Project Number: 901504

Project Start: Jan. 1, 2015[1] **Project Duration (in years): 2 [1]**

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

Ship Time	ROV	AUV	Wave Glider	Mini ROV
[ ]	[ ]	[ ]	[ ]	[ ]

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
[ ]	[X]	[ ]	[ ]	[ ]
	Time Series [ ]	Institute Initiative [ ]		

Project Manager[3]: Rob McEwen

Lead Engineer: Rich Henthorn

Project Title: Full-Speed Dorado Simulator

[1] This date and number should remain the same for the duration of the project. If your project start date for 2016 is not January 1, please indicate the start date in the first cell of the milestone chart.
[2] Development and infrastructure projects must complete the risk matrix (see item #5 at the 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.

1) PROPOSAL

b) Continuing Projects

Current status of project and results to date

We have been successful in 2015 with our main goal which was to speed up our simulation capabilities for the Dorado class AUV. For a variety of reasons, the simulation software previously ran at actual speed, which meant that an 18 hour mission took 18 hours to simulate. With the changes we have implemented, a factor of 60 speed increase has been achieved and an additional 5 times speed up appears possible. It is important to understand that the flight code (software that runs in the AUV) is a component of the simulation, and this makes it impossible to divorce the two entirely. The advantage of this is that the simulation exercises the actual code that executes on the vehicle, but it also means these two pieces of software need to be maintained together.

With a simulator that runs 60 times faster than the wall-clock, we have enabled a capability that has proven itself to be valuable in a variety of situations. For example, more complicated missions are now being created because validation before implementation is now feasible. As we push these vehicles closer to the bottom, accurate and fast simulation of the expected behavior has reduced the risk of collision. We have seen examples of dangerous problems caught in simulation before the vehicle was put at risk. Finally the ability to quickly simulate new missions while at sea (but before the vehicle dives out of sight) will increase the efficiency of the ship time usage by allowing adjustments to be made to the vehicle behavior on site that previously may have required simulation on shore, and hence a second ship day.

The technical details of this work largely followed the plan set out in the 2015 proposal and three of the four tasks in that proposal are complete. The final task "Final Testing and Validation" is ongoing. Although we have demonstrated the full-speed simulation code on shore, we have not yet completely merged the necessary flight-code changes into the operational flight code that resides in the version control system and runs on the vehicle. Because the operational flight code is always changing, the version of the flight code we have implemented in our simulation is gradually diverging from the code that operates on the vehicle on any given day. As more time passes, it becomes harder (although not impossible) to make the results of this project become a permanent feature of the AUV software. Additionally, as these codes diverge, the simulation results become less representative of the actual behavior the vehicle. Merging is the most important task remaining this year.

Significant changes from previous project proposal

There have been no significant changes so far this year from the 2015 proposal.

Publications based on the results of this project only

None thus far.

c) New and Continuing Projects: Plans for 2016

Research Activities

[Click here to enter text]

Engineering/technology development

We propose three objectives for 2016:

Objective 1: Single-Task Guidance, Navigation and Control

This work will result in another significant jump up in simulation speed, probably an additional factor of two to five. This is very significant because it further takes the pressure off of the dive days needed for AUV software development. The reasons are essentially the same as stated previously. A very fast simulator will allow us to quickly adapt to the often changing situation during a sea day, try permutations of missions, parameter settings, and locations, and then release the vehicle with confidence in what it will do. This will prevent us from wasting valuable sea-day time by not having to re-run missions when they don't work on the first try.

The Single-Task Guidance, Navigation and Control modification involves mostly changes to the flight code, but it does not change how it operates at sea. That is, these changes will be invisible to the operators.

A related advantage of this effort is that it will reduce the amount and complexity of the flight code. This makes on-going flight-code development easier with less debugging.

We will streamline the flight code by combining what are now separate tasks, Navigation, Layered Control, and Dynamic Control, into a single task. A single task eliminates unnecessary overhead and lowers the opportunity for inter-process communication bugs to occur during any future development. These types of bugs are non-deterministic and typically very difficult and time consuming to find and correct.

