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Advanced Unmanned Search System (AUSS) At-Sea Development Test Report

J. M. Walton

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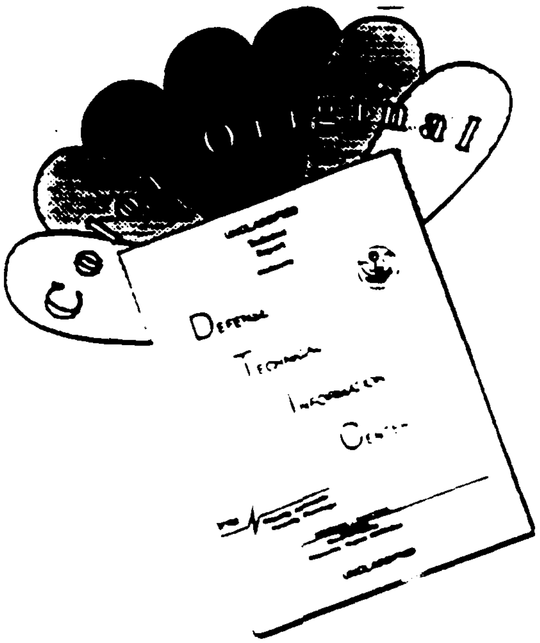

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NAVAL COMMAND, CONTROL AND
OCEAN SURVEILLANCE CENTER
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ADMINISTRATIVE INFORMATION

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Further information on this subject is available in related reports that represent NRaD efforts through FY92. The bibliography is found at the end of this report.

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Engineering and
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Department

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SUMMARY

OBJECTIVE

To describe and document the Advanced Unmanned Search System (AUSS) test planning and test results.

RESULTS

The test planning documentation for AUSS consisted of (1) broad overview plans with a high-level systems perspective, (2) more detailed plans covering focal technology and tactical test areas, and (3) detailed test plans written to assist in the direction of the activity during each individual dive. The three levels of planning allowed the AUSS effort to progress at a detailed technology and tactics problem-solving level without losing track of the big picture.

The test reporting consisted of three basic types. The first type were reports on the individual development test dives. The second type were reports on particularly important or interesting topics addressed during the development sea tests. The third type were reports on the sea tests that were dedicated almost entirely to the demonstration of the AUSS capability.

This body of test planning and test reporting documentation demonstrates the techniques and logic of the approach applied to the test program as well as the results.

CONCLUSION

The test program for the AUSS was highly successful due to many factors. Some predominant factors were system flexibility, the use of the acoustic link and flight recorder as test tools, a designed-for-test approach, safety considerations, system fail-safe properties, test philosophy, long-range test planning, and the short-term development interactive test planning. Without any one of or the synergy of these factors, the AUSS test program would not have enjoyed such success.

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INTRODUCTION

HISTORICAL BACKGROUND

The Advanced Unmanned Search System (AUSS) program began with the goal to improve the Navy's capability to conduct deep ocean search by an order of magnitude. The first AUSS efforts were to study and analyze existing search capabilities (1973 to 1979). Concurrently (1974 to 1979), a large-scale computer model was developed and used to do systems tradeoff analyses of search. A supervisory-controlled untethered vehicle search system concept emerged from these efforts as the best approach for accomplishing the AUSS goal.

A prototype AUSS based upon the supervisory controlled concept was developed and fielded (1980 to 1987). This system successfully completed 89 dives (see Walton, 1992a). The prototype proved the concept was feasible. It also showed that an order of magnitude improvement in search would be possible with this approach.

An improved system has been developed and fielded (1988 to 1992). The new AUSS was system engineered into a dependable and versatile test and demonstration platform. The testing of the improved system is the subject of this report. A detailed evolution of the AUSS is explained by Walton (1992b).

PRESENT STATUS

The improved AUSS has been deployed on 45 dives. The first 37 dives were dedicated to support system development. The last 8 dives were dedicated to demonstrating the capability of the AUSS. At the time of this writing, the AUSS system is not operationally active. Data from the last eight dives, however, have shown that the AUSS system outperforms all other search systems by at least an order of magnitude in deep-water applications.

SYSTEM DESCRIPTION

The AUSS vehicle is a special case within a broad classification of Autonomous Underwater Vehicles (AUVs). The AUV approach is a relatively new technology area emerging to displace many of the tasks performed by divers, manned submersibles, and tethered vehicles. AUVs will also perform underwater tasks never before possible. What sets AUSS apart from the field of AUVs is that the AUSS vehicle is supervisory controlled using a high-data rate acoustic link.

SYSTEM COMPONENTS

The AUSS consists of an untethered vehicle, human operators, a high-data rate half-duplex acoustic data link, a control van, a maintenance van, and a launch and recovery subsystem. The control van contains surface command, control, tracking, and data analysis computer/operator stations. All the AUSS system components are installed upon a single support ship as seen in figure 1. Jones (1992) gives a comprehensive system description of the AUSS.

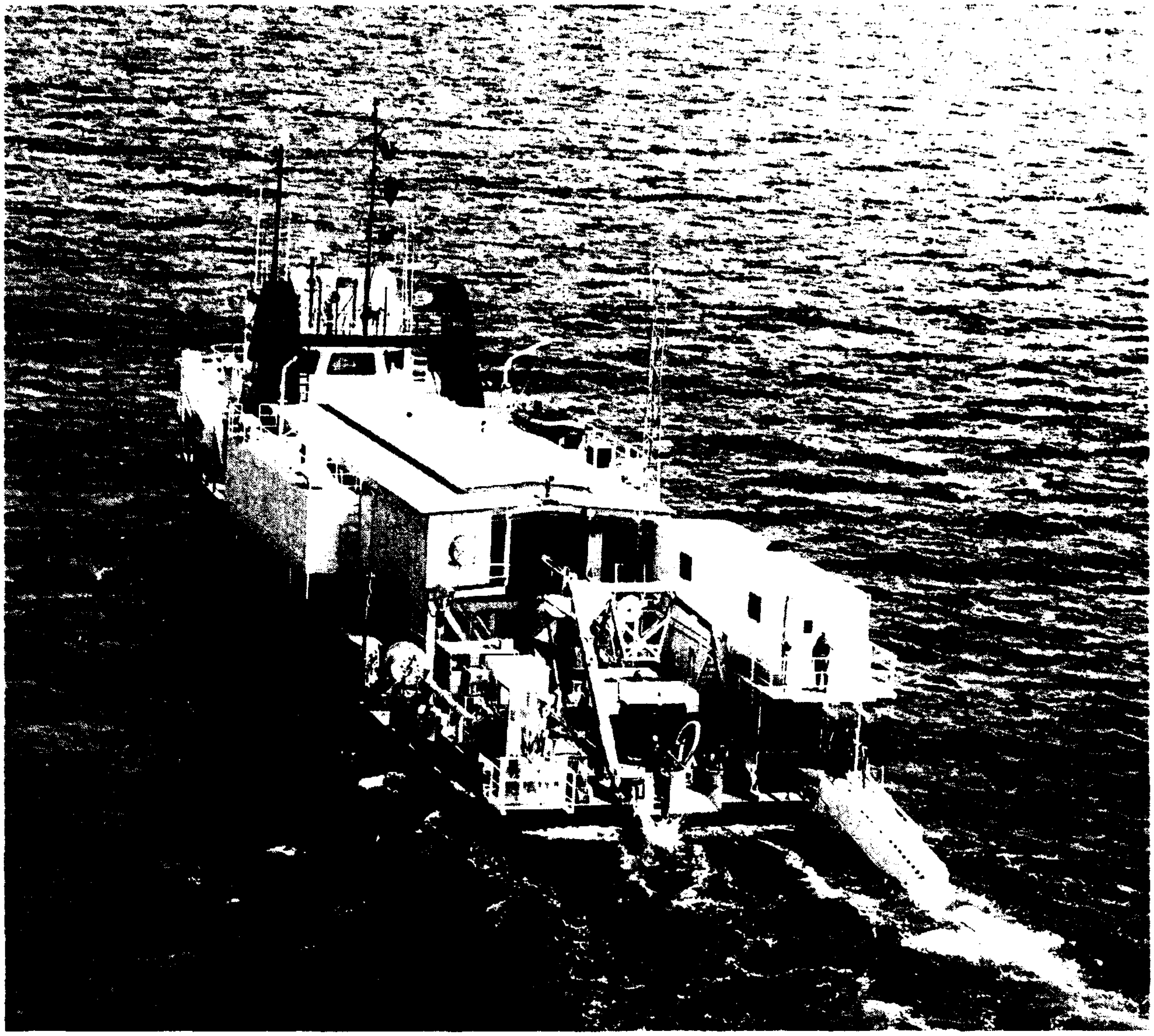

Figure 1. AUSS installed on board the offshore supply boat *MARSEA FIFTEEN* along with the 20,000-foot depth Advanced Tethered Vehicle (ATV). The control van is seen stacked upon the maintenance van. The vehicle is in the water just aft of the launch and recovery ramp. The external acoustic relay system (EARS), which is a communications batfish system, is located on the port stern. The rest of the deck equipment is ATV gear.

