Project Number: 901807

Project Start: Jan. 1, **2018**[1] **Project Duration (in years):** **Year 1 of 3**[1]

Please indicate if proposal includes requests for any of the following (mark all that apply).

Ship Time	ROV	AUV	Wave Glider	Mini ROV
X		X		

Please indicate what type of project is being proposed (mark only one).

Feasibility/Scoping [Less than 100 days effort]	Development[2]	Research	Infrastructure[2]	Education	Time Series	Institute Initiative
	X					

Project Manager[3]: Eric Martin

Principal Investigator: Kelly Benoit-Bird

Lead Scientist: Bruce Robison, Kelly Benoit-Bird

Lead Engineer: Eric Martin

Project Title: Next generation bioacoustic sensing from Dorado: i2MAP+

Please indicate percentage of effort on this project anticipated for 2018 toward these three highest institutional goals (percentage total should equal 100%).

Goal	Developing/adapting innovative technologies	Utilizing developments to explore and understand ocean systems	Technology/knowledge transfer[4]
Percentage	100%	0%	0%

[1] This date and number should remain the same for the duration of the project. If your project start date for 2018 is not January 1, please indicate the start date in the first cell of the milestone chart. Format for duration example: "Year 2 of 5".
[2] Development and infrastructure projects must complete the risk matrix (see end of the proposal form).
[3] Not all projects will require all four titles to be filled in. Please indicate individuals only for those titles that are appropriate for your project.
[4] This category includes transfer of hardware, know-how, publications, presentations, etc.

1) ABSTRACT (new projects only)

The unification of acoustical and imaging tools has been a goal of the community at least since the first descriptions of the deep scattering layer were made in the 1940s. These two approaches have complementary strengths, providing measurements with different resolution, coverage, and scale. Combined, these tools have the potential to answer challenging questions about life in the ocean's interior. This integrated view, however, has largely remained a challenge, one that recent developments leave MBARI uniquely poised to address. During 2017, we began the process of developing integrated acoustical-optical methods using the ROV Ventana. This work is beginning to provide critical information for interpretation of both acoustic data and visual survey data. We propose to extend this new perspective to the i2MAP payload, integrating a broadband echosounder with two transducers to cover frequencies extending from 50 to 250 kHz. One pair of transducers will be oriented parallel to the high resolution camera. A similar pair will ensonify the field directly below the vehicle to provide biological context in depth space. We have three immediate goals for these integrated measurements:

- Quantify the behavioral responses of animals to the survey platform (avoidance/attraction) and compare them to responses to Ventana as the midwater time series shifts platforms
- Obtain broadband backscatter measurements from individuals identified and sized with the camera system to improve acoustic classification.
- Measure the spatial distribution of organisms in midwater to determine the scales at which animals are aggregated, if those aggregations are organized by taxonomy, size or other features, and what role variation in the habitat plays in structuring the biota.

This integration effort will require tasks related to mounting new sensors and cabling in the payload, designing a subsea housing with an electronics chassis supporting control and data storage, and input power noise rejection.

Future extensions of this work include: **(1)** deployments in new locations to examine epipelagic and semi-demersal animals, **(2)** experimental manipulations of the platform (speed, light type, etc.) to minimize behavioral disturbances, **(3)** use of the acoustic payload in other Dorado configurations (CTD, gulper), and **(4)** real time onboard processing of acoustic data for adaptive mission actions. The proposed research will address several themes of the MBARI strategic plan: exploring the deep sea as well as providing new ways to visualize the variability in the abundance, distribution, and activity of biota in the water column; leveraging and building upon existing MBARI investments in order to enhance understanding of the fluctuations and fate of forage species from the surface to the upper bathypelagic; developing new tools to image the ocean while contributing new sensors and approaches for adaptive sampling.

2) PROPOSAL

a) New Projects

The complementary strengths of acoustic and in situ visual sampling have been evident from the earliest days of each technique. The Deep Scattering Layer, a feature now known to be globally distributed and of very high biomass (Irigoien et al. 2014), was accidently discovered using military sonars in the 1940's (Johnson 1948). This layer, thought at first to be geological because of its intensity and horizontal extent, was confirmed to be biological in origin via in situ visual observations identifying these aggregations zooplankton and micronekton (Barham 1965). This first example of combined acoustics and imaging highlights the complementary strengths (and weaknesses) of each tool and the power to observe biological phenomena in the ocean not fully resolvable with either technique alone. In this case, the large sampling volume and rapid coverage of acoustics was critical in finding the extensive layers. Later, acoustics helped target visual observations by a human observer in a manned submersible which resolved the source of the acoustic scattering as a collection of small animals of a variety of species.

Since then, the fields of acoustics and in situ observation (now, largely using imaging systems instead of/in addition to direct observation in manned submersibles) have made great advances in both technology and application. Yet, despite many attempts, they have been used together only infrequently (see, for example Brodeur 2001, Takahashi et al. 2004, Benoit-Bird & Au 2006). In most cases, the two tools have been used inequitably, with one approach doing a service for the other (e.g. imaging serving as ground truthing for acoustics) (but see, for example Johnson et al. 1956) rather than being used in a synergistic fashion to address a grand question. This lack of integration despite decades of desire is not surprising in that the level of technical expertise required for application and development of each approach is quite high. Few individual researchers or even research institutions have had the ability to make the coordinated investments required to fully exploit the strengths of an integrated approach. In this work, we propose to leverage MBARI's longstanding investments in imaging technologies along with its more recent strategic investment in acoustics to provide information about animal responses to sampling platforms, animal acoustic signatures, and spatial structure of animals in midwater not possible from either alone or even from both techniques used simultaneously from separate platforms. Table 1 highlights the characteristics of the two sampling approaches as well as their synergies. Of particular note are animal density and individual length which can each be estimated via two independent methods but only if data from both imaging and acoustics are obtained synoptically.

