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WOODS HOLE OCEANOGRAPHIC INSTITUTION

REFERENCE NO. 66-22

DEEP SUBMERGENCE RESEARCH
CONDUCTED DURING THE PERIOD
1 JANUARY THROUGH 31 DECEMBER 1965

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the agencies of the U. S. Government must have
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Boston Branch.*

WOODS HOLE, MASSACHUSETTS

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

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June 1966

TECHNICAL REPORT

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Approved for Distribution

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Abstract

Deep Submergence Research

1 January through 31 December 1965

The Deep Submergence Research Program at Woods Hole Oceanographic Institution (WHOI) made progress during this period by demonstrating an operational deep diving (6000 feet) research submarine after an extensive testing period. The 96' long catamaran tender was completed and successfully used to support the diving operations and provided repair facilities for the submarine overseas.

A major submarine modification program was carried out last winter at Otis AFB and completed at Cape Kennedy prior to shallow water testing. The catamaran was towed to Port Canaveral and there was outfitted for sea. Submarine launching and recovery procedures were worked out with a dummy ALVIN. The catamaran with ALVIN on board was towed to Coral Harbour, Bahamas, where 7500 foot unmanned and 6000 foot manned test dives were conducted following shallower testing. Operations were then moved to Bermuda after a short stay in Port Canaveral for repairs. In Bermuda several deep dives were made prior to termination by worsening weather. Two shallow scientific dives in the Woods Hole area were made before weather cancelled plans to make a geologic dive into Hydrographers Canyon. The submarine was then moved again to Otis AFB for annual inspection and minor repairs and modifications. The catamaran was placed in a Boston Shipyard for major modifications prior to deployment to the Bahamas in early 1966 for a scientific diving program. A summary of the dives is included and additional technical reports are referenced.

Reports and Papers

The following technical reports and papers contain detailed information developed under this contract during the report period:

1. WHOI Reference 65-11 "Deep Submergence Research Conducted During the period 1 January through 31 December 1964" dated February 1965.
2. WHOI Reference 65-1 "The Mechanical and Chemical Properties of the HY100 Pressure Hulls of the Submarine, ALVIN" by J. W. Mavor, Jr. January 1965.
3. WHOI Reference 65-32 "Observation Windows of the Deep Submersible, ALVIN" by J. W. Mavor, Jr. December 1965.
4. WHOI Technical Memorandum M-DS-19 "Fuse Testing in Oil for ALVIN Batteries" by M. J. McCamis, W. M. Marquet, G. Broderson, and D. Mason. February 1965.
5. WHOI Technical Memorandum TM-DS-19 "Weight, Buoyancy, and Stability Report on the ALVIN Vehicle as of May 17, 1965", by J. W. Mavor, Jr. May 1965.
6. "ALVIN Trial Specifications" by F. P. Omohundro, April 1965. DSRVG Report.
7. WHOI Technical Memorandum TM-DS-17 "WHOI Comments on ALVIN Design Review by Bureau of Ships" by WHOI DSRVG.
8. WHOI Technical Memorandum TM-DS-15 "Summary Report on Fabrication, Inspection, and Test of ALVIN Fixed and Variable Buoyancy Spheres", by J. W. Mavor, Jr. January 11, 1965.
9. WHOI Technical Memorandum TM-DS-18 "Weight, Buoyancy, and Stability of the Research Submarine, ALVIN", by J. W. Mavor, Jr. February 1965.
10. WHOI Technical Memorandum TM-DS-20 "Design and Manufacture of New Emergency Hull Release for ALVIN", by J. W. Mavor, Jr. and A. G. Sharp. August 1965.
11. WHOI Technical Memorandum TM-DS-20a "Comments of the WHOI DSRVG on the AUTECH I Specifications of May 27, 1965."
12. "DSRVG Management Plan" April 1965.

Introduction

ALVIN, and its support craft the 96 foot long catamaran, (Fig.1) Deep Submergence Research Vehicle Tender No.1, hereafter usually referred to as DSRVT-1, embarked on an ambitious test and scientific dive program last spring when they departed separately from Woods Hole en route to Port Canaveral-Cape Kennedy, Florida, for final outfitting and shallow water testing prior to going to the Tongue of the Ocean (TOTO) in the Bahamas for final deep testing. It was the same year that deep diving submarines like the DENISE (Cousteau-Westinghouse) was accomplishing significant dives on the west coast for science, and ALUMINAUT was moved to Miami to commence a testing program in generally the same area as ALVIN. There was a great challenge to get the testing job done successfully - and safely - and to start our long-planned and awaited scientific diving program in deep water in the Bahamas and in the Bermuda area, and hopefully in the Woods Hole area in the fall. As it finally turned out, the high hopes for carrying out the full program were partially thwarted by a series of malfunctions that took time to repair, and the weather. However, in spite of these frustrations, ALVIN did reach test depth (7500') unmanned on July 1 and operating depth (6000') manned on July 20, the first U. S. designed and built submarine to accomplish this. In addition and at the same time, the catamaran launching and recovery operation was perfected. This permitted a Sea State 3-4 open-ocean operation capability that was also a significant step forward in the deep submergence field. It should be said that without the hard work and dedication of the project personnel involved, these accomplishments would not have been possible. It also must be acknowledged that without the financial and technical support, moral support - and patience too - of the Office of Naval Research, the opportunity to prove this concept would never have gotten off the drawing board. A host of other activities and persons assisted in so many ways that limited space does not permit adequate expression of appreciation.

General

At the beginning of this report period, the submarine was at Otis AFB undergoing a major refit and overhaul. The DSRVT-1 was in Woods Hole being designed and built to handle and support ALVIN. Late in March, the catamaran, in a partially finished condition was towed to Port Canaveral, Florida, by the USS SALISH (ATA 176) at an average speed of 10.2 knots. ALVIN and most of the support equipment was not on board during this voyage of the catamaran. ALVIN and the four (4) support vans

were trucked to Port Canaveral overland in view of the fact that DSRVT-1 had never been at sea in rough seas prior to this time.

Upon arrival, the submarine was placed in a hangar on Cape Kennedy for final assembly and system check-out after the shipment and prior to shallow water tests and sea trials. In the meantime, DSRVT-1 was being outfitted for sea and several practice runs under its own power were made outside of Port Canaveral to test and evaluate the launch and recovery procedures and sea keeping capability of this unique support vessel. All possible provisions were made to support the submarine in all respects while operating in the Bahamas and other overseas locations. Fortunately, these preparations were made, as the self sufficient capabilities of the submarine support ship and crew were put to the full test on more than one occasion in the ensuing months.

Submarine trials were conducted in the vicinity of Port Canaveral including speed trials, endurance run, inclining experiment and trim dives. The submarine and all support equipment was then loaded on the catamaran and the tow to Coral Harbour, Bahamas was commenced by SEA DIVER (Mr. Edwin Link, owner and captain) in late May, arriving off the intended base of operations four (4) days later. The catamaran was based at Coral Harbour while further submarine testing was conducted. Dummy batteries were dropped, the sphere was released, and the mechanical arm release was tested. Minor difficulties arose that required removal of the batteries to replace cables and temporary repairs to the large fixed buoyancy package were undertaken. Scanning sonar checks were made submerged. Finally on July 1, an unmanned 7500' dive was conducted. A post test dive inspection required some minor repairs and the deeper dive testing commenced at the edge of the steep coral reef to the southwest of New Providence Island. A continuing series of deeper dives were conducted, culminating in a manned dive to 6000' on July 20th, the design goal. However, during the last two dives in this series, main propulsion difficulties were experienced that were to affect operations for the remainder of the summer.

