SCIENCE MISSION REQUIREMENTS FOR AUV-BASED MIDWATER RESEARCH

Mission One – Quantitative Transecting by a Survey AUV

Background and Justification

One of the great successes of MBARI's midwater research program has been the creation of a time-series data base from quantitative transects. This is the first data set of its kind, anywhere. It provides a high-resolution assessment of the abundance, vertical distribution and seasonal variability of midwater animals, that has led to significant new insights into the structure and dynamics of mesopelagic ecology. We have used the data base to good advantage in our lab's research on the siphonophores *Nanomia*, *Praya* and *Apolemia*, in our studies on larvaceans, in Jay Hunt's work on squids, in Jessica Silguero's thesis on calycophorans, Kevin Raskoff's thesis on hydromedusae, and Dawn Murray's thesis on scyphomedusae. It will also be the foundation of our study on the influence of El Niño.

There are however some limitations to conducting midwater transects with ROVs like Ventana and Tiburon. Effective transect length is limited to about 400 m. Transecting becomes more difficult with increasing depth because of tether drag, and below 700 m it is often a real struggle. Transecting above 100 m is not possible with Tiburon, and is problematic for Ventana above 50 m. Nighttime operations are difficult for the Lobos/Ventana. Finally, continuous transecting operations beyond 4 or 5 hours is hard on ROV pilots, ship's crew, and scientists alike.

The logical extension of our transecting program is to increase the spatial scale of these measurements in the horizontal plane, increase our resolution in the vertical plane, and improve our temporal resolution to include regular measurements at night. In the first case, we need to increase our transect length to at least a kilometer in order to examine patchiness and animal distribution patterns at a larger scale. In the second case, we need to reduce our vertical interval between transects from 100 m to 50 m, and to conduct transects to within 25 m of the surface. Lastly, nighttime data is the largest and most serious gap in our data base and we must gain the capability to transect regularly at night. The goal here is to expand and automate the midwater transecting process. These requirements are ideally suited to an AUV as a research platform. An AUV with the following characteristics should allow us to meet our research objectives.

Endurance: minimum of 24 hours underway
Range: minimum of 50 kilometers
Speed: sustained, stable operation at ½ knot
Depth Range: minimum to 1000 meters
Auto Depth Control: to ±2 meters
Auto Heading: to ±5°
Navigation: maintain position within a 2 kilometer circle
Instruments: CTDO, transmissometer, ambient light sensor, OPC, biolume sensor
Lighting: four, 500 W HMI lights
Camera: high-resolution, color, with a 5.5 mm lens (equivalent to Ventana's wide angle)
Alternate Imaging Systems: high-resolution, low-light video with IR lighting in a frame;

high-resolution, digital, coupled to strobes (operating at 2-3 sec intervals)
Video Recorder: digital, 18 hrs capacity
Other Capabilities: quiet, unobtrusive, IR transecting frame

Mission Profile
Deploy from surface vessel. Vehicle conducts 1 kilometer-long, horizontal video transects at 50 meter depth increments from 50 to 1000 m depth. Descent transect series during daylight hours. Vehicle parks at depth. Ascent transect series during nighttime hours. Transects can be run on reciprocal headings. Surface vessel recovery.

Long-Term Development Prospects
A valuable parallel development for this vehicle system would be an automated image analysis system for processing the video data. Developing an AUV with the characteristics outlined above will constitute a major advance in the technology for midwater research. However, if we can make it this far, then further increasing the endurance of the vehicle would yield substantial improvements in the scale of phenomena we could examine. This vehicle system could also be developed to operate within a network of moored stations to allow data transfer and battery renewal. Addition of a recording, scanning sonar would further enhance the vehicle's scientific utility.

Mission Two – Time-Lapse Stationkeeping by AUV Probes
Background and Justification
A second area of significant success in our midwater research program has been the ability to observe animal behavior patterns in situ. This breakthrough has revealed many important aspects of midwater ecology that have considerably expanded our basic understanding of ecological pattern and process. As examples, we have observed the feeding behavior and predator-avoidance strategies of many midwater species, we have measured swimming speeds and sinking rates, and we have measured activity levels.

The practical limitations of our ROV operations mean that observation times for midwater animals rarely exceed one hour. Unfortunately, many of the things we need to know about them may require hours or even days of observation. These include questions such as how frequently do larvaceans discard their houses, what is the daily ambit of a large siphonophore like *Praya*, and how often do individuals of a given species feed? Time-lapse videography has proven to be very important in studies of benthic animals but it has not been possible to apply this methodology in midwater. The reason, of course, is that it's not easy to park a camera in midwater to watch an animal. However, this application appears to be well-suited to advanced AUV technology. The following characteristics should enable this kind of research.

Endurance: one week
Range: 25 kilometers under power, with more as a drifter
Speed: maximum = burst speed to 2 knots, most movement will be <1/2 knot
Depth Range: to 1000 meters

Active Depth Control: ±10 centimeters
Buoyancy: able to adjust to neutral buoyancy
Active Heading Control: ±5°
Navigation: stationkeeping and tracking of a slowly moving target
Instruments: CTDO, transmissometer, ambient light sensor
Lights: low-level, possibly IR, keyed to video needs
Camera: high-resolution, low light, with a 55 mm lens
Video Recorder: digital, time-lapse, 20 hour capacity
Other Characteristics: quiet, unobtrusive

Mission Profile

Deploy with ROV. Target acquisition through ROV video, then tracking control transferred to AUV. Released from ROV. Vehicle follows target in three dimensions for a week, recording 5 seconds of video images, every 10 minutes. Recovery by surface vessel.

Long-Term Development Prospects

Increasing the endurance of the vehicle would allow longer periods of observation. Improved performance characteristics (e.g. speed, control systems for target acquisition and tracking) would permit active tracking and observation of many more species. Use of this vehicle within a benthic navigation grid would allow us to plot animal movement patterns within a 3-D GIS framework. Placement of tags or transmitters on appropriate species would considerably enhance the ability of the vehicle to follow targets or return to them after data transfer and recharge.