Table 1. A comparison of the characteristics of acoustic and imaging sampling approaches along with the measures that can be obtained from each. These two approaches are truly complementary. In **bold** are measures that can be obtained from both approaches while text in **blue** highlight information needed to interpret the acoustic information that imaging can provide while in **orange**, data provided by acoustical sampling that supports the interpretation of imaging data when the two are sampling the same volume of water as proposed here.

Acoustics	**Imaging**
Large sampling volume	Small sampling volume
Low taxonomic resolution	Resolve species
3-dimensional (with split beam)	Flattened 3D (with one camera)
Undetectable by most animals (at fisheries frequencies)	Requires lighting that can change behavior
Measure of **length** if **species** is known	Measure of **length** (with one camera) if **speed** or **range** from camera is known
Describe spatial relationships of individuals and volumes (e.g. aggregations)	Describe spatial relationships of individuals within frames and along transect
Provides context and gross individual movement (tracking)	Observe orientation and fine scale behaviors
Estimate **density** if **individuals** are well characterized	Estimate **density** if **volume sampled** is well characterized

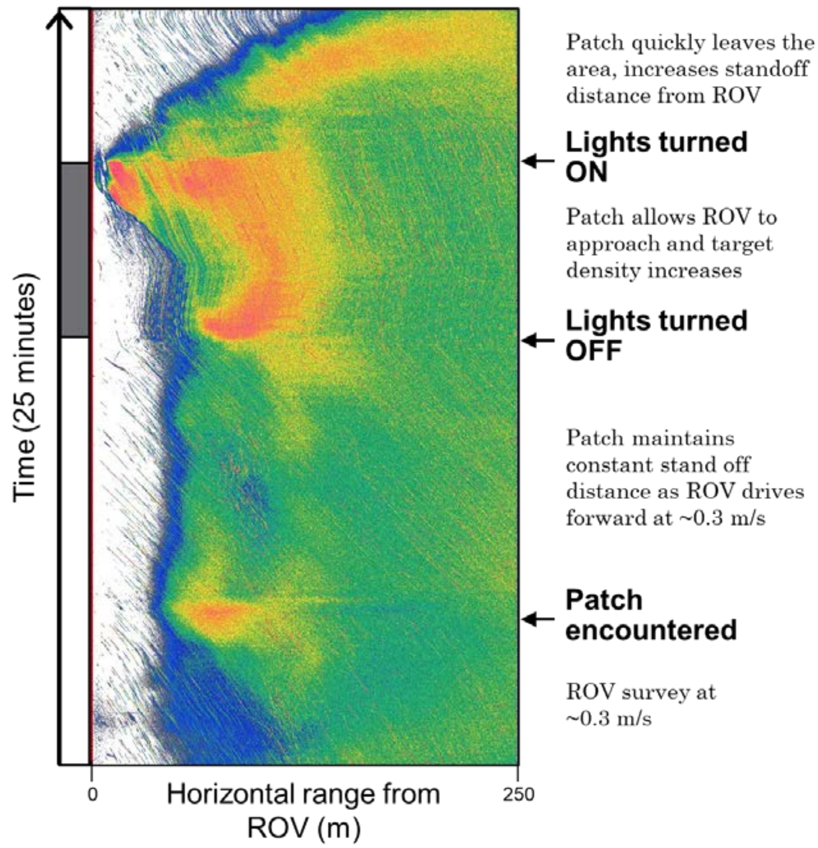
The measures of animals that can be obtained from acoustics and imaging used concurrently from a single platform promise to tell us much about the distribution of animals, their acoustic properties, their responses to the environment as well as sampling strategies. Ongoing efforts to integrate acoustics and imaging on MBARI's ROV platforms have focused on three types of questions:

1) What **behavioral responses** do animals exhibit to platforms and their lights? How do these responses differ between platforms and affect measurements obtained by each?
2) What are the species specific acoustic spectral responses or "**acoustic signatures**" of pelagic animals and how do they integrate when animals are grouped?
3) Is there **spatial organization of animals** by biomass, species, and/or size in midwater?

1. Behavioral responses

Responses of animals to platforms (Stoner et al. 2008, De Robertis & Handegard 2012, Dunlop et al. in review) and lights (Benoit-Bird & Au 2003, Benoit-Bird et al. 2010) has been well documented, largely using acoustic techniques. Addressing this question for ROVs and Dorado class AUVs is particularly timely for MBARI as the Midwater Time Series shifts from decades of video sampling using ROVs to utilizing an AUV as the primary platform. Ongoing work with the ROV Ventana has already demonstrated both avoidance (Figures 1 and 2) and attraction of animals (e.g., krill and squid) to the platform and its lights. Determining how platforms differ in their effects on the animals sampled is critical to providing a seamless, calibrated transition for the Midwater Time Series. We suggest that this effort should be conducted now to avoid any changes in the ROV or personnel expertise that would hinder the comparison of effects between platforms.

Figure 1. An example of avoidance to the lights of the ROV Ventana measured using two echosounders mounted to look forward to overlap the field of view of the camera. The patch of animals was able to maintain a constant distance of about 50 m during an underway survey with the ROV. The animals allowed the ROV to approach them when the lights were turned off but nearly immediately after the lights were turned on, the animals left the area, increasing their distance from the vehicle even further. The lights on the ROV have a warm-up period that is slower than the animals' response so no images were obtained. Note the sharp bands in the acoustic data that align with the warm up of each light.