Because of the propulsion problems, plans for dives off Andros Island were cancelled, and the expedition was towed back to Port Canaveral arriving on July 24th for a post deep dive check out, analysis, and repair of the propulsion malfunctions. Also it was necessary to await arrangements for a tow to Bermuda for the next planned operations.

On August 14th, the catamaran with ALVIN on board was towed to Bermuda, arriving there on August 20th. This was really much later in the year for operations in the Bermuda area than planned, or desired, but the weather was extremely good. Several deep dives were conducted south of Plantagenet Bank to photograph the geology of the slope, but it became apparent on the first of these dives that the propulsion problem had not been solved as anticipated. In addition, the daily trim data indicated loss of variable ballast and subsequent investigation showed the variable ballast rubber bags to have a very slow leak. Thus operations were suspended and another major disassembly and repair job was undertaken in Bermuda that consumed the rest of August and lasted well into September. After repairs were accomplished, a shallow test dive was made to test the systems and a 6000' test dive was then successfully accomplished on September 25th. After this, one more attempt was made to dive on Plantagenet Bank but the weather had turned foul as is normal in late September and it was considered wiser to return to Woods Hole. This was done in tow of the tug MARINIA, arriving on October 11th. Plans were made to conduct scientific observations during operations in the Woods Hole vicinity and two shallow dives were made -- one in Buzzards Bay and one in Cape Cod Bay. Late in October the catamaran was towed to Hydrographer's Canyon on the edge of the shelf south of Nantucket for a geology dive, but weather again forced a return to port without accomplishing this mission. The submarine and catamaran were then readied for inspection, refit and overdue modifications that commenced in early November and have continued to the end of this report period. Plans are now being made to depart Woods Hole in January 1966 for at least two months' work in TOTO for the Naval Oceanographic Office (NAVOCEANO) and the Acoustic Underwater Test and Evaluation Center (AUTEC). Future plans depend of course on the success of this program. Several investigations and independent testing programs were carried out at Woods Hole, which are reported in more detail in the referenced documents.

Personnel were added to the group during this period to meet the changing needs of the operations. It should be pointed out that even "visitors" were put to work during the testing period to assist in the handling of the ALVIN when necessary, in fact, without them, operations would have been almost impossible. This period was one of continuous experiment with new and untried devices and procedures. WHOI participated with ONR and the Bureau of Ships in the preparation of the requirements and specifications for two new deep diving research vehicles similar to ALVIN. Plans have been made to

procure these vehicles in 1966-67, one for ONR-WHOI, and one for AUTECH (BuShips).

ALVIN Inspection and Refit - Fall 1964 - Spring 1965.

The submarine was completely disassembled during this refit period. Inspection of the various systems and components revealed unexpected difficulties. These and anticipated ones caused a refit that was originally planned for approximately 5 months to extend another 3 months from early October, 1964, until early May, 1965. The introduction of the requirement for Bureau of Ships "certification" of ALVIN contributed to the time it took to accomplish the refit. Design and construction of the support ship, a catamaran, designated Deep Submergence Research Vehicle Tender (DSRVT-1), also was a factor in the time required to return ALVIN to an operational status, although its construction and outfitting went on independently of ALVIN. The work that was accomplished during this refit was generated essentially from four major sources as follows:

1. Known design or specification deficiencies or limitations.
2. Trials and operational features that were not satisfactory or acceptable.
3. Inspection deficiencies.
4. Bureau of Ships "certification" requirements.

These will be described below, but it is necessary to point out that changes or repairs made did not in all cases evolve solely from the source indicated, but in some instances from more than one of them. It should also be mentioned that not all deficiencies or limitations were corrected due to limited time.

1. Known or Suspected Design Deficiencies:

- a) Isolation of the batteries from the power busses -- No fault protection, other than fuses, existed from the batteries to the circuits supplying power to all other sources. It was deemed mandatory that it be possible to selectively isolate batteries from the line and from each other -- particularly if one propulsion battery pack were dropped. These battery disconnects were purchased from, tested and installed by, Litton (at WHOI expense). Note: These same relays were used for starting the main motors. In order to make room in the Control Centers, the VB electrical control circuits were moved to the VB box.

- b) Isolation of the emergency circuits -- the battery release, mercury dump and arm release were not electrically separate from each other and from the rest of the control system. This was considered a serious safety deficiency. The separation was accomplished and a separate emergency battery added as back-up to this circuitry. They were further isolated from each other by being routed through separate hull penetrators and disconnects.
- c) Variable Ballast System Ball Valve - If the VB valve failed "open", ambient pressure would motorize the pump and "flood" the VB spheres from the VB rubber bags. The VB box was returned to Litton to test this theory, devise a solution if the problem existed and test the system performance after revision. This was done when it was found that the potential hazard existed. A "check" valve, balanced with ambient pressure, was placed in the system to prevent "flooding" the spheres unless the VB pump was running and/or in the case the ball valve failed "open" when the pump was shut "off". The "low oil" cut off switch was also bypassed by a manual switch in case of malfunction of the cut-off switch.
- d) Leak Detection Circuit - it was believed that it was highly desirable, if not essential to provide the operator with knowledge that a salt water leak existed in the following critical places:
- (1) Variable ballast system.
 - (2) Forebody/Afterbody electrical disconnects.
 - (3) Control Centers.
 - (4) Main propulsion box.
 - (5) Variable ballast box.
 - (6) Fixed buoyancy packages.
 - (7) Main Ballast Box.
- A leak detector system to accomplish this was purchased from and tested by Litton (at WHOI expense). It was installed by WHOI. Isolation of the leak location was not possible unless the submarine was out of water. This was done to reduce through-hull leads required.

- e) Additional Main Ballast Air Capacity -- it was believed necessary to increase the amount of air available to blow main ballast tanks for multiple surfacings or emergency use. Therefore, an additional bottle was added to this system and tested by WHOI to provide double the original capacity. The charging connection was placed under an access hand hole cover on the side of the sail; both bottles were mounted upside down and a moisture drain was added.
- f) Electrical Meters and Gauges -- the meters supplied with the submarine for certain key functions were not satisfactory and were changed, recalibrated, and some were added.
The following are typical:
 - (1) Expanded scale Voltmeters for all 3 batteries.
 - (2) Emergency battery volt meters.
 - (3) External deep depth gauge.
 - (4) Variable ballast indication.
 - (5) Science battery ammeter.
 - (6) CO₂ and O₂ Monitoring Panel.
- g) Circuit breakers -- some circuits in the sphere did not have circuit breaker protection on both plus and minus sides of the line. These were added whenever possible without redoing the complete electrical system. Science power circuit breakers were added inside the sphere.