A cutaway depiction of the AUSS vehicle subsystem is shown in figure 2. The sensor suite consists of side-looking sonar (SLS) transducers on both sides of the vehicle, a forward-looking sonar (FLS) in the bow, a cooled charge-coupled device (CCD) camera and a 35-mm film camera in the nose, and two strobes in the after section of the vehicle. Propulsion is provided by four electric motors (two main motors at the rear, and two vertical motors in the forward and after sections respectively). Vehicle on-board navigation is accomplished using a four-transducer Doppler sonar in combination with a gyrocompass. Acoustic communications with the vehicle are accomplished through a transducer mounted on the top of the pressure hull.

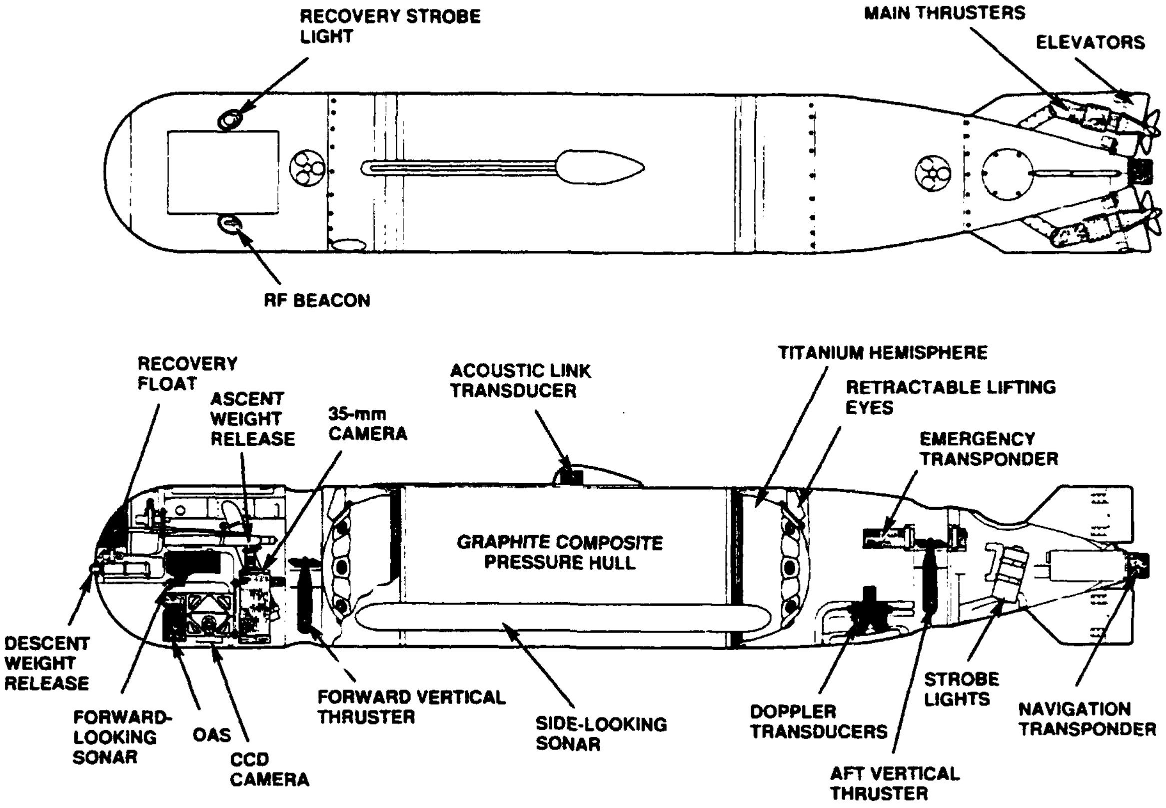

Figure 2. AUSS vehicle.

OPERATIONS AND TESTING FEATURES

Divers, submersibles, and tethered vehicles have allowed realtime undersea human presence (either remote or onsite). AUVs without communication links will not have a realtime human presence. This complicates not only the operational process for AUVs, but it can be crippling to the development process. Human interaction afforded by the AUSS acoustic communications link is critical to the supervisory-controlled operations of AUSS as well as its highly successful development process.

The AUSS acoustic link, in combination with an on-board flight recorder, were two of the most important development tools. Together, they overcame the problem of having no human presence for vehicle performance observation during development testing. The AUSS acoustic link allowed the operators to monitor the performance of the vehicle and its sensors during dives. The flight recorder and a capability to access the flight recorder data via the acoustic link at sea allowed the operators to inspect, in relatively high resolution, the performance of the vehicle. The flight recorder provided data after dives, which were analyzed to modify and improve later development efforts. The acoustic link also allowed the operators to change vehicle performance characteristics during dives.

The design of the AUSS hardware and software focused on providing a supervisory-controlled search capability. But the design effort was also committed to fielding a system that was well adapted for at-sea operations and testing. All aspects of operating and testing were considered during the design. In particular, system launch and recovery, system safety, system installation, system mobilization and demobilization, system navigation and tracking, data collection, data handling, system flexibility, and system expandability were taken into account throughout the effort. A process of iterating development with lessons learned at sea was considered throughout design and adhered to during development.

NORMAL AUSS OPERATIONAL SEQUENCE

During vehicle launch, the ship remains underway at minimum speed. The vehicle is placed in the launch ramp (figure 3), the ramp is pivoted over center into the water, and the vehicle is released to begin a dive. The vehicle remains on the surface as the ship continues to advance. A 6-foot line connects the nose of the vehicle to a descent float. As the ship steams away from the vehicle and the float, a transponder is pulled into the water via a line attached to the other end of the descent float. Another line, attached to the opposite end of the transponder, is payed out until it pulls a 100-pound descent weight into the ocean. The descent weight pulls the transponder, float, and vehicle to the bottom of the ocean. The descent float arrests the descent of the vehicle and the transponder after the weight has hit the bottom (figure 4).

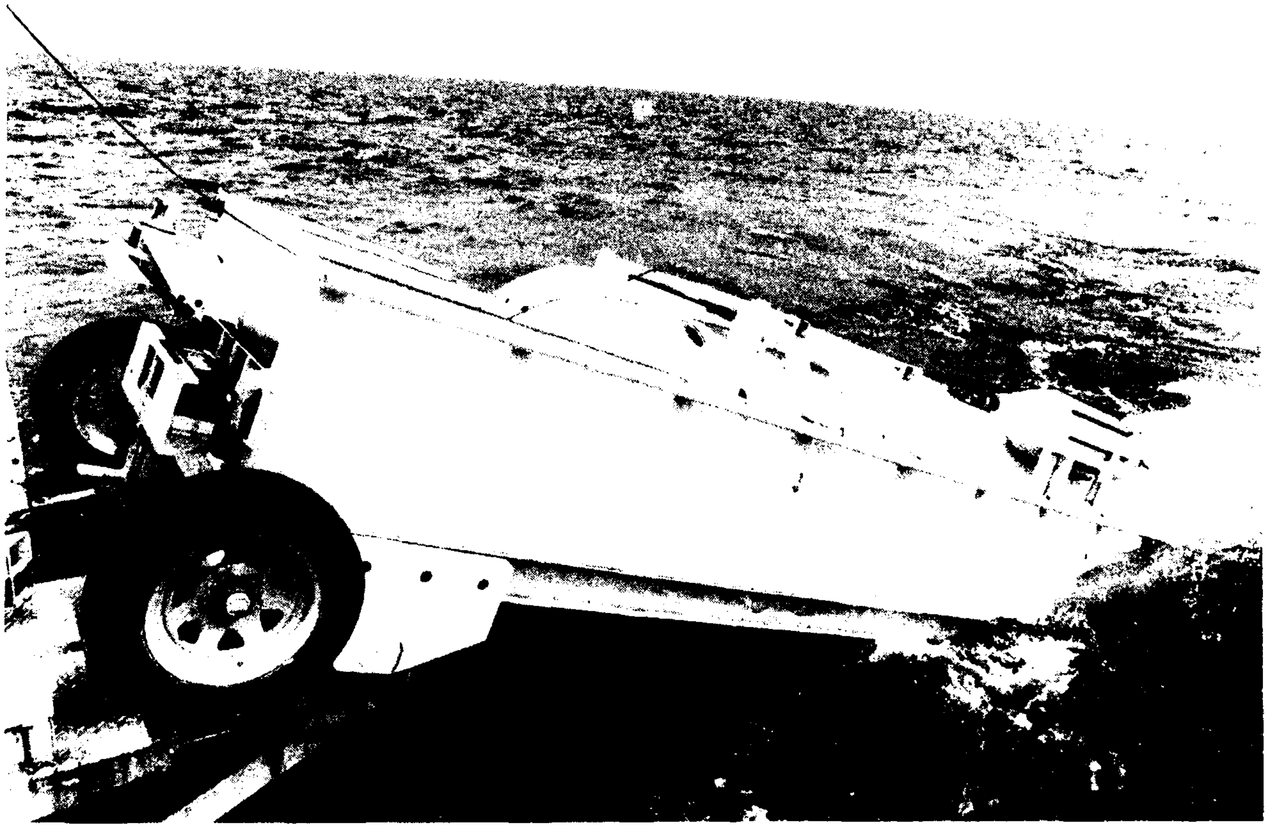

Figure 3. AUSS launch and recovery ramp.