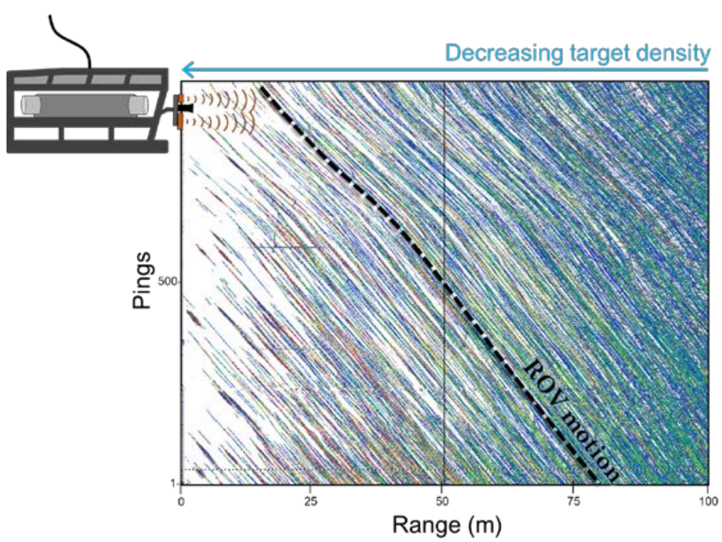


Figure 2. Responses to the vehicle can also be measured as changes in target density with range as the platform conducts a survey. In this example, as the ROV moves forward, targets appear to approach the sensors however a lower density of targets is detected 5 m from the vehicle than at either 25 m or 50 m away. No difference was observed in target density between 75 and 100 m providing an understanding of the total number of animals missed by the camera survey which has a view approximately 5 m for targets of this size as well as the horizontal extent of the effect.

2. Acoustic signatures

One key to interpreting acoustic data is identifying the most likely source of the scattering. Estimates of length and biomass, for example, both rely on accurate taxonomic classification. Taxonomic information is often obtained from other methods like trawling or drop cameras though the different scales and timelines for these data make alignment with acoustic information difficult and impossible at the level of the individual. Alternatively, the acoustic data can be interpreted directly by comparing the results to a known in an acoustic library. These library data are most often obtained from either dead specimens or those brought up to the surface and tethered in a laboratory (Stanton et al. 1998b) or from models based on morphology (Stanton et al. 1998a) which rarely consider the impact of the state of the animal or changes in pressure on the results (Benoit-Bird et al. 2003). While laboratory studies provide detailed measurements, they do so on a relatively small number of individuals and are generally limited to high frequencies and thus can be difficult to apply in the field.

One of the key recent advances for ecosystem acoustics is the commercial availability of broadband systems which promise to increase the information available for discrimination by expanding from a handful of discrete frequencies to a continuous band over a wide frequency range. However, only very few of the published studies of backscattering have considered spectral signals (Lavery et al. 2007) and many questions about applying these new tools remain. The most effective way to fill these gaps is to obtain a large number of in situ measurements of backscatter from individual animals that can be identified, their orientation observed, and their size measured. This is only possible from a single platform carrying sensors that can measure the acoustic properties while synoptically providing visual information. In addition to providing information about a wide range of species and collecting a large number of samples, this approach has the potential to address questions about how pressure may impact the resulting echoes (Benoit-Bird et al. 2003), a topic that has been much debated and has critical implications for the assessment of biomass. The first of this data has been collected from the ROV Ventana, showing the value of the approach (Figures 3 and 4). With relatively few dives (currently 3) this data collection approach has increased the size of the broadband backscatter library collected by all researchers by several orders of magnitude. Despite this rapid growth, building a library for the diverse life in Monterey Bay will require a substantial sample set that would be greatly facilitated by a similar integration in an autonomous platform.

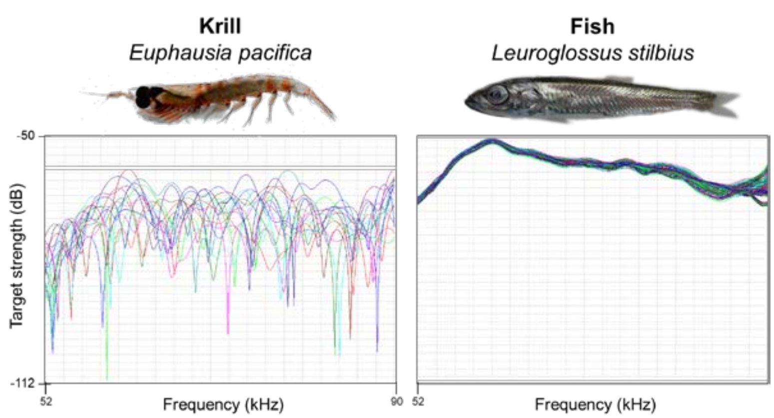


Figure 3. The spectral shapes of 25 echoes from krill (left) and the California smoothtongue (right), a fish with a wax invested swimbladder that is an energy rich food source for many predators in Monterey Bay, show dramatic differences despite similar intensities.

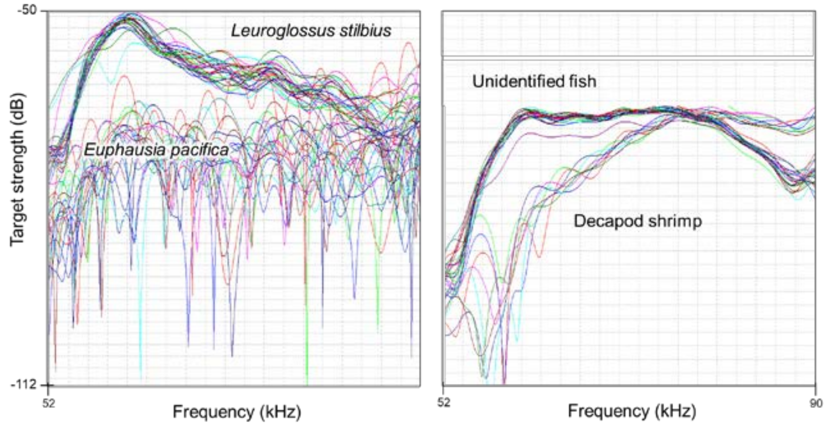


Figure 4. Echoes obtained simultaneously from two different mixed aggregations (identified to species via ROV video) reveal the potential to utilize acoustic signatures for classification in field data.