2. Trial or Operational Deficiencies

- a) Hull Release -- the hull release galled badly during release from 25' depth off the Woods Hole dock. An examination of the cause indicated certain design changes should be made. A new release was designed, procured and installed by WHOI.
- b) Electrical Disconnects -- during operations, the oil compensating tubing leaked salt water into the electrical disconnects causing a recurrent rudder operation fault. It was discovered that the plastic tubing had hardened and was the main reason for the fault. The tubing was replaced with rubber tubing and a bellows added to this compensating oil system. The salt water leakage into the disconnects required disassembly and

resoldering all of the wires plus the replacement of some of the pins.

- c) Vents and Drains -- predive and postdive checks of systems revealed that it was difficult to check oil levels in compensation systems. Therefore the vents and drains on all systems were improved to provide access and the ability to check them. In addition, relief valves were added to all systems to protect them from overpressurization or unexpected leaks. Low point drains were designed to also serve as "leak detector" monitor points.
- d) Main Ballast List Valves -- these valves prevented blowing main ballast at 70' during trials. The system was analyzed and these changed and tested to prevent reoccurrence.
- e) Main Ballast Tanks -- continuous problems with leaks and air spilling out of the floods required extensive repairs and the addition of tubes on the floods to extend them down to the keel. The latter improvement was not entirely successful because the joint leaked at the junction between the tube and tank bottom. Final modification was deferred.
- f) Battery Capacity -- a test discharge on the surface showed the batteries to be of much lower endurance than expected. An inspection of the batteries revealed serious shedding of the active material. This resulted in a search for a new replacement battery for the propulsion system as well as a tightening of the quality control on the manufacture of the replacement batteries for the Control and Science power. All batteries were replaced.
- g) Sphere Arrangement -- operating experience indicated more optimum positioning of instruments and instrument panels. This was done and in addition improved seating and stowage for loose gear was installed. The port (observer's) side was cleared completely to provide room for observation and special instruments or equipments. Lighting was improved. The gyro was relocated under the port

seat and a repeater mounted in the instrument panel. The M.B. blow switch was revised to go from "blow" to "shut" rather than through a "standby" position. An external light control panel was added as well as an echo sounder system (downward only). The doppler navigation system was installed for test.

- h) Speed Indicator -- this device did not operate at all and was removed from the submarine pending the design and procurement of an adequate system.

3. Inspection

- a) Variable Ballast Spheres (6061-T6 welded Aluminum)-- several deep pits (1/16") were discovered where the protective paint coating had been rubbed off by the fiberglass skin. These spheres were returned to Litton for repair by grinding, strain gauged in the areas repaired and retested to 3300 psi. The test results were acceptable and the spheres were replaced after carefully repainting all of them with Laminar X-500 paint and a final contrasting red coat over the white coat to detect scratches more easily. The skin was cut away in the area of abrasion and a rubber pad inserted.
- b) Frame -- a structural member was found to be cracked from a blow of unknown origin and cracks were found in several welds. X-rays revealed poor root welding and inclusions. The frame was removed and sent to Boston Naval Shipyard for repairs and reinspection. All serious flaws were ground out and repaired and the cracked member replaced.
- c) Mercury System - serious mercury carry-over into the oil side of this system was found. Mercury was observed in the valves and pump. This required a redesign and replacement of the traps and drains for same; and improved splash protection for the sphere "vent" tubing. This was done by Litton.
- d) Hull Paint -- corrosion was found under a major portion of the pressure hull Laminar X-500 paint that required removing to bare metal over 80% of the sphere surface and repainting.

- e) Windows -- the viewports were found to have minor indications of crazing and one was optically distorted from the original manufacture. Thus all windows were replaced after testing two to failure and testing the replacement windows in a WHOI furnished jig to 5000 psi prior to installation in the sphere.
- f) Electrical Penetrators -- the external termination of the leads as they enter the disconnect showed signs of breaking at the termination. The leads at this juncture were reenforced with tape and molding material.
- g) Buoyancy Spheres and Packages -- Both buoyancy sphere packages were opened and inspected. Several of the bonded "rubber bands" at the sphere joints were loose. It was found that the rubber used was not of the kind specified. The proper material was ordered, the joints epoxied and rubber applied. Considerable difficulty was experienced in reassembling the packages that was to cause trouble later. "Thio-tuck", the rubber used to seal the oil in packages has a "shelf life" of only 4 months. It is now believed some of this material that was overaged was inadvertently used in the reassembly of the large buoyancy package.
- h) Fiberglas Skin -- inspection showed that the skin had delaminated in service in many areas. A major effort was expended in repairing the skin by laying up new cloth with epoxy. In some areas using fiberglas matting was found to be more successful, such as the tops of the Main ballast tanks.
- i) Compensating Oil Bags -- the "glued" joints in two of these bags were found to have leaks in them. A search for molded bags was instituted that did not meet with success.

4. Bureau of Ships Design Changes

- a) Hull release mechanism -- the hull release mechanism was redesigned by WHOI, pressure tested and installed incorporating K-monel in critical areas in place of the 17-4 PH stainless. This was done primarily because of evidence accumulating in BuShips testing programs indicating some stress-corrosion problems with 17-4 PH stainless steel. Some sacrifice in

ultimate depth capability of the pressure sphere resulted from the difference in yield strength of the new material:

K-Monel -- 125,000 psi (new)

17-4 PH -- 170,000 psi (old)

While in the process of redesigning to replace material, the mechanical features were also improved; namely a 1/4 turn latching device was substituted for the 7 turn screw device originally furnished. The latter galled during the test as previously indicated.

- b) Unmanned Dive -- it was originally proposed by BuShips and concurred in by WHOI, that an unmanned dive to 7500' was desirable. The catamaran was therefore outfitted with a special 2-drum winch and 10,000 feet of polypropylene line for this test. (Figure 2)
- c) Replacement of Aluminum Spheres -- It was suggested that both the buoyancy spheres (7178-T6) and the variable ballast system spheres (6061-T6) be replaced by a suitable material to reduce the possibility of stress and electrolytic corrosion. A suitable substitute was not readily available so this item was deferred pending study of the engineering problems and procurement of replacements.
- d) Miscellaneous -- BuShips also required many of the changes previously discussed. Some, but not all of these were; testing windows, emergency battery disconnects, increased main ballast air capacity, frame inspection and repair, test of variable ballast system, battery and mechanical arm release trials, electrical isolation of emergency circuits, increased circuit protection devices, and many others. In other words, WHOI and BuShips were in close agreement on almost all of the requirements considered necessary to be accomplished to improve operating safety prior to a deep diving program.

ALVIN Refit -- October 1965 - December 1965

This refit commenced in October and was still in progress at the end of this report period. In general, the work planned to be accomplished stemmed from difficulties and deficiencies experienced during the very frustrating testing period during the summer and fall. In addition, inspection revealed some necessary repairs.

The work list consisted of the following major items, details of which will be reported in subsequent reports.

1. Replacement of VB bags with molded ones.
2. Test Discharge and Replacement of Batteries.
3. Replacement of Vehicle Control relays and the "joy stick" with a new control box.
4. Change in steering system.
5. Replace 4-way valves in propulsion system.
6. Modify MB vent valves.
7. Install improved mercury dump valves.
8. "Life" Test of buoyancy material.
9. Overhaul CTFM Sonar.
10. Improve meters.
11. Reduce usable capacity of VB sphere system.
12. Improve insulation of radio antenna system.
13. Add extra external lights (To a total of 4).
14. Add external camera and strobe system.
15. Improve fathometer system.
16. Add coring and sample rack.
17. Repair buoyancy package leaks. Inspect sample spheres.
18. Clean and paint window seats.
19. Repair main ballast tanks and line with rubber.
20. Repair Frame in area of after skids.
21. Improve navigation capability of both submarine and catamaran.