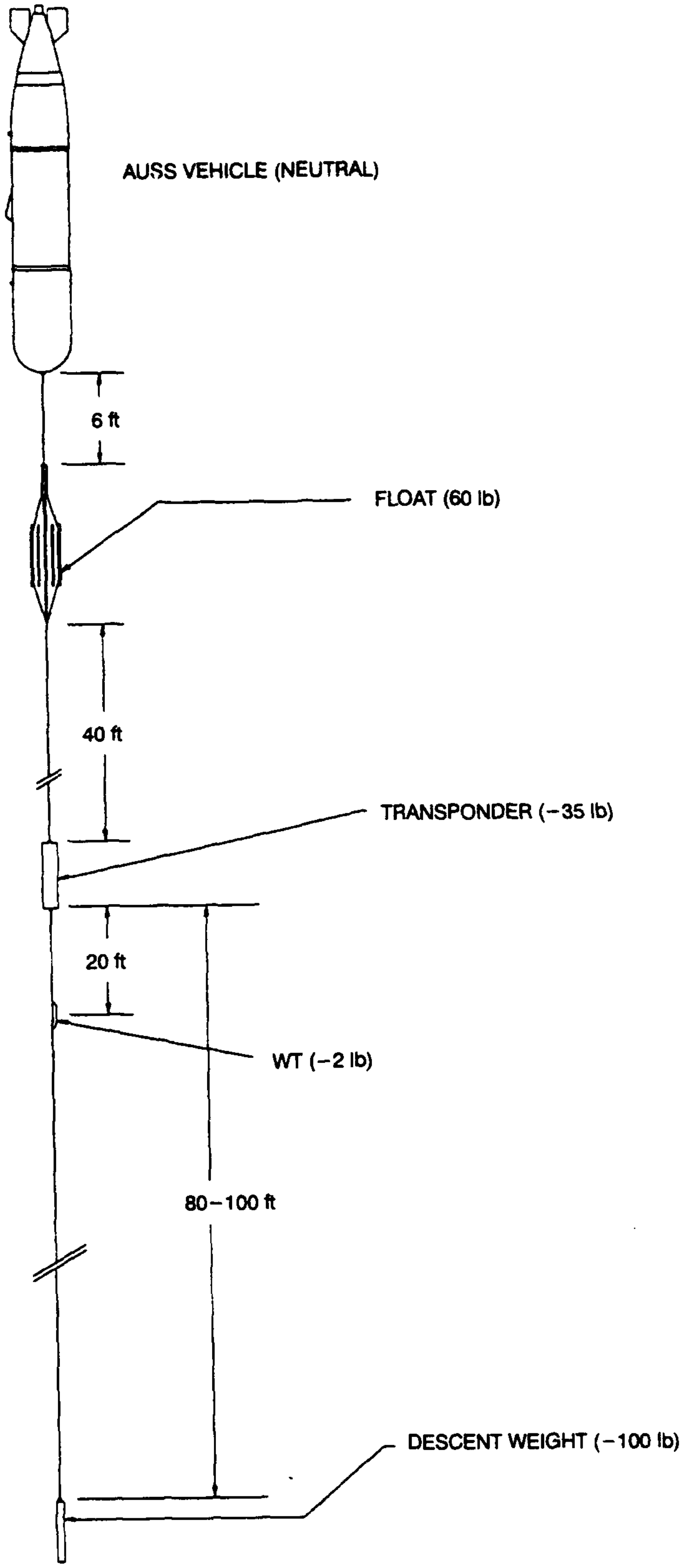

Figure 4. Descent string.

An acoustic link command to the vehicle initiates the release of the vehicle from its descent line. Another acoustic command (not an acoustic link command) releases the transponder and float from the descent weight and line. (The transponder/float release and recovery normally occurs at the conclusion of the dive.) The buoyancy of the float brings the transponder and float to the surface for recovery.

The free-swimming vehicle is supervisory controlled to conduct either development tests in which technology areas and subsystems are tested, or to conduct demonstration tests in which system capabilities are demonstrated.

At the end of a dive, the vehicle ascent weights are released and the vehicle comes to the surface. When it reaches the surface, a nose float is released. The nose float drifts away from the vehicle with a floating line attached between it and the vehicle. Upon release of the nose float, an rf beacon and flashing light emerge from the front of the vehicle. These are used to track the vehicle on the surface for both day and night recoveries (figure 5).

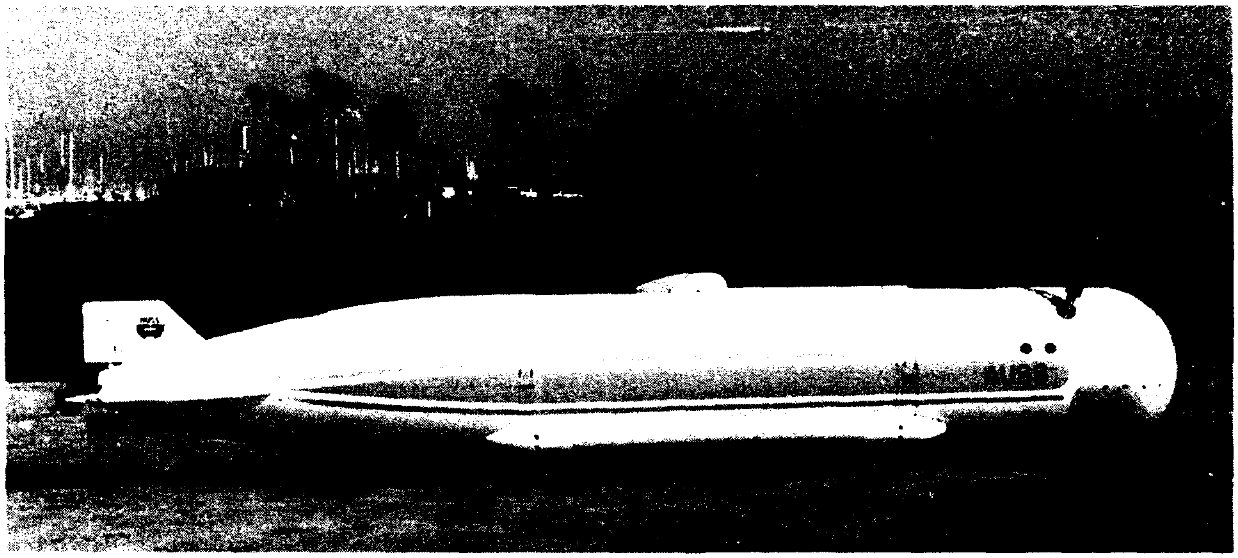

Figure 5. AUSS vehicle with RF beacon and flashing light.

The ship is maneuvered near the vehicle while the nose float line is grappled and the float is brought on board. The nose float is detached from the line, and a recovery line is attached to the nose float line. The recovery line has been prefed into the launch and recovery ramp. The ship continues ahead while the vehicle is taken in tow behind the launch ramp. During vehicle recovery, the ship remains underway. The vehicle is brought up to the bottom of the ramp by hauling in the recovery line with a capstan. The nose of the vehicle is latched up with a docking cart at the bottom of the ramp. The docking cart is driven up the ramp bringing the vehicle with it. When the vehicle is fully on board the ramp, the ramp is brought over center and onto the deck of the ship.

SYSTEM SAFETY

SYSTEM PARANOIA

As simple a concept as this may seem, it still stands as one of the major reasons why AUSS has been so successful. The AUSS concept of survival is one of paranoia. If anything goes wrong with the system, there is some fail-safe remedy or response to deal with the problem. For instance, if anything goes wrong on board the vehicle, the vehicle (if left to its own devices), will abort the mission and come to the surface. The operators may or may not be provided an opportunity to intercede. The system just will not tolerate malfunctions in its emergency subsystems. Also, the vehicle will not tolerate being ignored by its human supervisors.