3. Organization of life in midwater

The challenges of studying the immense, dark, and traditionally inaccessible midwater zone mean many relevant aspects of its biology remain largely unexplored. There is a long-held view that the volume beyond the ocean's photic zone is largely homogenous, both physically and biologically, in the horizontal plane. Yet, visual observations, primarily from MBARI's ROV program, have revealed that mid-depth waters have an incredibly diverse array of animals and particles that are quite active and highly spatially structured at small scales and our acoustic surveys from AUVs at depth have revealed significant variation in the distribution of animals at scales from hundreds of meters to tens of kilometers (Benoit-Bird et al. 2017). To observe these small scale patterns requires higher resolution acoustic sampling than is possible from surface vessels. Combining these in situ acoustic measures with concomitant imaging provides an unprecedented view of individuals, the group, and the environmental context, affording the opportunity to quantify structure of both biomass and taxonomic composition that has been previously unattainable (Figure 5).

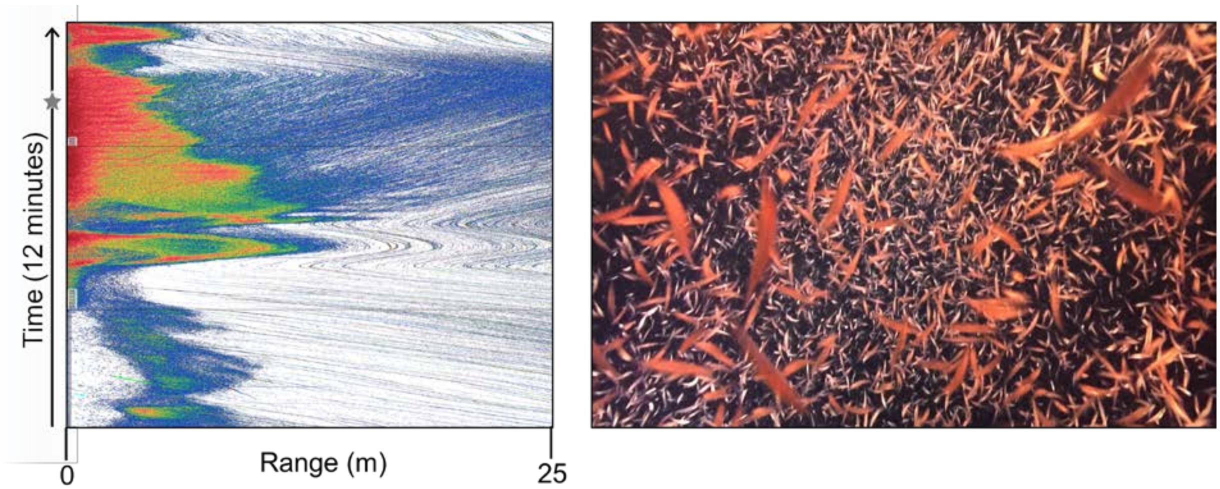


Figure 5. A patch of krill was measured at long range (shown here at 8 m but first observed >50 m) and then observed from within the swarm, providing two measures of the density of the patch, measurements of the patch's extent, shape, and internal organization, the species forming the group, and the distribution of individual krill length. Neither the acoustics nor imaging could have given a complete picture of the swarm independently and for swarms of this physical scale (<10 m across), even coordinated platforms with independent sensors would have been challenged to obtain matching datasets.

How does it relate/contribute to MBARI's mission and strategic plan?
The proposed research will address several themes of the MBARI strategic plan including exploring the deep sea as well as providing a new, integrated approach to visualizing the variability in the abundance, distribution, and activity of biota in the water column by leveraging and building upon existing MBARI investments in order to enhance understanding of the fluctuations and fate of forage species from the surface to the upper bathypelagic and the populations of larger marine animals for whom they are a primary food source.

How does it relate/contribute to the Packard Foundation's Ocean Visions Grantmaking policies?
(See http://mww.mbari.org/oed/OED_Documents.htm#Packard for documents.)
The technology development proposed here will facilitate the discovery of biological patterns and processes in midwater as well as an understanding of our sampling capabilities. The mesopelagic is an understudied region that is critically important for the success of a wide range of species including many important food fish and, through decreasing oxygen and shallowing of the oxygen minimum layer, is being dramatically impacted by climate change. In order to meet the PF's plan to provide information for the sound management of biological resources in the ocean, the animals in this critical yet undersampled region must be brought to light.

Does it relate to the Technology Roadmap? If so, please describe how.
(See http://mww.mbari.org/oed/TechnologyRoadmap.pdf.)
The toolset proposed here will provide critical support for the goal of 'taking the laboratory to the ocean' as we seek to understand how the presence of the laboratory affects the subjects of study. This work to understand how animals behave in response to platforms has implications far beyond the midwater time series that will serve as the backbone of the first observations, potentially influencing all studies of mobile animals from AUVs and ROVs. This understanding of platform effects will become

increasingly important as MBARI continues to make progress in enabling a persistent presence in the ocean, largely through the application of underwater vehicles. To support the goal of enabling targeted sampling, this effort explicitly includes a system architecture capable of supporting on board data processing and communication for future efforts which could include control of lights and cameras, vehicle location, water sampling, and more.