The risk here is in modifying the existing, proven flight code. But, we will be able to reduce this risk by using the full-speed simulator to quickly test a variety of scenarios.

The next two objectives are simulator improvements not directly related to simulation speed, but have enhanced utility due to the speed.

Objective 2: Basic Animation

We would like to develop a basic 3D animator for both simulation results and vehicle data. This will give engineers and mission planners a way to visualize how the vehicle is moving and reacting, which now is nearly invisible with the existing strip charts. Further, the animation of sonar beam ranges as the vehicle moves can reveal crucial patterns that are masked in static plots. These patterns result from things like occluded areas and interference from other sonars, a common problem.

An example of the value of animation arose recently when Prof. Rock developed a 2D animation of the vehicle flight coupled with obstacle-avoidance sonar-ranges. Figure 1 shows a frame from the 2D animation. The 2D animation has proven pivotal in understanding where and how noise occurs, which will lead to the correct sonar parameters, and further, will provide a sense of how to design a good filter algorithm. Correct parameters and filtering are crucial in making a sonar work.

Our intention is to develop basic cartoon-level animation with a minimum of fancy graphics. The objective is to visualize vehicle motion and correlate it with sensor noise and readings, not accurately depict vehicle appearance. The first step here is to determine if it is best to do this in Matlab, or to use something else such as VRML as was done for BEDS.

The speed of the animation is independent of the speed of the simulation. The animation just displays the results after the simulation is completed, or the vehicle data is downloaded. The animation speed will be adjustable from real-time to fast forward.