The system paranoia proved particularly important during the earliest of sea tests. Many "infant mortality" situations caused the vehicle to surface in lieu of jeopardizing the continuation of the project. Many of the causes of these surfacings became apparent upon inspecting the flight recorder data after the dives. By the time the demonstration testing began, the problems which had caused necessary (and in some cases unnecessary) surfacings had been corrected. Table 1 includes many of the conditions under which the system is fail-safe protected, and where the vehicle will abort a dive and come to the surface.

Table 1. AUSS failure modes and their remedies.

SUBSYSTEM DEFICIENCY	REMEDIES
Surface power failure	Lead acid powered UPS backup
Batfish communications failure	Transducer Pole backup with separate power amplifier
Long baseline tracking system failure	1. Two independent LBS systems 2. Use short baseline tracking system
General vehicle failure	1. Reset vehicle with special tone 2. Reset vehicle through independent backup transponder system 3. Send acoustic link abort command 4. Send abort command to independent backup transponder system
Acoustic downlink failure	1. Send abort command to independent backup transponder system 2. Vehicle aborts mission after 45 minutes of no communications from surface
Leak in pressure hull	Vehicle immediately aborts mission
Low main battery voltage	1. Vehicle warns operators 2. Vehicle aborts mission if no action taken by operators
Low individual cell voltage	1. Vehicle warns operators 2. Vehicle aborts mission if no action taken by operators
Low emergency battery voltage	Vehicle aborts mission
Weight drop capacitor voltage low	Vehicle aborts mission
Vehicle main processor failure	Emergency processor takes over, and will abort mission
Ascent weight drop failure	1. Two independent ascent weight systems 2. Each system has separate weight and mechanism 3. Each system has serial corrosive link release
Vehicle on-board communications failure	1. On-board computers reset each other 2. Operator resets vehicle using special tone

SEARCH AND RECOVERY PLANNING

Before the system was ever deployed on sea trips, a detailed search and recovery (SAR) plan was prepared (appendix A). The SAR plan gives a quick description of the AUSS, a description of the SAR philosophy, detailed descriptions of the SAR equipment, responsibilities of personnel involved in the search and recovery effort, SAR procedures under different conditions, SAR procedures for the External Acoustic Relay System (EARS) fish, and helpful information and photographs of the AUSS system and its support ship. The SAR plan for AUSS applies whenever the normal termination of an AUSS dive is not possible. This means that the vehicle has not dropped its ascent weights, has not come to the surface as the result of dropping ascent weights, or if it has dropped the weights, it has not been found by normal means.

The AUSS search and recovery plan was successfully implemented on one occasion. The AUSS vehicle was suspended and drifting free at a depth of 600 feet after dive 7. All of the SAR plan actions were taken, and the official SAR plan contacts were made. The Advanced Tethered Vehicle (ATV) was used to make a historic midwater recovery of the AUSS vehicle. The ascent weight corrosive releases, the last level of redundancy on the vehicle, were within hours of dropping the weights when the recovery was made.

SEARCH AND RECOVERY EQUIPMENT

The primary SAR equipment on the AUSS are the rf beacon and the flashing light (fi 5). The flashing light is tracked visually, and the rf beacon is tracked with an automatic dire finder (ADF). If the ascent weights fail to release from the vehicle, corrodible links in line n the mechanical solenoid weight releases will eventually drop the weights. If the vehicle is below the surface of the ocean (and sometimes when it is on the surface), it can be tracked with a short baseline acoustic tracking system.

TEST SUPPORT

Two major support requirements outside of the AUSS system are needed for a successful AUSS operation. They are a support ship and an area of the ocean to operate in.

SUPPORT SHIP

The support ship used for the AUSS at-sea testing and demonstrations was the M/V *MARSEA FIFTEEN*. Figure 1 shows the M/V *MARSEA FIFTEEN* with both the AUSS and the ATV on board. The AUSS components are highlighted in the figure. The recently launched vehicle is seen in the water just aft of the launcher. The splash adjacent to the stern is the transponder entering the ocean. On the port side is the surface acoustic link transducer towfish and its support winch system. The control van is stacked on top of the maintenance van. This configuration was used for the first 32 AUSS dives. For the remainder of the AUSS dives, the ATV was removed, and the vans were both placed on the main after deck of the ship.

OPERATIONS AREAS

The AUSS operations areas are listed in tables 2 and 3. The first 37 AUSS dives were conducted in a 2,500-foot-deep operations area centered at lat 32° 59′ long 117° 31′ within Navy operations area 3703. This was a convenient area due to its close proximity to our laboratory, availability for use, shallow depth, and flat featureless bottom. A nonrecoverable long-term long baseline (LBL) acoustic transponder net was installed and surveyed in this area. This area was used almost exclusively for system developmental testing purposes.

Starting with the 38th dive, demonstration testing began. Locations with water depths between 4,000 feet and 12,000 feet were used for dives 38 through 45. Tables 2 and 3 show the dive numbers, test identifications, test dates, dive durations, locations, and depths for development and demonstration testing respectively.

Table 2. AUSS development test history.

TEST IDENT OR DIVE NUMBER	DATE	DIVE TIME (hours)	LOCATION	DEPTH (feet)
Dockside Trim	05–02–90	–	S.D. Bay	10
Dockside Thrusters	05–08–90	–	S.D. Bay	10
Dockside Wt. Rel.	05–09–90	–	S.D. Bay	10
Dockside Thrusters	05–17–90	–	S.D. Bay	10
Gyro and Doppler	05–22–90	–	S.D. Bay	10
Dockside Vehicle	07–26–90	–	S.D. Bay	10
At-Sea SAR & L/R	08–01–90	–	32°32′/117°12′	
Dockside Controls	08–07–90	–	S.D. Bay	10
1	08–22–90	3.6	3703	500
2	09–13–90	4.8	3703	2,500
3	09–28–90	6.3	3703	2,500
Dockside Controls	10–04–90	–	S.D. Bay	10
Dockside Controls	10–16–90	–	S.D. Bay	10
4	10–18–90	4.9	3703	2,500
5A	12–05–90	0.3	3703	2,500
5B	12–05–90	8.8	3703	2,500
6	01–17–91	0.12	3703	2,500
7	01–17–91	0.5	3703	2,500
8	02–07–91	3.8	3703	2,500
9	03–07–91	8.4	3703	2,500
10	03–07–91	0.4	3703	2,500
11	03–29–91	2.4	3703	2,500
12	03–29–91	3.8	3703	2,500
13	03–29–91	0.6	3703	2,500
14	04–08–91	4.7	3703	2,500
15	04–08–91	0.8	3703	2,500
16	04–08–91	0.5	3703	2,500
17	04–16–91	5.7	3703	2,500
18	04–16–91	1.2	3703	2,500
19	04–16–91	1.9	3703	2,500
20	07–16–91	5.6	3703	2,500
21	07–18–91	6.6	3703	2,500

Table 2. AUSS development test history (continued).

TEST IDENT OR DIVE NUMBER	DATE	DIVE TIME (hours)	LOCATION	DEPTH (feet)
22	07–18–91	3.0	3703	2,500
23	08–06–91	14.9	3703	2,500
24	08–21–91	3.2	3703	2,500
25	08–21–91	9.5	3703	2,500
26	09–10–91	2.0	3703	2,500
27	09–10–91	6.0	3703	2,500
28	09–25–91	3.6	3703	2,500
29	09–25–91	5.9	3703	2,500
30	10–31–91	9.5	3703	2,500
31	11–21–91	14.0	3703	2,500
32	12–19–91	13.5	3703	2,500
33	02–14–92	11.3	3703	2,500
34	03–03–92	3.5	3703	2,500
35	03–03–92	11.0	3703	2,500
36	04–01–92	5.5	3703	2,500
37	04–01–92	8.5	3703	2,500

Table 3. AUSS demonstration test history.

DIVE NUMBER	DATE	DIVE TIME (hours)	LOCATION (N lat/W long)	DEPTH (feet)
38	05–05–92	14.5	32° 35.5′/117° 31′	4,000
39	05–12–92	7.5	32° 37.5′/117° 31′	4,000
40	05–12–92	0.7	32° 37.5′/117° 31′	4,000
41	05–27–92	14.0	32° 37.5′/117° 31′	4,000
42	06–03–92	12.0	32° 04.5′/117° 14′	4,200
43	06–18–92	1.0	32° 37′/117° 31′	4,000
44	06–22–92	4.0	32° 09.5′/117° 21.5′	4,000
45	06–23–92	11.0	31° 0′/119° 0′	12,000

TESTING APPROACH

DEVELOPMENT TESTING PHASES

There were Three basic phases in the development testing process. They were laboratory tests, dockside tests, and at-sea tests. The laboratory tests were prerequisites to the dockside tests, and the dockside tests were prerequisites to the at-sea tests.