The Catamaran, Deep Submergence Research Vehicle Tender (DSRVT-1)

Completion and Trials

At the beginning of this period, the DSRVT-1 was in the process of final construction in Woods Hole by Dan Clark, Inc. The design details of the lifting system, the Holly Hoist for repair capability, (Figure 3 and 4) and the sea-going requirements were finalized, the equipment and material ordered and drawings completed. The electrical system was designed and most of the wiring completed prior to departure. At the last minute, a windlass capstan with associated anchor and anchor chain was procured and installed. The Murray-Tregurtha main propulsion unit was installed.

On March 29 before completion, the catamaran was towed unmanned to Port Canaveral, Florida, by the USS SALISH for final outfitting and sea trials. A dummy ALVIN made from a steel cylinder and capable of being ballasted to the weight of the submarine had been placed on board. This was done to permit testing launching and recovery procedures before actually handling ALVIN and to statically test the lifting systems. The special two-drum winch for the unmanned test with 10,000 feet of polypropylene line was placed on board for later installation.

At Port Canaveral, with the assistance of the Naval Ordnance Test Unit and Lockheed, the following major items were accomplished and services furnished:

1. Installation and repair of anchor-windlass.
2. Installation of the long-line winch.
3. Air Controls and remote electric steering for the main propulsion unit.
4. Installation of mast and lights.
5. Installation and test of the lifting cradle winch wire and final assembly of the cradle.
6. Installation of the ship's service air piping, engine air starting and engine salt water cooling systems.
7. Cleaning, touch-up and purification of the fresh water tanks.
8. Completion of bridge enclosure and arrangement.
9. Construction of a shark cage.
10. Completion of hold-down bolts, and necessary wire rigging for the portable vans, Holly Hoist and ALVIN.
11. Addition of tending line cleats, divers ladders, and repair of the starboard hull walkway.
12. Modification of the Holly Hoist to permit pick-up of forebody and the complete submarine with sling from overhead.
13. Manufacture of battery removal pedestals forward on the main deck.
14. Electrical connection and check-out of vans to the ship's electrical system.
15. Manufacture of two sets of hardware for cushioning the pick-up shock on the cradle if needed. (Note. These were not used.)
16. Procurement of a large amount of ground tackle, rigging and consumable supplies.
17. Installation of a freezer and water cooler.
18. Loading and securing the ship for sea.
19. Shore power, water and telephone service for the periods at Port Canaveral.

20. Miscellaneous raw stock, welding supplies, welders, cleaners, etc.
21. Crane service at all hours.

DSRVT Sea Trials

The DSRVT put to sea under its own power for the first time on May 4. The purpose of this sea trial was to test the sea-keeping qualities, the maneuverability and ship handling problems of the single trainable screw. This trial was successful. Successive trials were conducted to establish submarine handling techniques. Modifications were made to the lifting and tending gear as a result of these trials. It was tentatively established that maximum wave heights this system was capable of, was 2 1/2 - 3 feet, less than planned. However, subsequent events and experience proved the system capable of handling ALVIN in seas up to 5 feet in height, the design goal. This was accomplished later in the diving program on more than one occasion. The final preliminary sea trial of the DSRVT was on the tow from Port Canaveral to Coral Harbour, the Bahamas with submarine, all support equipment and part of the crew on board. Stability in waves up to 8 feet in height was excellent. The tow ship on this leg was the SEA DIVER, Edwin Link, Captain and Owner. Upon arrival at Coral Harbour, the catamaran was moored inside until completion of shallow water trials of the submarine. On many days after this, while deep diving was in progress, the catamaran moored outside, using its own propulsion to get to and from deep water, 3-4 miles to the west. As many as 22 persons were berthed and fed on the vessel during this period, but living conditions were very crude. Overnight excursions were not undertaken unless absolutely necessary. This experience determined many of the needed improvements undertaken during the shipyard period late in the year.

The DSRVT Performance and Modification

During the operations in the Bahamas, and later in the Bermuda area, the catamaran fulfilled the purpose for which it was built, namely as the handling vessel, repair facility, logistic support and living accommodations at sea for the crew. In the matter of living facilities and navigation capabilities, the catamaran was most deficient because these areas were not adequately provided for in the limited investment concept embarked upon in the beginning. However, the main requirements, namely recovery (Figure 5) and launch, stability, and seaworthiness plus repair capability, were more than adequately met, and the final outfitting and completion of undone features were undertaken in Munro Shipyard in December. The DSRVT came back from Bermuda in October in tow

with a full load on board, including ALVIN. (Figure 6) Waves up to 30 feet in height were encountered without damage to any of the equipment. Thus it was believed the concept had been proven and the following major improvements were underway at the end of this report period:

1. Sandblast and Painting.
2. Adequate bunk and locker stowage for 20 persons.
3. Increased generator capacity.
4. Improved galley, food stowage and dining space.
5. Improved self-propelled capability. Another Tregurtha unit is to be added and both mounted on the stern. Associated Pilot House controls and instrumentation is planned.
6. Increased navigation aids are programmed. Among these are: a gyro compass, radar, Loran C receiver, improved submarine tracking mast, and improved bridge facilities. All of the navigation, ship control, and submarine communication are concentrated in the improved Pilot House.
7. Improvements in cargo handling and lifting rigging are being made. The Holly Hoist has been overhauled and is in the process of modification.
8. Two vans, the power generating and utility vans are being removed and these functions being provided for in the new deck house and a smaller charging shack using ship-generated power.
9. Addition of heating and air conditioning to the starboard living quarters.
10. Improved boat handling davits.
11. Improved battery removal and maintenance platform to be added to the cradle.
12. Static test of all lifting rigs.
13. Procurement of an adequate reel for the 10,000 feet of polypropylene line if required in the future (Normally this will be stored in Woods Hole unless needed, as well as the long-line winch).
14. Removal of excess weight from the hulls by removing frames remaining from original purpose of the hulls no longer needed for strength.
15. Improved access to both hulls.

It should not be implied that this program of improvement will make the catamaran a completely self-sufficient, long ocean trip vessel. It will still be necessary and much more efficient to provide tug towing for major transits such as to TOTO and Bermuda from Woods Hole. The maximum estimated speed of the

modified propulsion system is about 6 knots. Living facilities will be far from adequate for full time occupancy. This means that the normal operations will be primarily land based as before, but with increased ability to stay at sea for periods not to exceed 2 weeks and the ability to transit to nearby operating areas independently.

Fuel and water storage, plus inadequate living facilities will be limiting factors in this prototype vessel. To materially improve these limitations will require major modification to the present DSRVT or a new design based on the invaluable experience gained with the present one. A study of this matter is in progress.

ALVIN Diving Program 1965

The diving program that was actually accomplished this year was quite modest in comparison to the one planned. From the dives made and tests conducted, we were able to say with a great deal of confidence at the end of the period, that we had a truly operational submarine capable of diving safely to 6000' depths and had developed an extremely useful surface support ship and handling procedures for independent operations. Furthermore, we had a system that could operate in the open sea when weather conditions were not ideal; that is in waves or swells up to 5 feet in height. We have not found, nor do we wish to test the system to destruction, what our actual upper sea state limit is. We do know that it is quite a bit better than we had ever expected.

