wheel.
- Watch standers come with a variety of backgrounds and such a data base is vital to the correct logging of observations.

Comments on frame grab management functionality

- Frame grabs and stills should be easily correlate with the other video and acoustic cameras. You could provide a synchronized master view (in 4k?) or collage containing all relevant cameras and sonar output.
- Tough to put together, but incredibly useful. Makes everything easier to go back to after the cruise.
- Without this much of the valuable/critical information about dives will be lost, sample information will also be missing. Frame grabbing must be tied to integrated logging system as should digital still imagery. It optimizes the usefulness of these data, must be tied to lat, long, depth, etc.
- This is easy to do based on time stamp, and is largely a shore-side data management issue, in my opinion. I don't envision that most scientists would adopt use of this at sea. Not yet, anyway.
- Images are an insufficiently exploited data type, in no small part due to the size of files, inability to "search," etc. I encourage efforts devoted to facilitating use of images.
- Again, because of the mass of total video, frame grabbing of images of publishable quality is important.

Comments on post-dive data management functions

- Maintaining an organizational structure would be useful.
- In particular, it may be interesting to have efficient search and replace features available during a dive, in case of a misclassification. Possibly coupled with a time constrained as in: "We misinterpreted that feature for the last two hours!"
- I feel like every PI has their own system, and that this might vary from cruise to cruise depending on the focus of the project. Would be useful, but very hard to standardize and still be inclusive.
- Definitely after the dive. The jury is out whether its all that necessary during the dive.
- Critical - it would be fabulous to be able to embed sample data into the dive observational series following a dive.
- Here is where Schmidt could be the real leader!
- Data management functions are essential.
- I don't anticipate that this would be something most scientists would invest their time in using.
- Effort dedicated on this front has the ability to transform the "cruise report" into a more dynamic and usable aggregation of data products.

Comments on data query interface

- This would be brilliant - for students, educators, scientists.
- Keep it simple, with a limited set of search terms.
- Should be part of a frame grabber system.
- Does this have to be integrated with ROV software, or can the ROV data and metadata be put into existing public databases containing global data sets?
- This provides an important window into the logged metadata - without it the utility of investing in and using an annotation system will be lost. Existing tools that do this for similar vehicles are woefully problematic.
- Yes, insofar as it enables SOI-developed data use functions described above (but other please don't reinvent data repository functions).

Comments on navigation and waypoint management functionality

- It is to be seen how well the sonardyne solution really works. I assume the INS-merged nav signal will be available, eliminating the need to correct hopping USBL position picks. Still, points may shift upon nav postprocessing and it would be good to provide correction of annotation positions as a service asap after the dive.
- Could be useful for grid surveys and mapping new discoveries but let's not add too much complexity to dive operations right away,
- Why have a navigation system if you can't tell it where you are and allow custom underlays of existing high res bathymetry?
- No brainer in my mind. This has been a very important function on every cruise I've ever been on.
- Critical if folks want to know where they have been and want to return to areas in the future, tie other environmental data to dives - etc
- Such management is essential for dive planning and syn-dive modifications.

- Most scientist who need to do this kind of planning have homegrown tools for it already, many don't go anywhere near this kind of stuff. That said it certainly has value, especially if it streamlines operations and planning.