All basic subsystems were operated, adjusted, and calibrated to the extent possible in the laboratory. All reasonable subsystem and overall systems tests were performed within the constraints of the local shallow turbid bay water before the system graduated to at-sea operations. A mere nine structured dockside tests were required to support the system development.

The first two dives at-sea were limited by the attachment of a small nylon safety line to the vehicle. But on the third at-sea test, the vehicle was released to operate untethered in 2500 feet of seawater. During dives 3 through 37, hardware, software, and systems development issues were addressed.

DEMONSTRATION TESTING

The focus of dives 38 through 45 was demonstrating the system capabilities of AUSS. Table 4 lists the major capabilities that were demonstrated during this time period. Large-area search (also referred to as broad-area search) is the process of searching a large area at a high rate with a relatively low-resolution sensor. AUSS uses a side-looking sonar (SLS) system for large-area searches.

Optical search involves higher resolution sensors to cover a smaller area. AUSS uses both a cooled charge-coupled device (CCD) camera and a 35-mm still camera during optical search. AUSS optical searches are normally structured photomosaics where successive images are slightly overlapped, and successive image path coverages are slightly overlapped.

Table 4. Major AUSS capabilities.

LARGE-AREA SEARCH
OPTICAL SEARCH
IMMEDIATE CONTACT EVALUATION
DELAYED CONTACT EVALUATION
DETAILED INSPECTION

An immediate contact evaluation is accomplished when a contact seen on the SLS screen during large-area search is immediately pursued. This involves interrupting the SLS large-area search, moving the AUSS vehicle over to the contact, optically documenting the contact, and immediately returning the vehicle to the SLS large-area search.

A delayed contact evaluation is accomplished when (1) a contact is seen on the SLS screen during large-area search, (2) the contact is marked in the vehicle navigation system coordinates, and (3) the contact is pursued at a later time (the original SLS large-area search is not interrupted). AUSS has been used for delayed contact evaluations within a dive, and for delayed contact evaluations of items found in previous dives.

A detailed inspection is accomplished when the AUSS vehicle remains at a contact location to thoroughly inspect it. Options demonstrated during detailed inspections include (1) retransmitting previous CCD images at higher resolution, (2) marking positions of an image and moving over those locations, (3) hovering vehicle at higher or lower altitude, (4) taking another CCD and/or 35-mm image, (5) taking a series of pictures while moving in any direction, (6) performing an optical photomosaic area coverage, (7) and backing away to take forward-looking sonar (FLS) scans at higher resolution or at longer range to identify other positions to inspect further. For more detail on the AUSS capabilities, see Uhrich and Watson, 1992.

TEST PLANNING

A considerable amount of test planning documentation was developed for the AUSS program. The planning started with the design of the system, and plan formulations were continued and revised up until the end of the last dive.

To allow the most efficient use of valuable test time, objectives were set for each test, but an extensive amount of contingency planning was available to fall back on. This contingency planning existed in the body of the prevailing test plan and in backup plan documentation. This allowed the test team to make use of the versatility of the system and to adjust to subsystem problems while at sea.

The appendices to this report include a sampling of the test planning documentation written for the AUSS. These particular planning documents were selected for inclusion because they represent the full range of test planning documents produced for the AUSS. The test plan categories are (1) General Development Test Documents, (2) Prerequisite Development Testing Plans, (3) Background Development Test Plans, (4) Development Dive Plans, and (5) Demonstration Dive Plans.

GENERAL DEVELOPMENT TEST DOCUMENTS

The general development test documents were written before the vehicle fabrication and assembly were completed. These documents laid out the overall development testing program for the system including the laboratory, dockside, and development sea test phases. Appendix B contains general development test documents.

PREREQUISITE DEVELOPMENT TESTING PLANS

The prerequisite development testing plans were the documents used onsite for the dockside tests and the at-sea tests that occurred before the vehicle was considered ready to operate without a safety tether line attached to it. Appendix C contains prerequisite development testing plans.

BACKGROUND DEVELOPMENT TEST PLANS

The background development test plans were written before the major development sea test effort was underway. These plans provided test objectives (and in many cases procedures) for the collection of data later used to analyze, improve, and report the performance of the system. These plans were frequently referred to when contingency planning was required. Appendix D contains background development test plans.

DEVELOPMENT DIVE PLANS

The evolution and development of AUSS set the pace for the development sea test schedule. The criteria for a sea trip were clear test objectives made possible by completion of a specified list of system developments, subsystem integration, and repairs. For these reasons, the specific development dive plans were completed just prior to the deployment for which the plans were written. This took full advantage of the status of the system, and allowed written-in contingencies when necessary and possible. Appendix E contains development dive plans.

DEMONSTRATION DIVE PLANS

On 1 April 1992, word was received that traditional funding for AUSS was ending. The program was given a 2-month period to establish the system performance capabilities. This sudden program redirection changed the sea test planning significantly. System development was essentially discontinued, and the criteria used to move on to the next sea trip were the completion of the previous sea test, and the availability of a desired operations area.

Test plans were written more as "mission" plans. Each sea trip had mission objectives that included searches for items on the sea floor, and demonstrations of the capabilities of table 4. A few of the loose ends of the development effort were written into the demonstration dive plans. Appendix F contains demonstration dive plans.

TEST REPORTING

AUSS test reporting provided an account of the development and demonstration progress, and demanded that the data from the dives were formally reduced and documented. These test reports also became the background material for progress reporting and eventually for the development of formal overall program reports (refer to the bibliography). A major benefit of the reports was keeping technical and management personnel informed on the technical progression of the project.

A sampling of the test reporting is contained in appendices G, H, and I. The categories for these appendices are (1) Development Test Reports, (2) Topical Development Test Reports, and (3) Demonstration Test Reports. The samples included in these appendices cover the major at-sea accomplishments during the testing.

Some of the test reports contain plots of system performance, and, in some instances, sensor images. These data were added to reports when major milestones were reached such as completion of hover control implementation or transmission of the first compressed CCD images.

Most of the report plots were produced by using flight recorder data collected on board the vehicle to produce postdive data files. These files were loaded into a PC with software that produced the plots on a color pen plotter. Some of the plots of Doppler navigation data are presented as they were seen by the operators on the Doppler navigation screen at sea. These plots are produced from files stored at the surface ship, and later used to produce hard copies.

The report sensor images are usually produced by taking files stored at the surface ship, and using them to produce postdive hard copies on high-resolution laser printers. These image files are produced from images collected on board the vehicle, compressed, transmitted through the acoustic link, and reconstructed at the surface for display and file storage.

DEVELOPMENT TESTING RESULTS

Results of development testing were documented primarily in numbered dive reports. Multiple dives were reported in a single report when a single ship deployment included several dives. Appendix G contains the development test reports.

TOPICAL DEVELOPMENT TEST REPORTS

Topical development test reports were written on some of the major technical areas in the AUSS development. Appendix H contains topical development test reports.

DEMONSTRATION TESTING RESULTS

Demonstration tests were not thoroughly reported in individual dive reports as were the development tests. They are, however, very well covered in other formal documentation produced after all dives were completed and time was allowed for analysis of the mission data (refer to Uhrich and Watson, 1992). Appendix I contains demonstration test dive reports.

Part of the demonstration testing was the discovery, position fixing, contact evaluating, and inspecting of several items on the sea floor. As part of the inspections, the AUSS tracking system was used to determine the location of these items. Table 5 is a list of several items detected and inspected by AUSS, and their positions (latitude and longitude). Each position in the table was determined by finding an average position of several vehicle fixes while hovering over the item. Except for the 12 kft automobile case, the AUSS position fixes were determined by integrating ultrashort baseline acoustic tracking with GPS surface ship tracking. In the case of the automobile in 12 kft, long baseline (LBS) tracking was integrated with GPS tracking. Tracking accuracy and position fixing is discussed in table 6, and table 6 notes [8] and [9].

Table 5. Locations of some items inspected by AUSS.