Approach to the problem

We propose to further the integration of imaging and acoustics at MBARI by developing an acoustics payload for the Dorado class vehicles that can be deployed within the existing i2MAP imaging vehicle. While acoustics and imaging can be used in a coordinated fashion from independent platforms, this kind of true integration provides resolution at depth not possible with surface vessels, allowing the observation of behavior in response to the platform, identification of targets and measurement of their sizes, and independent, simultaneous assessments of animal density at sub-patch scales. This approach parallels efforts undertaken with the ROV Ventana, allowing an increase in the sample size of visual-acoustic data. More importantly, this development provides the opportunity to quantitatively compare the responses of animals to these two sampling platforms to permit appropriate integration of the data from the ROV and AUV surveys as the midwater time series changes its core sampling approach. As the midwater group has observed, there are differences in some types of animals observed and the frequency of observation of others. This is not surprising given the differences in the size of the two platforms the differences in their radiated noise, the number, intensity, and range of the lights on each, and the factor of 2 in their survey speeds. Observation of the behavior of animals in response to the platforms (as in Figures 1 and 2) provides a direct approach to quantifying these effects and developing correction factors to scale the data sets for comparison.

To accomplish this, we will integrate a dual-frequency Simrad EK80 Mini scientific echosounder into a Dorado payload with two transducers (one at 70 kHz and one at 200 kHz) looking forwards to align with the video data and two looking downwards to provide context across the water column.

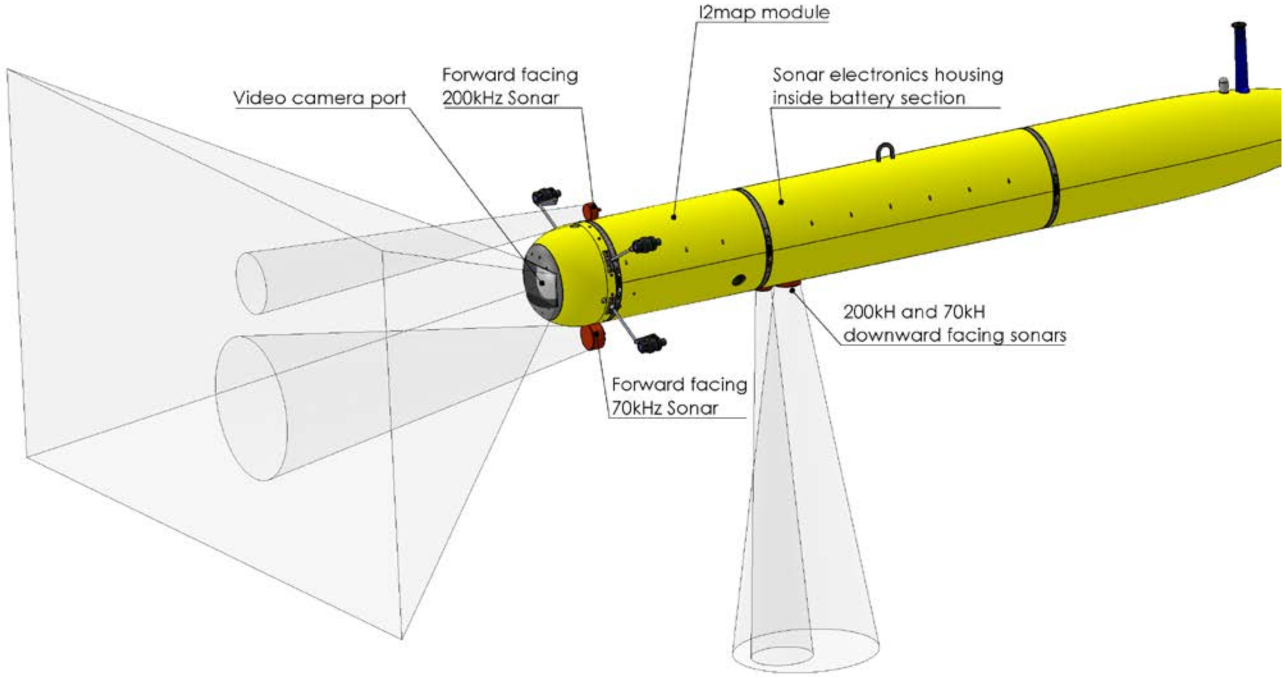


Figure 6. A drawing of the proposed acoustic system integrated into the i2Map vehicle. The positioning of the transducers is optimized for a combination of vehicle stability, avoidance of interference between instruments, and overlap between imaging and forward-looking acoustic systems.

The requirements we have identified for the proposed system are:

1. All components must be contained within the I2Map Payload area.
2. The system must facilitate deck configuration and start/stop operation.
3. Data (up to 100 MB per dive), must be available post-dive.
4. There must be a dedicated Windows-based processor to operate the software.
5. Time, depth, and position data from the vehicle must be incorporated in the recorded data via a NEMA string
6. The acoustic system must survive the depth rating of the overall payload, 1500 meters.
7. Transducers cannot impact the video data.
8. The transducers' field of view must overlap with the field of view of the camera from 1-5 m of the vehicle.
9. I2Map must remain deployable without the acoustic payload and during development.

Other considerations include maintaining design features (connectors, cabling, etc.) consistent with the Dorado class to facilitate transfer to other vehicles, incorporating enough processing overhead to allow future onboard acoustic data processing for targeted sampling, and consistency of design solutions with other development efforts (OSU glider, LRAUV) to simplify operation and allow interoperability. Figures 7 and 8 show the solution we propose to meet these requirements.