General Comments on ROV Data Annotation System

- My experience is with the virtual Jason van. It is terrific and valuable, and was amazing when it first came on line, but the user interface and experience is not great. The missions do not talk to one another in the VJV, so global context is lost.
- You may want to contact Jose Nuno Gomes Pereira, he has a review paper of most relevant Annotation systems in review: https://scholar.google.de/citations?user=NRcgSEwAAAAJ&hl=de&oi=ao
- Online data annotation is important since there is never as much time to do so as at sea, plus this might be an upfront choice that SOI may stick with for quite some time.
- This system cannot be too good. More data is lost because of difficulty in retrieving it one year after a cruise then is maintained for most systems.
- I don't know how easy it will be for mission scientists to maintain a high standard of annotation, etc, during acquisition of data - possibly some of this could be done or revised during data replay?
- Do not underestimate the importance of linking observations to location - i.e. give all your frame grabs, audio notes, metadata whatever a PLACE. Often during the dive itself the navigation has some errors which can be corrected by post-processing (bad USBL fix, for example, which is edited out post-dive). The position information for all the observations etc. then needs to be updated! It can be done with a good combined time-stamp and navigation system, but needs to be in place from the start.
- Humans navigate in space, not time, annotations and frame grabs help make 20 hours of video into a cloud of points in space – much easier for us to navigate in. But those points need to be well located.
- The above represent a remarkable improvement in the ability of dive scientists to make robust quantitative integration of multiple forms of data.
- Your data are your most valuable asset, plan accordingly, and treat them well.
- More is better - and ideally in real time so it gets done, and done right.
- Learn from others doing this - whoi, mbari, etc.
- This is just as important as critical sensors. The community has lost years of valuable observations for some vehicles because of antiquated logging systems, poor metadata...that have very poor search functions.
- SOI can benefit from academic, government, and industry ROV data annotation systems.
- Annotation formats to be of a standard, self-documenting format (like XML?) so the information can be easily harvested shoreside and made available via webservices.
- Making a distinction between capabilities needed on the cruise versus those after the cruise by the science party and by other users would be helpful.
- Our experience on the Falkor suggested that having a flexible visualisation system that can be accessed by a browser was very helpful in keeping everybody on the same page (and could also have outreach value).
- It is a fact of life that non specialists in a given field will be logging data for that field. It is important to provide specific, simple methods to tag video such that it can be easily reviewed later by experts.

Final Comments on General Science Mission Requirements

- Perhaps include navigational requirements, including RT visualization? Precision to within < 1 m? Also include flexibility to include science-supplied instrumentation/sensors/payload?
- The payload limitation I have most often run into with Jason II is actually it's out of water weight: when using multiple boxes that hold water and a rotary suction sampler we would stress the crane.
- I was just wondering if the 100 kg payload is in water or in air. In air you might quickly reach this weight.
- Among the core capabilities of the vehicle should be a Variable Ballast system that allows the vehicle to trim to neutral buoyancy, or to trim heavy or light, depending on need. All four of MBARI's ROVs have had this capability and it has proved its worth again and again.
- The payload capacity (when coupled with elevators) will be fine, the manipulators will provide excellent sampling capability and the video system sounds first-rate.
- Consider ancillary support systems, such as elevators to enhance payload capacity and increase bottom time.
- Shore based-live telepresence is questionable at full video resolution - as this is more for education and outreach, and separable from the actual vehicle, more a "management" philosophical decision.
- Perhaps consideration has already been given to a through-vehicle lift capability and latching mechanism. Having used ROPOS significantly, this capability is of great use for heavy loads and for eliminating the need to hunt for elevators. It is a much more efficient, and less risky system than using cables to get platforms through the air-sea interface, or free fallen elevators to get equipment and samples to and from the seafloor. It also saves significant time re deck operations and is safer.
- In my experience, telepresence has been very useful for science, engineering, and outreach efforts. It takes careful planning and the ability to utilize telepresence differently for different audiences.
- Is the 4500 m rating locked in at this point? It's too bad this falls just above the exciting hydrothermal vents at the Mid-Cayman Rise, which are at ~5000 m.
- This sounds like a very feasible set of "mission requirements". Some may be asking why you don't build a 6500 m vehicle. In my mind, there are lots of good reasons, including the fact that a LOT of good science can be done at <4500 m. In addition, I think the SOI should focus on using this vehicle as a platform to really push the envelope on deep sea technology. I would wager that a 4500 m vehicle gives you a LOT more flexibility/opportunities to focus on the tech development, and be burdened by the infrastructure and weight and cost needed to operate a 6500 m vehicle.