INSPECTED ITEM	LOCATION	
	LATITUDE NORTH	LONGITUDE WEST
Dauntless dive bomber	32° 37′ 11″	117° 30′ 29″
*Skyraider aircraft	32° 31′ 36″	117° 28′ 40″
*55-foot yacht	32° 33′ 03″	117° 29′ 15″
*"Pancake" debris	32° 35′ 39″	117° 30′ 19″
*"Jumbled" debris	32° 35′ 38″	117° 30′ 18″
*Old desk	32° 35′ 13″	117° 31′ 24″
*"Mast" pipe structure	32° 37′ 36″	117° 31′ 00″
*Cable coils	32° 37′ 37″	117° 31′ 02″
12-kft automobile	31° 01′ 44″	119° 02′ 10″
14-inch sphere	32° 37′ 38″	117° 31′ 02″
*"Safe"	32° 35′ 37″	117° 30′ 33″
*"Bike frame" structure	32° 35′ 40″	117° 30′ 51″
"Nova"	32° 59′ 16.20″	117° 31′ 08.64″
"Brown"	32° 59′ 00.08″	117° 31′ 24.31″
"Block 1"	32° 59′ 08.83″	117° 30′ 36.42″
"CAD"	32° 58′ 58.01″	117° 30′ 23.60″
"Sphere"	32° 58′ 59.73″	117° 31′ 05.86″
"Pontiac"	32° 58′ 45.49″	117° 30′ 57.56″
"Block 2"	32° 59′ 11.67″	117° 30′ 40.49″
"98"	32° 59′ 01.13″	117° 30′ 57.23″
"Block 3"	32° 59′ 07.48″	117° 30′ 41.76″
"LTD"	32° 58′ 56.72″	117° 31′ 01.47″

NOTE: Items preceded by an * are items "discovered" by AUSS. Other items were found with prior knowledge of their existence.

PERFORMANCE CHARACTERIZATION AND QUANTIFICATION RESULTS

In response to program requirements, a document titled AUSS Performance and Quantification Tests Objectives (see appendix D) was produced in September of 1990. These objectives were kept in mind throughout the AUSS test program. Procedures were written into dive plans and data were collected to satisfy these objectives whenever possible. Table 6 lists the results of this effort.

These data were collected using only the AUSS equipment. No independent measuring devices were used to provide these results. For instance, the maximum speed of the vehicle was determined from the velocity indicated by the AUSS Doppler sonar. The performance data presented were not derived from statistically significant populations, but the data are nevertheless real and therefore representative. The program was canceled before a dedicated system performance effort could be pursued.

Table 6. Performance and quantification tests results.

PARAMETER	DEMONSTRATED PERFORMANCE	REQUIREMENT
Depth	12,000 feet	20,000 feet
Speed	5.3 knots	5 knots
180° turn (hover)	42 seconds [1]	120 seconds
180° turn (powered)	45 seconds	120 seconds
Ascent, hover	0.94 foot/second	1 foot/second
Descent, hover	1.25 feet/second	1 foot/second
Ascent, powered	6 feet/second [1]	2 feet/second
Descent, powered	6 feet/second [1]	2 feet/second
Ascent, weighted	50 minutes [2]	60 minutes from 20 kft
Descent, weighted	72 minutes [2], [3]	60 minutes to 20 kft
Ascent, weighted	5 minutes	10 minutes from 2.5 kft
Descent, weighted	8 minutes	10 minutes to 2.5 kft
Obstacle detect	[4]	500 feet
Obstacle avoid	80 ft (4.85 knots) [1]	Stop within 100 feet
Hover radius	9.5 feet/2 min. [5]	25 feet/2 minutes
Hover depth	± 2 feet	± 5 feet/2 minutes
Hover altitude	± 5 feet	± 5 feet/2 minutes
Hover heading	± 1°	± 15°/2 minutes
Transit (5-knot) depth	± 1 foot/5 min.	± 5 feet/2 minutes
Transit (5-knot) altitude	± 5 feet/5 min.	± 5 feet/2 minutes
Transit (5-knot) heading	± 2°/5 min.	± 15°/2 minutes
Endurance, hotel	33 hr (extrapolated)	10 hours
Endurance, heading/ depth hold	24 hr (extrapolated)	10 hours
Endurance, 5-knot transit	10 hr (extrapolated)	8 hours
SLS Search Pattern	7.8 legs x 3-nmi long [6]	Demonstrate capability
Photomosaic	Several demonstrated	Demonstrate capability
Acoustic Link	4.8 kbits/s, 10^{-5}ber [7]	4.8 kbits/s, 10^{-5}ber
LBS Veh. Tracking	See figure 6, and [8]	Within 5.5-yd radius

Table 6. Performance and quantification tests results (continued).

SBS Veh. Tracking	See figure 7, and [9]	Within 54.5-yd radius
Weight release	45 dives/44 releases	Demonstrate consistent
SAR equipment	About 90% deployment	Demonstrate consistent
Radio beacon track.	3 nautical miles	1 nautical mile
Fail-safe ascent	Demonstrated in prelaunches	Demonstrate dependable
Battery exchange	Not demonstrated	1.5 hours at sea
Battery recharge	Demonstrated	Recharge at sea
Launch/Recovery	Sea state 3 [10]	Sea state 3

Explanation of bracketed numbers.

[1] Initial velocity = 5 knots.

[2] Extrapolated from 12,000-foot dive data.

[3] 72-minute descent extrapolation is based upon 100-pound descent weight used for 12,000-foot descent. Larger descent weights can be used to speed up the descent.

[4] Not demonstrated. Obstacle-Avoidance System (OAS) was not fully developed, although OAS hardware is on board the vehicle.

[5] Actual data collected were 147 feet of drift in 31 minutes. This was measured using fish cycle long baseline tracking.

[6] *Basic capacity demonstrated in several* dives. The 3-nmi long legs in the specific case noted were separated by 1,800 feet for a total area coverage of 7.5 nmi^2.

[7] Demonstrated under good acoustic conditions. Read as 4,800 bits per second with 10^{-5} bit error rate.

[8] Summary of results: The 28 data points in figure 6 are long baseline (LBS) **fish-cycle fixes** of a moored beacon in 12,000 feet of water. The combined error contributions of the fish cycle tracking and the LBS net calibration result in individual geodetic fixes with an error of about ± 7.5 yards. The standard deviation about the average of these position fixes is 3.5 yards.

Error determination: The vehicle fish cycle positions reported during AUSS operations and in table 5 are average positions. All of the 28 fixes in figure 6 are within a 6.4-yard radius of the average plotted position. The distribution is assumed to be normal and the standard deviations about the average position in the x and y directions are 1.3 yards and 2.5 yards respectively. The subject fish-cycle beacon was inside an LBS net that was calibrated using a large set of integrated GPS/LBS data. The LBS transponder net calibration resulted in a 2-yard rms transponder geodetic position error. Assuming a normal distribution for the transponder position error, the 95 percent probable error is 1.96 x 2 = 3.92 yards (see Miller & Freund, 1965—the normal distribution table). Using root sum square combination of the errors results in:

error radius for a single fix in this data set (fish-cycle LBS) =

$(6.4^2+3.92^2)^{1/2} = 7.5$ yards (about 95 percent probability)

standard deviation about the average position of this data set (fish-cycle LBS) =