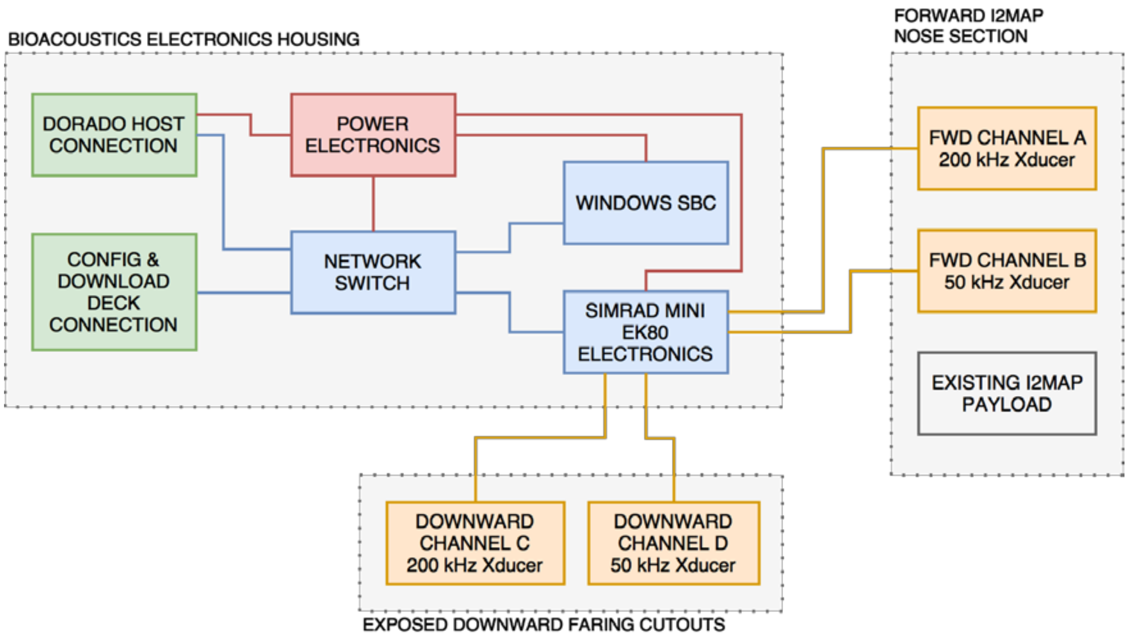


Figure 7. A diagram of the components in the acoustic payload and the planned interfaces between the acoustic system and the Dorado vehicle.

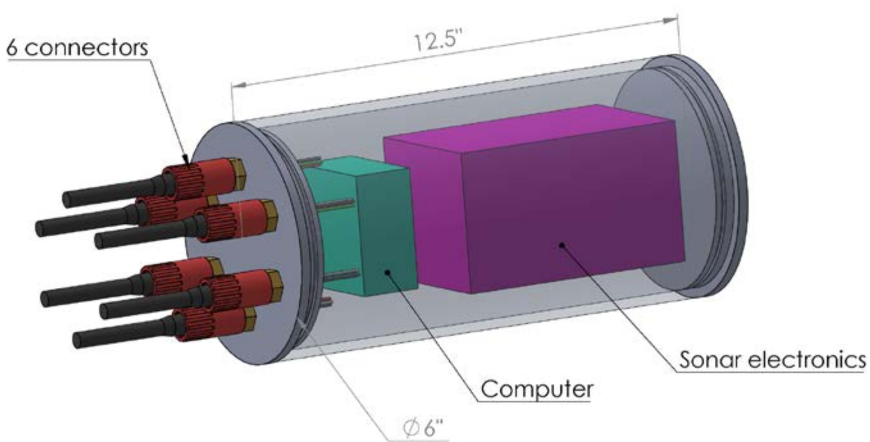


Figure 8. A diagram of the housing for the electronic components of the acoustic system proposed.

Application and extension plans
Year 1 (2018) of the project will be dedicated to development, integration, and testing. Years 2 and 3, we anticipate enabling the acoustic system during the Midwater Time Series deployments which will provide data on responses of animals to the platform, data for the ongoing development of an acoustic library, and characterization of the spatial structure of biota in midwater. In out years, in addition to

continuing data collection as part of the time series, we anticipate coordinating with additional science teams to enable:

- Deployments in new locations to examine epipelagic and semi-demersal animals (e.g., rockfish)
- Experimental manipulations of the platform (speed, light type, etc.) to minimize behavioral disturbances (partnership with Haddock)
- Use of the acoustic payload in other Dorado configurations (CTD, gulper; Chavez, Scholin)
- Real time onboard processing of acoustic data for adaptive mission actions (Zhang)
- Virtual reality integration of 3D acoustic data and video imaging to exploit the integrated data products

During the out years of the project (2019-2020), technical goals for the project include:

- Scripting of mission control to increase robustness and mission duration capabilities
- Optimization of power and data utilization
- Testing the capabilities needed for adaptive mission actions including onboard data processing

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b) New and Continuing Projects: Plans for 2018

Research Activities

This project is primarily a development effort in 2018.

Engineering/technology development

Upon availability of funding, the first task is to place an order for the pair of new transducers with Simrad. The existing system (electronics and transducers) will be evaluated for compatibility with Dorado electrically and initial ballasting requirements will be determined. Requirements will be drawn from initial findings and feedback from the PIs, leading to a small concept review.

Following the concept review, New embedded processors and other critical components will be selected and evaluated. Bench testing will affirm compatibility, with a special focus on noise susceptibility in the sonar electronics (a known concern). Power electronics components will be designed as well. At this point, final designs are expected for the transducer from Simrad, and mechanical bracketry design can begin, alongside design for the electronics housing that will contain the small board computer, a switch, and power electronics. This work will culminate in a preliminary design review. Final designs and drawing for brackets, housings, foam, wiring, and printed circuit boards will then be created and submitted for final review

Post-fabrication, system will be assembled and tested. Initial tests will commence on bench to confirm power consumption and system functionality. Secondary tests will occur in place on the Dorado AUV in the test tank, again watching for noise and ground faults.