The diving program was carried out in several phases as described below.

Submarine Trials

An extensive series of trials were scheduled upon completion of the assembly. The submarine was launched on 17 May and the first trim dive conducted to establish neutral buoyancy and the location of the oil in the Variable Ballast System for this condition. In addition, the following tests or trials were conducted at Port Canaveral:

- (a) Doppler navigation system calibration.
- (b) Submerged Inclining Experiment.
- (c) Endurance Run (45 amps propulsion lasted for 7 hours and 45 minutes at a speed of approximately 1.6 knots).

- (d) Scanning Sonar Submerged check-out.

In the clearer waters near Nassau, the following trials were conducted:

- (a) Battery release (No.1 & 2 dummy batteries were dropped).
- (b) Sphere release.
- (c) Submerged maneuvering which was photographed.
- (d) Unmanned tethered dive to 7500'.

Submarine Deep Water Testing - Bahamas

Upon completion of the unmanned test dive to 7500', a series of deeper dives was planned to a final depth of 6000'. Two relatively shallow dives (less than 200' in depth) were made on the edge of the sharp drop-off to deep water from the shelf south of New Providence Island, to test systems, photography, and for training purposes. Then on 8 July, the first deep manned dive was made to 1600' without any electrical or mechanical problems. The next two deep dives were made to 1300' and 2700' respectively without any difficulty. However, on Dive No.98 to a planned depth of 4500', the first of a continuing series of propulsion systems failures occurred. At 3500', the main propeller failed to operate. Changing depth to 3000 feet did not correct the malfunction. However, at the surface the malfunction disappeared and ALVIN made a normal landing for recovery under its own power. Electrical system faults were suspected at this time, but disappearance of the malfunction prevented isolation of the fault, and therefore determination of the cause and prevention of re-occurrence. Operation of the scanning sonar had been less than acceptable, so the next dive was made in shallow water with the manufacturer's representative on board. The repairs he had made seemed to have the sonar working, and no further problems were experienced with the propulsion system after a thorough electrical and mechanical check-out. It was therefore decided to try for design depth and on July 20, with BuShips, ONR and WHOI representatives of the Acceptance Board present, ALVIN reached 6000' for the first time and bottomed. Movies were taken and several fish, "Benthosaurus", were seen in addition to mounds made by other bottom dwellers. On the descent at 4500', the main prop again failed to operate, but both lift props were operating so the dive was not terminated. The lift props continued to operate to the bottom. After about 20 minutes on the bottom, steering with the lift props, they also failed and surfacing was accomplished on the variable ballast system, which is the normal method of surfacing. The propulsion system

did not operate again until the submarine had been on the surface for several minutes and then the main prop returned. A normal landing and recovery by the catamaran was made. However, it was strongly suspected that there was a design problem that was related to depth in some way. Thus dives off Andros Island for AUTECH were cancelled, and the DSRVT-1 and submarine were towed by a local work-boat, the "Aquanaut", to Port Canaveral, Florida, for repairs to the fixed buoyancy package (temporarily patched for the deep tests) and for disassembly and possible correction of the propulsion problems. The catamaran arrived at Port Canaveral on July 24 after an uneventful crossing. No tugs were immediately available for towing to Bermuda from Coral Harbour, Nassau, at this time, in spite of extensive efforts to secure same.

Post Deep Dive Refit

Upon arrival in Port Canaveral, the support of the local Navy and Lockheed was, as previously experienced, outstanding. Work was begun immediately on disassembly and inspection of the control centers and removal of the fixed buoyancy package for repair. These were accomplished. The only evidence found in the control centers was a small amount of foreign matter under one of the contactors. All circuits were electrically measured and appeared normal. Two (2) new interconnecting cables were replaced that had been field-spliced in the Bahamas. These were suspected at this point in time of contributing to the propulsion problem, if not the cause of it. In addition, since the batteries had to be removed to inspect the control centers, they were inspected and several "salted" cells from No.1 battery box were reworked and replaced. Some salt water was found in each battery box, apparently entering through the battery vent system during ascent from deep depth. A baffle was put in the battery box No.1 to prevent re-occurrence of salt water entering the cells. A shallow test dive in the harbor, to check out systems and the sonar, was made. All systems were satisfactory, except this time, on the surface the main propeller failed and remained out of commission after recovery. This was the first time a propulsion failure had occurred that permitted full post-dive analysis. A switch in the four-way valves for controlling hydraulic power to the main prop had not functioned and prevented the "pull-in" coil from operating. This required dropping the main propulsion box to inspect all of the coils on these valves for discrepancies. A loose terminal on the solenoid in question was at fault so all terminals were soldered to prevent a similar problem and the coils replaced. This, it was assumed, caused the propulsion problems. In the meantime,

a tug to tow the catamaran to Bermuda was scheduled, and the work was rushed to completion to meet the sailing date. On 14 August the tow to Bermuda was commenced by the tug MARINIA, arriving off "Argus Island" on 20 August, where it was met by the rest of the DSRVG personnel, who had returned to Woods Hole in the interim.

Submarine Operations at Argus Island, Bermuda

It was believed that the propulsion problem had been solved and a deep test dive to 4500' was attempted 2 miles southeast of "Argus" on 22 August. However, at 4100 feet, the main prop failed in reverse and although several attempts to regain it by changing to a shallower depth did restore it to operation, a descent to deeper depth lost it again. It was decided from this dive that the submarine could probably work effectively above 3000 feet without problems, assuming the malfunctions were only depth sensitive. In the meantime, Litton Industries had been urgently requested again to run some laboratory tests of our contactors and valves' solenoids, if available, in oil under pressure. Also during this dive, telemetry experiments on the UQC for the Applied Science Laboratory, Brooklyn, New York, were conducted. These were well planned by them and did not interfere with operations. On this dive, the main ballast vent valves did not operate properly, making expeditious diving of the submarine difficult, another problem that needed correction due to the up to 1 knot surface current in this area setting the submarine off diving position. (Observation from the submarine indicates that this current continues at some magnitude down to 1000'). On the assumption that the submarine could operate at 3000' without problems, a second dive was conducted to investigate the geology of the area at that depth. The submarine again had trouble with the main ballast vents which resulted in a descent to an area well to the southeast of the planned one. After an extensive submerged run back to the area of interest, a cable was found and followed for a distance. During the cable-following operation, however, the main propeller again failed and surfacing was necessary. Still believing the problem of propulsion was depth sensitive, a third dive was made on the south slope of Plantagenet Bank. At 1800 feet the lift props failed and surfacing again was mandatory. At this time hurricane "Betsy" also forced evacuation of "Argus Island", so DSRVT-1 returned to port under tow of YTM 176.