$(1.3^2+2.5^2+2.0^2)^{1/2} = 3.5$ yards

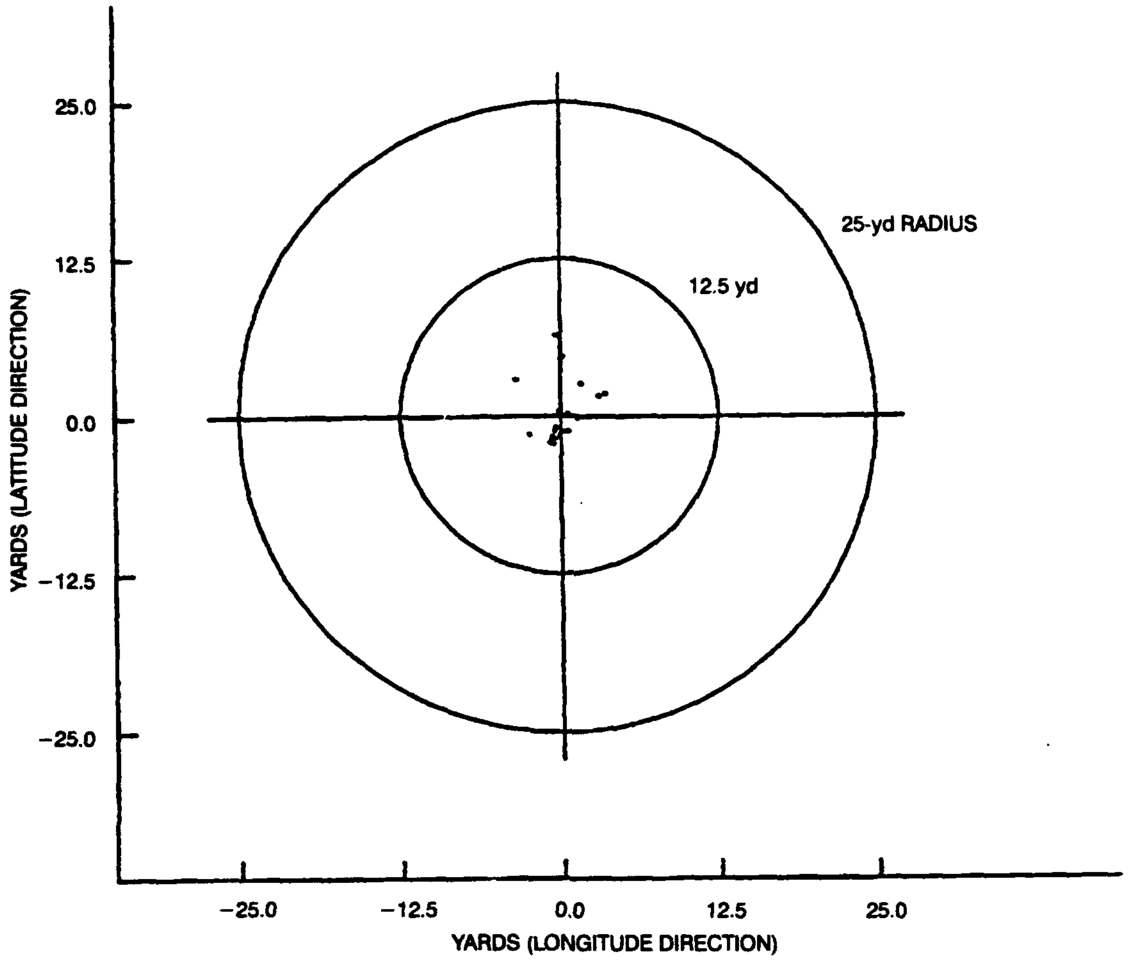

Figure 6. LBL fish-cycle fixes of AUSS vehicle attached to line moored to the sea floor. Vehicle depth: 11,350 ft. Vehicle altitude: 150 feet.

[9] Summary of results: The 10 data points in figure 7 are **ultrashort baseline (USBL) fixes** of the vehicle hovering over a 55-foot fishing boat in 4,000 feet of water. The combined error contributions of the SBL tracking and the GPS ship tracking result in individual fixes with an error of about ± 120 yards. The standard deviation about the average of these position fixes is 65 yards. (These numbers are probably good for reacquisition with the AUSS navigation assets. Use of another navigation system to reacquire items marked using AUSS and USBL may suffer from offset error introduced by the AUSS-USBL system).

Error determination: The ultrashort baseline positions reported during AUSS operations and in table 5 are average positions. All of the 10 fixes in figure 7 are within a 49-yard radius of the average plotted position. The distribution is assumed to be normal and the standard deviations about the average position in the x and y directions are 24.7 yards and 20.8 yards respectively. The fixes were taken on the hovering vehicle as it inspected the full length of the 18-yard-long boat (this is typical of tracking data collected during inspections). The 95-percent probability single fix GPS accuracy specification for Course Acquisition (C/A) code data is ± 100 meters = 109 yards geodetic (NAVSTAR GPS User Equipment, 1991). The C/A code GPS data are

Gaussian, but this data set was taken in less than 1 hour and is too small to benefit from averaging. Therefore, the 95-percent probable GPS error of the averaged position is also ± 109 yards. For a normal distribution, this results in a standard deviation of 56 yards (Miller and Freund, 1965, normal distribution table). Using C/A code standard GPS, root sum square combination of the errors results in:

error radius for a single fix in this data set (USBL and C/A GPS) =

$(49^2+109^2)^{1/2} = 120$ yd (about 95 percent probability)

standard deviation about the average position of this data set (USBL and C/A GPS) =

$(24.7^2+20.8^2+56^2)^{1/2} = 65$ yards

The GPS error can be improved by using the AUSS differential GPS system that has an advertised accuracy of 5 to 10 meters.

[10] Sea state 3 launch and recovery was demonstrated with the launcher and the prototype vehicle. The same launcher was used for the improved vehicle, but sea states over sea state 2 were never experienced during improved vehicle operations.

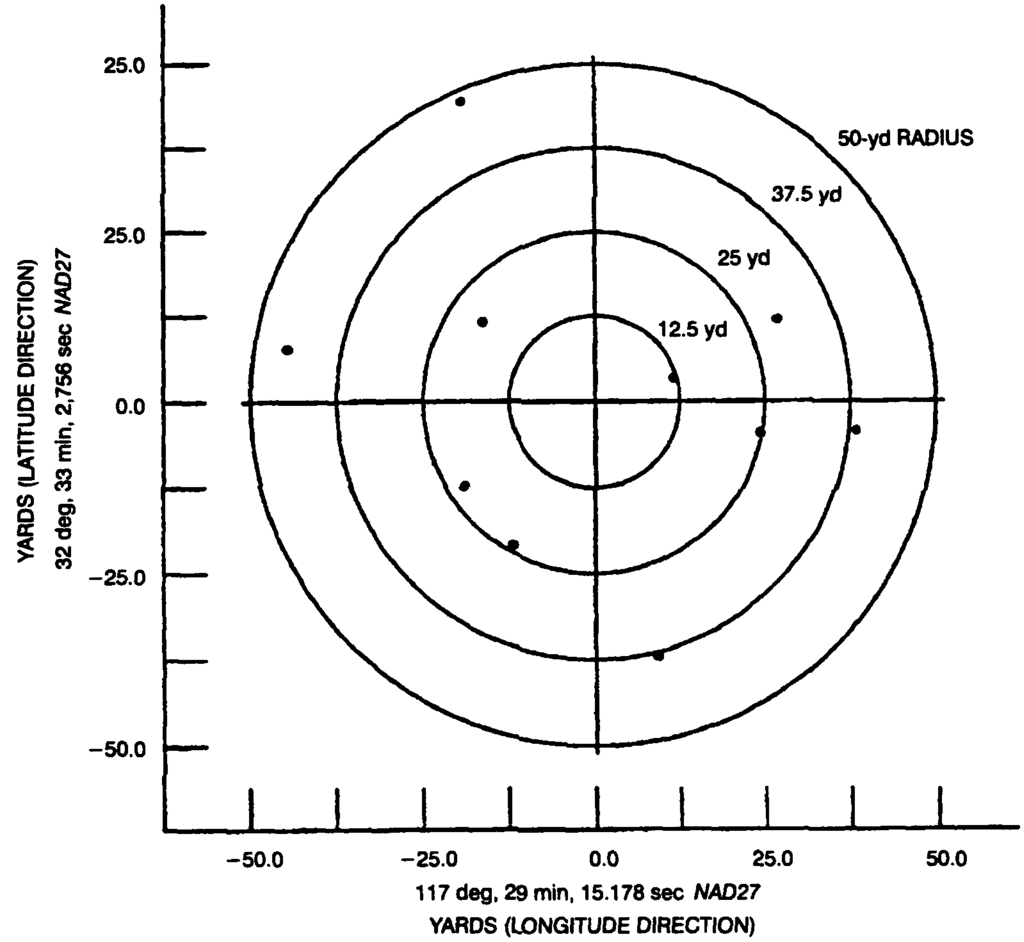

Figure 7. USBL fixes of AUSS vehicle in hover mode over target (pleasure craft found during AUSS dive 41).

CONCLUSION

The test program for the AUSS was highly successful. This success was due to many factors. Several of these factors were system flexibility, the use of the acoustic link and the flight recorder as test tools, a designed-for-test approach, safety considerations, system fail-safe properties, test philosophy, long-range test planning, and the short-term development-interactive test planning. Without any one of or the synergy of these several factors, the program would not have enjoyed such success.

GLOSSARY

ADF	automatic direction finder
Ah	ampere-hour
AL	acoustic link
ASCII	American Standard Code for Information Interchange
async	asynchronous
ATV	Advanced Tethered Vehicle
AUSS	Advanced Unmanned Search System
AUV	Autonomous Underwater Vehicle
ber	bit-error rate
bps	bits per second
C/A	course acquisition
cb-cg	center of buoyancy-center of gravity
CCD	charge-coupled device
CMD	command
CMD	operator command console computer; command
CPA	closest point of approach
CRT	cathode ray tube
CSDG-1	Commander Submarine Development Group One
CTFM	continuous transmission frequency multiplex
CURV	cable-controlled underwater recovery vehicle
CW	continuous wave
dB	decibel
DF	direction finder
DR	dead-reckoning
DSRV	deep submergence rescue vehicle
EARS	External Acoustic Relay System
EP	emergency processor
E/W	east/west (position)
F-A	fore-aft (or vice versa)

FLS	forward-looking sonar
FRD	flight recorder data
FRS	flight recorder sample rate
ft	feet
GFI	ground fault interrupt
GPS	Global Positioning System
IMG	image
kft	thousand feet
kHz	kilohertz
lat	latitude
lb	pound
LBS	long baseline system
long	longitude
L/R	launch and recovery; also left/right
mi	mile
mm	millimeter
msec	millisecond
mW	milliwatt
NAV	navigation, navigational (also nav)
nmi	nautical mile
N/S	north/south (position)
OAR	Ocean Applied Research (company name)
OAS	obstacle-avoidance system
OR	operational requirement
P.R.	public relations
PTR	portable test range

RAM	random access memory
rf	radio frequency
RMS	root mean square
rpm	revolutions per minute
ROM	read only memory
SAR	search and recovery
SBS	short baseline system
sec	second
SLS	side-looking sonar
S-P	starboard-port (or vice versa)
sync	synchronous
TEMP	test and evaluation master plan
UPS	uninterruptible power supply
USBL	ultrashort baseline
VCR	video-camera recorder
VHF	very-high frequency
wrt	with respect to
XBT	expendable bathythermograph
yd	yard

REFERENCES

Jones, H. V. 1992. "Advanced Unmanned Search System (AUSS) Description." NRaD TR 1528 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Miller, I., and J. E. Freund. 1965. *Probability and Statistics for Engineers,* Prentice-Hall, Englewood Cliffs, NJ.