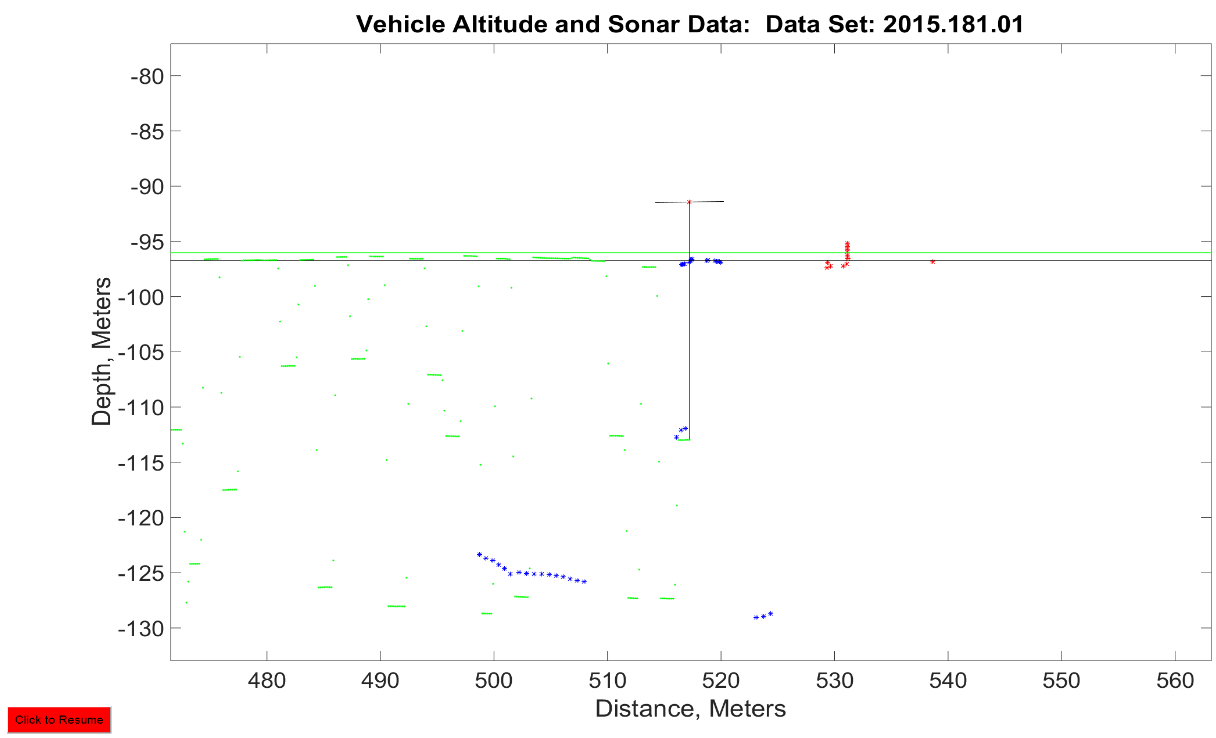

Figure 1. A single frame from a 2D animation by Professor Rock. Here you can easily see that the blue and black points below the flat bottom (long black/green line) are the bad ones. Some of the forward (red) ranges are also obviously artifacts. The real value is in the animated version, which reveals patterns that correlate with vehicle depth and pitch, depicted by the short black horizontal line, which change as the vehicle moves over the bottom.

Objective 3: Water-Column Modeling

In 2014 reviewers suggested adding water-column modeling to the full-speed simulator in 2016. This would allow us to test new algorithms that steer the vehicle based on embedded, real-time water-sensor readings. An example is a front-tracking algorithm.

While water-column modeling is still valid for the reasons stated in the last proposal, we now propose to reduce this to a feasibility study in 2016. Further investigation this year has shown that typical models such as ROMS and HF radar have resolution on the order of 3 km, much larger than the dynamic response of the vehicle, which is on the order of 10's of meters. Thus it is unlikely that model-generated data will be useful for testing sensor-driven AUV control algorithms such as front tracking. More likely, idealized water-property simulation models will be developed case-by-case. These probably will not need to be complicated.

The long-range program has used static ROMS data, but a quick investigation shows that an idealized model would also have sufficed.

In 2016 we will investigate the following:

1) How many users would have a need to simulate an AUV guidance algorithm that steers based on water properties such as salinity or chlorophyll?
2) Are there any cases where model data would be necessary, given the comparatively low resolution?
3) Are there any models or situations that will produce water-column data with a resolution comparable to that of the vehicle dynamics?
4) How much code from a similar effort from the Linux port of 2010 can be reused in QNX?

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

None.

Specific deliverables

Working code checked into CVS.

Milestones (see personnel classification list)

These milestones are late in the year to accommodate the iceberg and TRN projects, which cumulate in a trip to Newfoundland, Canada in June. Also, there may also be an Ocean Imaging Hovering AUV PDR in June. Thus this project is not expected to start until mid-year.

The Single Task GNC milestone will probably involve significant debugging. It is difficult to estimate the duration of this, so that deliverable is last.

2016 Project Start Date: 01/01/2016	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Total Resources**[4] for each resource category for all milestones listed here
Milestone Date	**1 October**	**1November**	**31 December**			
Milestone Description	**Animation**	**Water Model Feasibility**	**Single Task GNC**			
EE						
SE	**160**	**80**	**360**			
ME						
EE Tech						
SE Tech						
ME Tech						
Machine Shop						
Divers						

Budget justification

Personnel:

- Headley: 80 hours; 40 hours to investigate water-column modeling, and 40 hours to assist with Single-Task GNC.
- Henthorn: 240 hours; 40 hours to investigate water-column modeling, and 200 hours for Single-Task GNC.
- McEwen: 260 hours; 160 hours on animation, and 100 hours on Single-Task GNC.
- Thomas: 20 hours; technical consulting.

Project team

Rob McEwen – Project management and final simulation verification.
Rich Henthorn – New full-speed simulator code and testing.
Kent Headley – Synchronous operation of GNC flight code and testing.
Hans Thomas – Technical consulting.

Project lab and office space requirements

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

None additional.

An overall advantage of this project is that it does not require ship time, additional office space or equipment.

Data storage requirements (see Todd Ruston for assistance)

None beyond what's needed for routine simulation and code development. This is probably less than 40GB.

Data availability outside project team, uniqueness

[Click here to enter text]

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

No.

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.

No.

Monterey Bay National Marine Sanctuary 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.

Risk matrix (development and infrastructure projects only)

	Technical Risk	Organizational Risk	Tech Transfer Risk	Labor Estimate Risk
High				

Medium			x	x
Low	x	x		