Refit in Bermuda

Upon arrival in port, evidence from Litton indicated that

the solenoid circuit contactors were "making" carbon in oil under pressure that most likely would account for the various symptoms experienced in the propulsion system failures. In addition to this, loss of buoyancy suggested that the variable ballast bags were leaking oil, and a test of this system revealed that this was the case. Thus operations were suspended until the spare variable ballast bags became available (fortunately these had been ordered 2 months previously). These were installed and the variable ballast system recalibrated. It was also decided to move the propulsion contactors inside the sphere to eliminate their operation in oil. Subsequent tests by Litton of the previously suspect switch in the four-way valve solenoid confirmed that this could also contribute to the observed malfunctions. Elimination of this problem necessitated dropping the main propulsion box again and removing the six coils, rewinding and reinstalling them. This eliminated the suspect switch, but raised the control power necessary to continuously operate them. Thus a temporary solution was installed. External drains for the battery boxes were also added to permit frequent draining of salt water therefrom.

The conning tower was removed during this refit and leaks in the main ballast tank temporarily repaired. The main ballast vent valves were removed and replaced with spares. The problem with these seemed to be an accumulation of corrosion around the core which is exposed to sea water on flooding the tanks. Corrective action is being taken to remove the problem on next refit.

Resumed Operations in Bermuda

The submarine was ready for sea on 19 September but weather delayed departure until 21 September. Weather prevented a deep test dive off St. Davids as planned, so the DSRVT-1 was towed to Argus again. Extreme weather did not permit a dive at this time so DSRVT-1 was returned to port by YTM 176. On 25 September weather permitted and the deep test dive off St. Davids was conducted successfully to 6000'. One very minor problem occurred. Deep scoring on the inside of the stern prop shrouds caused by props making contact with the shrouds at about 5800 foot depth was noted. To correct this, approximately 1/4 inches was machined off the stern prop blades to insure propeller blades would clear the shroud at all depths. On surfacing of the submarine, the "lost submarine" procedure was thoroughly tested on this dive as the surface support units were considerably removed from the submarine's surfacing point due to ocean currents and loss of communications. However, prior anticipation of

such an event resulted in a happily successful rejoining with the help of the U. S. Coast Guard Air-Sea Rescue Units. Plans to proceed to Argus from there were cancelled by weather predictions and a main motor casualty on YTM 176.

One final attempt to operate off "Argus Island" was made after the successful deep test dive. The tug MARINIA was engaged to guel "Argus Island" and tow the DSRVT-1 to the scene. However, the weather again turned nasty and a return to port was necessary. Docking in a 60 knot wind was part of this operation. At this point, with the strong concurrence of USN USL, Research Detachment, Bermuda, operations were terminated and plans to return to the U. S. were hastily made.

Local Operations in Woods Hole

Upon the return to Woods Hole, much later in the year than planned, or desired, a short series of dives of scientific interest were undertaken. Two were shallow dives, one in Buzzards Bay and one in Cape Cod Bay on Fishing Ledge. A sortie to Hydrographer's Canyon, 120 miles out on the edge of the continental shelf, in tow of the fishing vessel "Narragansett", was made in late October for the first manned exploration of this geological phenomena. However, weather conditions worsened after spending 24 hours in the area, so a dive was not attempted and the expedition returned to port. The submarine was then moved to Otis AFB for annual inspection and refit. The Catamaran was prepared for overhaul and modification.

Instrumentation

No major changes were made in the submarine's instrumentation during this period except for the operations at "Argus Island". USN USL leased a 70 mm camera-strobe light-TV camera assembly from Ocean Engineering Corporation (O.E.C.) which had, by previous arrangement, been adapted for mounting on the mechanical arm mounting plate. The droppable feature of the arm was incorporated into this assembly as a safety measure. This assembly was mounted for all dives in the Bermuda area, but low battery voltage prevented taking any pictures at the bottom on any of the dives. The TV camera did work very well and a still camera was mounted inside the sphere, on the last dive of the series, to take pictures of the TV screen as a back-up in case the external cameras did not operate. On this dive the submarine did not bottom, so that the value of this camera was not fully assessed.

An additional E, G & G light was added to the submarine looking ahead and 20° up. Faster black and white 16 mm film was used on this dive and several feet of pictures were obtained. Color movies taken on all of the previous dives were a great disappointment, as were the color 35 mm stills. Only a very few were obtained. The light levels available are not presently adequate for acceptable color shots. More work on this part of the submarine capability is necessary and is being done. One of the conclusions reached is that it is better to get black and white shots than none at all, so in the future both will be taken when possible. Black and white film is faster and can be quickly developed to provide information for the next dive, whereas most color film has to be returned to the U. S. for developing. This takes at least two weeks or longer to determine results.

The scanning sonar operation has not been reliable. Further work on this set is required. The Janus doppler navigation system has not operated properly all summer and other high priority problems have precluded repairing it. The mechanical arm was mounted on only the first deep dive (No.95) and operated satisfactorily on this dive. It was removed and droppable lead weight substituted during the subsequent test dives in TOTO. All other installed instrument systems operated well. The underwater telephone experienced trouble only when near the bottom in rough terrain when reverberation became severe. The radio, however, performs very poorly on surfacing, probably because of salt water grounding in the antenna coils. This problem needs immediate attention.

A high intensity flashing light that is pressure activated on return to the surface without attention from the occupants of the submarine was installed and was very useful during the search for the submarine on the surface at night on Dive No.106.

Testing Program

Litton conducted some laboratory experiments in oil of the relays and switches suspected as causes of the propulsion difficulties. These tests confirmed suspicions that these were in fact the probable cause of the experienced erratic behavior. The buildup of carbon on the contactors operating in oil under pressure at service loads and conditions could account for the majority of the malfunctions. This conclusion was strongly enforced by the success of Dive No.106. This phenomena, while not new to others had not occurred during the extensive component testing program. It is now believed that the reason for this

was that the relays for the solenoid coils were not tested in oil under the conditions experienced in service. Arc-suppression across these coils reduces, if not entirely eliminates, the carbonization. All of the other motor circuits in which similar relays are used and were tested, have not caused any operating problems. These motor circuits are all arc-suppressed. WHOI has conducted a series of "life" tests under pressure for 1000 hours on samples of the buoyancy material taken from the buoyancy material in the submarine. A report of this testing will be available in the near future.

AUTEC I Vehicle

Meetings of WHOI, BuShips, and ONR representatives continued, to assure the input of a maximum of ALVIN operating experience to the design and construction specifications. A report of WHOI comments was submitted to ONR in early July and brought up to date in August after the initial deep dives.

Investigations

ALVIN Propulsion Study - A study was conducted, in more depth than previously, of the propulsive coefficient of the main propulsion of ALVIN with the dual objectives of providing background for recommendations to BuShips for the AUTEC I vehicle and of improving the performance of ALVIN. ALVIN is presently equipped with an off-the-shelf commercial propeller, having a propeller efficiency of about 52%. The two major results of the study are as follows: (a) the very low loading of the propeller makes it appear possible to design a propeller having an efficiency of 85%, well above that possible with the usual surface ship and submarine propeller loadings. (b) the hull efficiency on the basis of incomplete data appears to be as high as 150%. This parameter is being investigated further by model test in the M.I.T. propeller tunnel.

ALVIN Variable Buoyancy Sphere Replacement - though no significant deterioration of the present aluminum spheres has been observed to date, proposals have been solicited from industry for the manufacture of Titanium alloy replacement spheres in the event that they might be needed. The Bureau of Ships has approved the use of unprotected Ti-6Al-4V alloy and WHOI has in hand a bid package with complete specifications for use when needed. In the event the replacement is not required for structural reasons, it is recommended that it be made to establish service experience under support of a materials research program.