Finally, 3 days have been requested to conduct field trials of the new system, alongside the existing i2MAP payload. Special attention will be given to movement stability, as new transducers will impact the drag characteristics of the AUV. If the system is strongly affected, addition of stabilizing fins may be employed, since they were shown to be beneficial during the i2MAP development. Days are requested to be split so that these adjustments may be made.

Field programs (detail ship requirements/deployments/diver requirements)

We request 3 deployments of the newly integrated vehicle carrying both the i2MAP and acoustic payloads from the Rachel Carson to test flight stability, electrical and acoustic noise, and verify data quality prior to scientific implementation in years 2 and 3 of the project.

Isotope Usage
Project teams must provide details regarding any planned isotope use on shore, on ships, in the Sanctuary, etc. Please review the guidance on isotope usage at http://www.mbari.org/at-sea/cruise-planning/hazardous-materials/ and policy at http://mww.mbari.org/safety/SafetyManual/Isotope_Use_Policy.pdf, and then provide details on plans below.

N/A

Specific deliverables

Main deliverable of this development is a subsea sea system optimized to run semi-autonomously on the Dorado AUV in its i2MAP configuration that enables use of the Simrad EK80 Mini. The system will include custom bracketry, foam, and an interface housing that are supplemental, not integral to the existing payload.

Milestones (see personnel classification list for staff classifications)

Milestone 1 – Concept Review and System Qualification
The echosounder system will be evaluated for compatibility with Dorado electrically and initial ballasting requirements will be determined. Requirements will be drawn from initial findings and feedback from the PIs, leading to a small concept review.

Milestone 2 – Preliminary Design Review
New embedded processors and other critical components will be selected and evaluated. Bench testing will affirm compatibility, with a special focus on noise susceptibility in the sonar electronics (a known concern). Power electronics components will be designed as well. At this point, final designs are expected for the transducer from Simrad, and mechanical bracketry design can begin, alongside design for the electronics housing that will contain the small board computer, a switch, and power electronics. This work will culminate in a preliminary design review.

Milestone 3 – Critical Design Review
Final designs and drawing for brackets, housings, foam, wiring, and printed circuit boards will be created and submitted for review. The transducers should be in hand prior to final review.

Milestone 4 – Initial System Build, Integration and Tank Testing
Post-fabrication, system will be assembled and tested. Initial tests will commence on bench to confirm power consumption and system functionality. Secondary tests will occur in place on the Dorado AUV in the test tank, again watching for noise and ground faults.

Milestone 5 – Field Trials
Finally, 3 days have been requested to conduct field trials of the new system, alongside the existing I2Map payload. Special attention will be given to movement stability, as new transducers will impact the drag characteristics of the AUV. If the system is strongly affected, addition of stabilizing fins may be employed, since they were shown to be beneficial during the I2Map development. Days are requested to be split so that these adjustments may be made.

2018 Project Start Date: 1/1/2018	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Total Resources**[5] for each resource category for all milestones listed here
Milestone Date	**2/1/2018**	**3/15/2018**	**4/15/2018**	**6/1/2018**	**11/1/2018**	
Milestone Description	**Concept**	**PDR**	**CDR**	**Build & Test**	**Field Trials**	
Electrical Engineer	**EM: 12**	**EM: 77 PM: 5**	**EM: 47 PM: 10**	**EM: 16 PM: 10**	**EM:24**	**EM: 210 PM: 25**
Software Eng-Embedded						
Software Eng-Info Eng						
Mechanical Engineer	**FC: 4**	**FC: 65**	**FC: 67**	**FC:18**	**FC:26 RM: 40**	**FC:180 RM:40**
Mechanical Eng-Division						
Mechanical Eng-Mfg						
Associate Engineer						
Electrical Tech		**TBD: 10**	**TBD: 10**	**TBD:30**		**TBD: 50**
Software Tech						
Mechanical Tech						
Machinist				**TBD:110**		**TBD:110**
AUV Engineer	**HT: 7**	**HT:2**	**HT:7**	**HT:12**	**HT:7**	**HT:35**

[5] This number should be the same number you entered on the resource requests for this particular resource.

Budget justification

Group	Item	Quantity	Cost	Total
Wet Cabling	Download GigE Bulkhead (NETG)	1	$265.00	$265.00
	Download GigE Cable	1	$600.00	$600.00
	Download Bench Cable	1	$900.00	$900.00
	Download GigE Dummy	2	$200.00	$400.00
	AUV Host Bulkhead ()	1	$1,100.00	$1,100.00
	AUV Host Cable	1	$2,200.00	$2,200.00
	AUV Host Bench Cable	1	$1,100.00	$1,100.00
	AUV Host Dummy	2	$400.00	$800.00
	Transducer {A:D} Bulkhead	4	$330.44	$1,321.76
	Transducer {A:D} Cable	4	$445.50	$1,782.00
	Transducer {A:D} Dummy	8	$44.00	$352.00
Sonar	70 kHz license	1	$19,470.00	$19,470.00
	70 CDK transducers	2	$19,800.00	$39,600.00
Subsea Housing	1,500-m Tolerant 1 ATM Housing	1	$242.00	$242.00
	Anodizing For Housing	1	$440.00	$440.00
	Housing Chassis	1	$220.00	$220.00
	Compact 4-port Network Switch	2	$330.00	$660.00
	Power Electronics	1	$3,300.00	$3,300.00
	Compact Small Board Computer	2	$1,760.00	$3,520.00
	Windows Software License	2	$143.00	$286.00
	Miscellaneous Components	1	$3,300.00	$3,300.00
Support Gear				
	Dedicated laptop control computer	1	$1,400	$1,400
	External storage	1	$500	$500
Dorado Mechanical	Fairing Section	1	$2,200.00	$2,200.00
	Fairing Hardware	1	$550.00	$550.00
	Syntactic Foam	1	$5,500.00	$5,500.00
	Mounting Brackets	1	$440.00	$440.00
			Subtotal:	**$92,448.76**
			Tax:	**$7,164.78**
			Total:	**$99,613.54**

Project team

Kelly Benoit-Bird – PI
Bruce Robison – Senior Scientist
Eric Martin – Lead Engineer, Electrical Engineer
Paul McGill – Electrical Engineer
François Cazenave – Mechanical Engineer
Rob McKewen – Mechanical Engineer
Chad Waluk – Research Specialist
Kim Reisenbichler – Research Specialist
Hans Thomas – AUV Group Leader

Project lab and office space requirements
In addition to any changes to current space usage, please also include anticipated office and lab needs for students, postdocs, collaborators, etc.

