Propulsion, Handling & Navigation
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1. Handling and Maneuverability: Command/Control System

Despite its greater weight and slightly bigger size, the upgraded *Alvin* does not appear to be slower or less nimble. There are several changes that have significantly improved the vehicle's maneuverability and ease of handling:

- The addition of the forward lateral thruster has been a major improvement to the propulsion system. The most noticeable benefit is the ability to "crab" sideways rather than having to alternate between forward and reverse to move the same distance. A specific demonstration of this was crabbing along sideways on an escarpment rather than having to back away, move and re-approach. This type of maneuver uses less power than required in the previous mode of operation. In addition, the use of the lateral thruster allows a maneuver to be done more quickly, thereby increasing the efficiency of the use of bottom time.
- The upgrade to closed loop control (auto-x, y, auto-depth, auto-altitude, and auto-heading) has provided automatic positioning and station-keeping. Implementation of the auto-x, y and auto-heading are enabled by the addition of the lateral thruster. This system seems to be working very well and provides better positioning that the previous vehicle. It also increases efficiency of bottom time usage, and allows the pilot to be more engaged in the science and dive objectives.

  Some tuning of the gain settings for the auto-pilot would optimize the efficiency and allow better control of the sub's movements. The gains are currently set based on tests with the thrusters on the old vehicle. On this cruise, data were collected during tests on the engineering dive that will be sent back to WHOI to contribute to definition of new settings. Engineering dive time will then be required to implement and test the new gain settings.

There is a steep learning curve for the pilots using the new command/control system, particularly as there were a lot of modifications made during the SVC cruise (e.g., range and bearing function added after the first dive). This will improve with time. However, the pilot is currently hampered in interacting with the command/control system by the GUI because the response of the touchscreen is very poor. This problem is known and there are ideas to get an interface more equivalent to a modern tablet.

2. Maintaining Neutral Buoyancy

A new automated control system for adjusting the variable ballast to trim buoyancy has been installed. The pilot is now able to dial in a weight or a change in weight, and the command/control system controls the pumps and automatically adjusts the ballast. One user who unloaded a heavy instrument on the seafloor reported that the pilot was able to easily and quickly tweak the weight accordingly to maintain neutral buoyancy after deployment.

3. Vehicle Speed

Users were happy with vehicle speeds and most made transits between sites at 0.25-0.5 knots. Since the vehicle specification called for *Alvin* to be able to transit at 1 knot or more, a test was carried out on one dive to determine speed vs. battery consumption. This demonstrated that *Alvin* is capable of reaching speeds of 1 knot or more, although it is at the expense of power as the following Table shows:

Speed (m/s)	Speed (knots)	Power usage both batteries (amps)
0.2	0.4	20
0.35	0.7	20
0.43	0.84	30
0.49	0.95	35
0.55	1.07	40

(At the time of this test, the SOG readout was in m/sec. Subsequently, the GUI was able to display both m/sec and knots).

4. Battery Power

Experience with battery power was better than expected for a normal dive with some transits between sites, imaging, instrument deployment, and sampling. No dive returned to the surface early because of lack of power. One example: a shallow dive to 1000 m worked the vehicle for 6.5 hours until it was time to come up. The pilot estimated that there was still probably another 30+ minutes of battery power left when the vehicle left bottom.

From a mapping perspective, significant thruster use during mapping transects has the potential to shorten mapping dives. Part of this issue could be resolved by adjustments to the auto-x, y system. At the ends of tracklines and during speed changes, the thrusters were working hard to get the sub to do exactly what we asked it to do (e.g., stop on a dime). It may be better to lessen the reliance on auto-x, y in these situations and use only auto-heading and auto-altitude. Then the pilot can drive the line and control speed in a more logical manner.

5. Navigation

The navigation worked very well in *Alvin* and appears robust. The code NAVEST that is installed is a variant of DVL-NAV and uses the same algorithms. It has been proven in *Sentry* and *Nereus*, and will be installed in *Jason2* later this year. The DVL appears to work well, and tests performed suggest it works well up to and above 85 m altitude, which is more than sufficient to conduct surveying with *Alvin*.

There needs to be a better protocol to disseminate the targets/waypoints prior to the dive. There were some inconsistencies between actual planned dive targets and those entered into the top lab navigation and *Alvin* navigation. Establishing a protocol that is clear from the beginning, or rather, reinforcing established protocol would probably eliminate these issues.

No major problems were encountered with the navigation during the dives. Bathymetry underlays were entered prior to dives (after the first dive) and proved very useful in exploration. Targets created during the SVC cruise were re-occupied without a problem, as well as targets established on previous cruises to the dive areas. However, some difficulties were encountered by the pilots in terms of entering targets because of the problems with the response of the GUI (discussed above).

The new navigation display in the sphere is very useful. As the pilot's get more familiar with the available capabilities (e.g., changing color on target, tracks, vehicles, etc.). It is also easy for the port observer to reach up and get a screen grab of the nav display which can be useful.

One area that could be improved is how the navigation data gets delivered to the user. With a little knowledge, any user can grab the USBL navigation and get an accurate overview of the sub's position in time, but quality navigation can be obtained only by combining the USBL and DVL data streams. Either a data product could be provided to the user, or a set of Matlab scripts could be provided.