Outside Assistance -

Cooperative Program with Massachusetts Institute of Technology -
Three (3) Naval officers from M.I.T. enrolled in postgraduate courses in Naval Architecture and Marine Engineering joined the group for the summer. LCDR. Dwight Hutchinson and Lt. Millard Firebaugh joined the field operations after a short indoctrination at Woods Hole, and Lt. Henry Morgan remained at Woods Hole, working with Dr. Andrew Fejer of Illinois Institute of Technology on the problem of propulsion efficiency for small submersibles. A subject for his Master's degree thesis probably will evolve from this work concerning propeller efficiencies.

Many parts of the Navy cooperated with the ALVIN operations during this period, including Fleet Weather Forecasting, BuShips Code 525, and Code 420, several Codes in ONR and AUTEC, and our progress was aided considerably by their efforts. LCDR. J. Pining and Mr. Donald Cobb of USN USL Research Detachment, Tudor Hill, Bermuda, were outstanding in assisting operations while in Bermuda.

A major assist to the program was furnished by NOTU, Patrick AFB, Florida (Cdr. Kenneth Brisco) and Lockheed Aerospace Division at Port Canaveral and Cape Kennedy. Without their generous and willing assistance, our preparations for the diving program this summer would not have been possible or else would have been severely delayed.

Personnel

The DSRVG continued to grow during this period as required by the sea-going operation away from Woods Hole and the operation of the DSRVT.

Full Time Employees

<u>Staff</u>	Earl E. Hays
	W. O. Rainnie, Jr.
	J. W. Mavor, Jr.
	H. M. Horn - (Resigned August/65)
	W. M. Marquet
	F. P. Omohundro
	A. G. Sharp
	W. S. Shultz
	Charlotte Muzzey, Secretary
	Mable Reese (Secretary - Resigned June/65)

Operations

M. J. McCamis, Pilot
W. O. Rainnie, Jr., Pilot
V. P. Wilson, Pilot
A. R. Davison, Captain, DSRVT
G. deP. Broderson
A. C. Bartlett
M. P. Fox
R. G. Graham
D. H. Mason
C. R. Porembski
J. P. Rozum
F. Buckley (Resigned December/65)
P. E. Hamman, Pilot (Resigned June/65)
C. I. Tyndale (Resigned March/65)
R. A. Chandler (Resigned March/65)

Part Time Employees

W. Lane, Summer
C. Rea, Summer
J. Wilska, Summer
K. Saunders, Summer
J. Duff, Summer
Solomon Moxey
William Hatfield

Associates

L. Baxter, II
A. C. Vine
J. H. Stanbrough, Jr.
A. Fejer
M. Firebaugh, Lt. JG, USN
D. Hutchinson, LCDR., USN
H. Morgan, Lt. JG, USN
J. B. Walsh

Future Program

It is anticipated that ALVIN and the DSRVT will be ready for deployment on or about February 1966, at which time it is planned to return to Tongue of the Ocean to conduct the first deep investigative dives. The tentative schedule is as follows:

1 February - Depart Woods Hole
10 February - Arrive AUTECH
15 February - 15 March -- Dives in TOTO for AUTECH
15 March - 15 April -- Dives in TOTO for NAVOCEANO

15 April - Depart AUTECH
30 April - Return to Woods Hole. Conduct dives in vicinity.
1 June - Depart Woods Hole
10 June - Arrive Bermuda, Conduct dives in vicinity of
Argus Island.
15 July - Depart Bermuda
25 July - Arrive Woods Hole
1 August - 1 October -- Scientific dives in vicinity of
Woods Hole.
1 October - 31 December -- Annual Refit.

It is planned that WHOI scientists participate in dives in the TOTO and Bermuda areas. These may be geological or biological dives. In the Woods Hole area, interest is high in observing the canyons on the shelf, the bottom features of the shelf and the biological activity of both the slope and the shelf. There are dives planned for investigation of the scattering layer, sound transmission studies, cetaceans in their natural environment, and gravity measurements. Current studies may also be possible. Instrumentation and special tools for some of these dives must be developed. Participation in the procurement of a new submersible will be part of the activity of the DSRVG in the coming year.

Diving Log Summary

Diving No.	Date	Place	Purpose	Pilots	Observers	Deepest Depth Ft.	Dive Time Hours	Sea State	Remarks
78	5/17/65	Port Canaveral	Trim Dive	McCamis Wilson	None	25	1 hr.	N.A.	Remained tethered to establish first neutral trim
	5/17/65	Port Canaveral	Inclining Experiment	McCamis Wilson	None	15	1 hr.	N.A.	Obtained new data after refit modifications
80	5/20/65	Off Cocoa Beach	Training	Rainnie McCamis	None	35	1 1/4 hr.	203 ft.	First dive in open ocean. Visibility poor surge a problem
81	5/21/65	Port Canaveral	Training & Sonar Check	McCamis Wilson	Marquet	37	1 1/2 hr.	N.A.	Used FM sonar for retraining & adjustment
82	5/24/65	Port Canaveral	Training & Sonar Check	Rainnie Wilson	Marquet	39	2 hr.	N.A.	Used FM sonar retraining & adjustment
83	5/25/65	Port Canaveral	Training	McCamis Wilson	None	37	2 hr.	N.A.	Pilot training including diver salvage of sub
84	5/25/65	Port Canaveral	Training	McCamis Wilson	None	37	2 hr.	N.A.	Pilot training in emergency procedures
85	6/4/65	In Coral Harbour	Training & Salvage	McCamis	Porembski R. Hakamaki	15	2 hr.	N.A.	Divers raised sub with lifts
86	6/5/65	Off Coral Harbor	Training & Photo	Rainnie Wilson	None	19	1 hr.	1-2 ft.	1st clear water underwater movies taken of sub
87	6/5/65	Off Coral Harbour	Training	McCamis	W. Lasley	20	1 hr.	1-2 ft.	Clear water dive Underwater movies taken of sub
88	6/14/65	Off Coral Harbour	Battery Drop	McCamis Wilson	None	16	1 1/4 hr.	1-3 ft.	1 battery dropped, one did not, due to wave surge