No new space needs are anticipated for this effort.

Data storage requirements (see Todd Ruston for assistance)

Up to 100 Gigabytes per dive for acoustic data for a 2018 maximum of 300 Gigabytes.

Data availability outside project team, uniqueness

The data collected during field trials, if of suitable quality, will contribute to the development of an acoustic library for interpretation of backscatter from all platforms as well as our understanding of scattering processes. These kinds of in situ, broadband measurements, along with those being collected by a sister instrument on Ventana, are unprecedented. Observed animal responses to the platform will be of great interest to many investigators at MBARI who are interested in sampling animals from ROVs and AUVs. These results will be shared widely and we anticipate discussions begun on mitigation of effects and interpretation of data that will influence science plans for this effort in coming years.

R/V *Paragon* Requests
If the project team will be requesting time for the R/V Paragon, please specify the operators in the group and provide estimates of their availability to operate the vessel.

N/A

Export Regulation
Does the project team anticipate any foreign collaborations or international travel? If so, please identify collaborators by name, institution, and country.

No foreign involvement or travel anticipated

Does the project team plan or anticipate export controlled purchases, shipments, or transfers of items (e.g., research instruments, proprietary data, hand-carried tools or samples) outside the U.S. temporarily or permanently? If yes, please identify country or countries and indicate whether these items will remain under MBARI control while abroad or controlled by others. Will the items be exported to more than one country? Please include foreign collaborator information as described above.

N/A

<u>Monterey Bay National Marine Sanctuary (MBNMS)</u>

General Permit
Projects teams need to indicate if any work will be performed that is either: (1) currently authorized under our general permit; or (2) will require that we obtain authorization. The current permit can be viewed at http://mww.mbari.org/pco/permits/mbnms-2015-002_feb2015.pdf. Please see Mandy Allen for questions.

Is a permit with MBNMS required for your work?

Yes; covered under the existing permit.

SESAs (General map)
*Projects will need to indicate whether or not work will be conducted within one of the Monterey Bay National Marine Sanctuary's Ecologically Significant Areas (SESAs). An interactive map can be found on the Sanctuary's SIMoN webpages at http://sanctuarysimon.org/maps/sesa/. (*Note: It may take a moment for the page to load, so please be patient. Also, if prompted for a login, hit "Cancel" and then you will be able to access page.*) To determine if your work will occur in a SESA, specific coordinates can be entered using the locator function (click on the red "target" button in the toolbar at the top of the map). If your work will be conducted in one of these areas, please indicate which area, by number.*

None

<u>California Department of Fish & Wildlife</u>
A Scientific Collecting Permit will be required for biological and geological sample collections offshore California (even in Federal waters and beyond), and for many activities in State Marine Protected Areas. Please see Mandy Allen for questions.

Will you be collecting samples that require a permit?

No

Will you be working in a State Marine Protected Area?

No

Authorizations/Permits from other Agencies or Organizations

Is the project team aware of any other permits or authorizations that will be necessary to perform the proposed work? If so, please list below along with status of authorizations (obtained, pending, need to apply, etc.). Please see Mandy Allen if you have questions.

None

Active Acoustics

We are keeping an inventory of acoustic instrumentation. The current list is posted here: https://mww.mbari.org/resources/2018_Proposal_Process/documents/mbari_acoustic_instruments_2016-08-08_ver_10.pdf. If you have or plan to use equipment that is not already on this list, please be sure to include that information here.

All equipment proposed already included in the list

Risk matrix (development and infrastructure projects only)

	Technical Risk	Organizational Risk	Tech Transfer Risk	Labor Estimate Risk
High				
Medium	X[1]			X[2]
Low		X	X	

[1]Many of the most substantive risks (power use characterization, data management in the vehicle, acoustic architecture, noise mitigation, and onboard data processing approach) have already been borne by another project, through the successful development of an echosounder equipped Slocum underwater glider. The glider uses the same echosounder system proposed here in a much smaller platform with substantially lower power capabilities and much more sensitive flight characteristics. However, it only utilizes two transducers at one frequency.

[1]Another identified risk is that the transducers, particularly the forward facing ones, affect the flight stability of the vehicle by changing the drag characteristics. Added drag at the nose of the vehicle can create moment forces that effect pitch and heading control. This issue was explored in the original i2MAP development to great extent, so any problems that arise have previously identified solution pathways.

[1]The prototype of the second frequency transducer we propose to utilize is currently in testing by the manufacturer. Given that the transducer has not yet been released, the size and weight may change slightly from the current design and the delivery timeline is still an estimate. To mitigate this, we remain in close contact with Simrad’s engineering team and have paced our effort to provide a buffer for potential delivery delays. This would not impact the electrical and software integration and the system could be operational at one frequency with parts on hand.

[2]Electrical noise interference with the acoustic data is a known concern for this issue and can be challenging to identify and mitigate, potentially affecting labor estimate accuracy. The team is aware of

the issues, has successfully resolved them in a number of platforms, and has incorporated mitigation measures into the planned design that should minimize the impact.