Diving Log Summary

Diving No.	Date	Place	Purpose	Pilots	Observers	Deepest Depth Ft.	Dive Time Hours	Sea State	Remarks
89	6/17/65	In Coral Harbour	Sphere Release	Rainnie Wilson	None	16	1 1/4	N.A.	Sphere released successfully. To test new release mechanism.
90	6/21/65	Off Coral	Battery Drop	McCamis Wilson	Omohundro	19	1 1/2 hr.	1-2 ft.	Battery dropped successfully
91	6/24/65	3 miles SW Coral Harbour	Training & Photos	Rainnie Wilson	None	70	3 1/2 hr.	1-3 ft.	Maneuvering movies of sub. First movies from sub.
92	7/1/65	L.25 03N	Unmanned tethered dive	None	None	7500'	9 1/2 hr.	1-2 ft.	Deep unmannd dive. First night recovery for DSRVT.
93	7/6/65	2 miles S.of Clifton Pt., Nassau	Training & Photo	Rainnie McCamis	P.M.Fye	70	2 1/2 hr.	1-2 ft.	On edge of deep water cliff
94	7/7/65	3 miles S.of Clifton Pt., Nassau	Training & Photo	McCamis Rainnie	None	180	2 1/2 hr.	2-4 ft.	1st attempt deeper depth
95	7/8/65	4 miles S.of Goulding Cay, Nassau	Deep Test	Rainnie McCamis	None	1600	4 3/4 hr.	1-3 ft.	1st Deep Dive
96	7/13/65	5 miles S.of Goulding Cay, Nassau	Deep Test	McCamis Rainnie	None	1300	4 1/2 hr.	1-2 ft.	Grouper observed at 1100 feet
97	7/15/65	5 miles S.of Goulding Cay, Nassau	Deep Test	Rainnie Wilson	None	2700	5 1/4 hr.	1-2 ft.	
98	7/16/65	5 miles S.of Goulding Cay, Nassau	Deep Test	Rainnie McCamis	None	3600	4 1/2 hr.	1-2 ft.	1st propulsion failure
99	7/19/65	Off Coral Harbour, Nassau	Sonar Check	McCamis Wilson	K. Sharpe	25	1 1/4 hr.	1-3 ft.	
100	7/2/65	2 miles NW Goulding Cay, Nassau	Deep Test	Rainnie McCamis	None	6000	5 1/2 hr.	3-5 ft.	Attained design operating depth

Diving Log Summary

Diving No	Date	Place	Purpose	Pilots	Observers	Deepest Depth Ft.	Dive Time Hours	Sea State	Remarks
101	8/10/65	Port Canaveral Florida Harbor	Post-Refit Test	Wilson	W. Marquet D. Hutchin- son	32	1 3/4 hr.	N.A.	Main prop failed
102	8/22/65	2 miles SE Argus Island, Bermuda	Deep Test	McCamis Rainnie	None	4500	5 1/2 hr.	2-4 ft.	Main prop failed 4500'; Telemetry tests conducted
103	8/23/65	1 1/2 miles S Argus Island Bermuda	Deep Test & Topography observation	Rainnie McCamis	None	3000	6 1/4 hr.	2-4 ft.	Main prop failed. Telemetry tests
104	8/26/65	1 mile S. Argus Island, Bermuda	Photo & Topography observation	Wilson Rainnie	None	1900	3 1/4 hr.	3-6 ft.	Lift props at depth, main prop on surface
105	9/24/65	Port Royal Bay, Bermuda	Post-Refit Test & Photo.	Wilson McCamis	None	40	1 3/4 hr.	N.A.	Photos of sub not possible due poor visibility
106	9/25/65	5 miles SE St. Davids, Bermuda	Deep Test & Photo.	McCamis Rainnie	None	6000	7	4-6 ft.	Successful design depth dive, ALVIN temporarily lost on surfacing
107	10/19/65	In Buzzards Bay off Nashawena Is.	Bottom Ecology	Wilson	Marquet L. Bennett	38	48 m.	1-2 ft.	
108	10/23/65	Cape Cod Bay Fishing Ledge	Geology of ledge	Wilson	J. Trumbull	93	53 m.	1-2 ft.	

APPENDIX A

A Description of the Unmanned Dive

General. The decision was made to lower ALVIN to a depth of 7500 feet, unmanned, to give a final assurance test on the assembled vehicle before commencing manned dives. Although practically all parts or representative parts had been tested separately to a corresponding pressure, the testing of the complete assembly seemed to be a logical step. This test was a static test only, with no attempt made to run any of the equipment. It was felt that the trade-offs between preparing for a remote operating test, and the redundancy of safety factors in ALVIN coupled with a successful static test, were in favor of manned operational tests.

The problem left was a simple one; to lower ALVIN on a line to 7500 feet and bring it back with a high degree of success probable. The test was designed to circumvent any one type of failure, but not two.

The failures anticipated were flooding of the main pressure hull or buoyancy spheres, tending line failure, or failure of the weight release mechanism.

Briefly, the dive was accomplished as follows. ALVIN was trimmed to be positively buoyant when submerged by several hundred pounds. A twelve hundred pound anchor (Figure 7) was attached to the bottom of ALVIN by two time release mechanisms in parallel. The line used for lowering was positively buoyant. Water depth was measured by the mother ship's echo sounder, and a 12 KC pinger aboard ALVIN gave acoustic information to the mother ship about ALVIN's height above the bottom.

The line was sized with a safety factor of more than two to retrieve the total load if the pressure hull flooded. If the line were cut in some way, ALVIN would sink to the bottom, but only one time release mechanism had to function in order for ALVIN to return to the surface. The buoyant line would aid in this case, rather than pull ALVIN down.

The Line and Winch. Ten thousand feet of six inch circumference braided polypropylene line was purchased. The braided line reduced any spinning of the submarine due to lay of the line. The breaking strength of this line is nominally 50,000 pounds, but it was delivered in three pieces. Long splices were made

which probably reduced the strength by a factor of one third. (This number is not exact but a good approximation).

The winch was designed according to the recommendation of the line manufacturer. Two drums were used that were grooved to match the line size. The winch actually acted as a capstan, with the line itself being flaked in one hull of the catamaran. Two ten horse power synchronous motors drove the drums at a line speed of 30 feet per minute. It was found necessary to feed the oncoming line under some tension onto the drums. Otherwise a periodic slipping and burning of the line occurred at the tension end during lowering.

Acoustics. (Depth measurements). A twelve KC pinger system similar to that used on deep sea cameras was aboard ALVIN to tell height above the bottom. A twelve KC UQN-1b with PGR aboard the catamaran was used to tell the depth of water, and record the information from the 12 KC pinger aboard ALVIN. In addition it was possible to see an echo from ALVIN itself on the ship borne echo sounder down to seven thousand feet. As a further check on depth, the line paid out was measured, and checked within about one hundred feet of the other methods at the final depth of seventy-seven hundred feet.

Rigging. The weights and releases were fastened to ALVIN while it sat in the cradle. A temporary line was used to hold ALVIN after being lowered into the water, while the cradle was lowered away from underneath (Figure 8) and then the load was transferred to the line used for the lowering which went through a sheave attached to the aft bridge. The winch was located forward on the catamaran.

The timed releases were a model made by Geodyne Corporation and were set to release at first light the morning after the lowering.

A battery was used in the submarine to hold the vents on the main ballast tanks open during the launch, as this function is normally performed by the pilots.

Conclusion. The dive went smoothly but slowly, lasting about nine and one half hours. A careful inspection of ALVIN was made afterwards and no damage or leakage was discovered. The subsequent manned dives were approached with confidence, and although operational problems were encountered the ultimate safety of the submarine was never doubted.

Illustrations

- Figure 1 - Bow and Port Side of the 96' Long Catamaran(DSRVT-1)
- Figure 2 - Long-line Special Winch and Polypropylene Line
Used for the Unmanned Deep Dive.
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Lowering Line.

Figure 1 - Bow and Port Side of the 96' Long Catamaran(DSRVT-1).

Figure 2 - Long-line Special Winch and Polypropylene Line Used for the Unmanned Deep Dive.

Figure 3 - ALVIN Being Carried Forward on its Cradle by the Holly Hoist.

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