Uhrich, R. W., and S. J. Watson. 1992. "Deep-Ocean Search and Inspection: Advanced Unmanned Search System (AUSS) Concept of Operation." NRaD TR 1530 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Walton, J. 1992. "Advanced Unmanned Search System (AUSS) Testbed: FY 1987 Development Testing." NRaD TR 1525 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Walton, J. 1992. "Evolution of a Search System: Lessons Learned with the Advanced Unmanned Search System." NRaD TR 1529 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

BIBLIOGRAPHY

Acoustic Systems, Inc. 1992. "Definition of the Advanced Unmanned Search System (AUSS) Sonar Characteristics." NRaD TN 1704 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*

Bryant, S. B. 1979. "Advanced Unmanned Search System (AUSS) Performance Analysis." NOSC TR 437 (Jul). Naval Ocean Systems Center, San Diego, CA.

Cooke, M. W. 1992. "Advanced Unmanned Search System (AUSS)." NRaD TD 2348 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Endicott, D. L. Jr., and G. R. Kuhl. 1992. "Fast Area Search System (FASS): Feasibility Study Appendices." NRaD TN 1703 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*

Endicott, D. L. Jr., and G. R. Kuhl. 1992. "The Fast Area Search System (FASS): A Feasibility Study." NRaD TR 1526 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Grace, D. R. 1992. "Brownian Reber Search Theory for the Advanced Unmanned Search System." NRaD TR 1534 (Oct). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Gunderson, C. R. 1978. "Advanced Unmanned Search System (AUSS), Preliminary Search Systems Analysis." NOSC TR 375 (Dec). Naval Ocean Systems Center, San Diego, CA.

Held, J. L. 1992. "Automatic Hovering Algorithms for the Advanced Unmanned Search System." NRaD TR 1535 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Held, J. L. and H. B. McCracken. 1993. "Automatic Transit Algorithms for the Advanced Unmanned Search System (AUSS)." NRaD TR 1536 (Jan). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Jones, H. V. 1992. "Advanced Unmanned Search System (AUSS) Description." NRaD TR 1528 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

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* NRaD Technical Notes (TNs) are working documents and do not represent an official policy statement of the Naval Command, Control and Ocean Surveillance Center (NCCOSC), RDT&E Division (NRaD). For further information, contact the author(s).

Keil, T. J. 1992. "Advanced Unmanned Search System (AUSS) Deep Ocean Floor Search Performance Computer Model: Executive Summary." NRaD TN 1702 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*

Kono, M. E. 1992. "Surface Computer System Architecture for the Advanced Unmanned Search System (AUSS)." NRaD TR 1538 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Mackelburg, G. R., S. J. Watson, and W. D. Bryan. 1992. "Advanced Unmanned Search System (AUSS) Acoustic Communication Link Development." NRaD TR 1531 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

McCracken, H. B. 1992. "Advanced Unmanned Search System (AUSS) Supervisory Command, Control and Navigation." NRaD TR 1533 (Nov). Naval Command, Control, and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Osborne, P. D., and C. C. Geurin. 1992. "Advanced Unmanned Search System (AUSS) Surface Navigation, Underwater Tracking, and Transponder Network Calibration." NRaD TR 1532 (Oct). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Rasmussen, M. E. 1992. "Advanced Unmanned Search System (AUSS) Battery Monitor/Charging Systems." NRaD TR 1539 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Schwager, M., and J. Stangle (SAIC). 1992. "Advanced Unmanned Search System (AUSS) Software Description: Vol I Surface SW/Vol II Vehicle SW." NRaD TN 1705 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*

SEACO, Inc. 1992. "Development of the Acoustic Telemetry System." NRaD TD 2336 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Stachiw J. D. 1984. "Graphite-Reinforced Plastic Pressure Hull for the Advanced Unmanned Search System (AUSS)." NOSC TR 999 (Oct). Naval Ocean Systems Center, San Diego, CA.

Stachiw J. D. 1986. "Graphite-Fiber-Reinforced Plastic Pressure Hull Mod 1 for the Advanced Unmanned Search System (AUSS)." NOSC TR 1182 (Dec). Naval Ocean Systems Center, San Diego, CA.

---

* NRaD Technical Notes (TNs) are working documents and do not represent an official policy statement of the Naval Command, Control and Ocean Surveillance Center (NCCOSC), RDT&E Division (NRaD). For further information, contact the author(s).

Stachiw J. D. 1988. "Graphite-Fiber-Reinforced Plastic Pressure Hull Mod 2 for the Advanced Unmanned Search System (AUSS)." NOSC TR 1245 (Aug). Naval Ocean Systems Center, San Diego, CA.

Uhrich, R. W., J. Walton, and S. J. Watson. 1978. "Portable Test Range and its Application to Side-Looking Sonar." NOSC TR 258 (Jan). Naval Ocean Systems Center, San Diego, CA.

Uhrich, R. W., and S. J. Watson. 1992. "Deep-Ocean Search and Inspection: Advanced Unmanned Search System (AUSS) Concept of Operation." NRaD TR 1530 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Uhrich, R. W., S. J. Watson, and G. R. Mackelburg (Eds.). 1992. "Advanced Unmanned Search System (AUSS) Surface Acoustic Link Description." NRaD TN 1706 (Oct). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.*

Vought Corporation. 1992. "Design Analysis and Operations Research for the Advanced Unmanned Search System (AUSS)." NRaD TD 2337 (Sep). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Walton, J. 1992. "Advanced Unmanned Search System (AUSS) At-Sea Development Test Report." NRaD TR 1537 (Dec). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Walton, J. 1992. "Advanced Unmanned Search System (AUSS) Testbed: FY 1987 Development Testing." NRaD TR 1525 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Walton, J. 1992. "Advanced Unmanned Search System (AUSS) Testbed: Search Demonstration Testing." NRaD TR 1527 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Walton, J. 1992. "Evolution of a Search System: Lessons Learned with the Advanced Unmanned Search System." NRaD TR 1529 (Nov). Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

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APPENDIX A

AUSS SEARCH AND RECOVERY (SAR) PLAN

3900
Ser 941/11-91
25 Feb 91

MEMORANDUM

From: J. M. Walton (Code 941)

To: AUSS Team

Via: Head, Systems Engineering Branch (Code 941)

Subj: AUSS SAR PLAN

Ref: (a) My memo 3900 Ser 941/57-90 of 20 Aug 90

Encl: (1) AUSS SAR Plan (Revision A)

1. Enclosure (1) is the AUSS Search and Recovery (SAR) plan and is a revision of reference (a). Please maintain a copy of this in your files. It may also be useful to maintain a copy of the SAR plan at home.

J. M. WALTON

Copy to:
642
642 (Dyncorp (3))
645 (Lahtela (3))
90
94
941
941 (Cooke,Held,Jones,Rutkowski,Walton,file)
942
CSDG-1 (CDR Baccei (3))

AUSS SEARCH AND RECOVERY PLAN

(REVISION A)

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FIGURES

TABLES

AUSS SEARCH AND RECOVERY PLAN

I. INTRODUCTION

The purpose of this Search and Recovery Plan (SAR Plan) is to define the various loss modes that the Advanced Unmanned Search System (AUSS) or the External Acoustic Relay System (EARS) might experience, and explain the steps that will be taken to locate and recover the equipment, if lost. In addition, SAR equipment and system redundancies are explained. This plan should be made available to activities involved in any search and recovery effort for AUSS or EARS.

II. GENERAL DESCRIPTION

AUSS is a free-descending/free-ascending search system with communication to and from the surface on acoustic channels only. Operational depths as of July 1990 are 100 to 2,500 feet. No mechanical connection normally exists between the surface support craft and the AUSS vehicle.

EARS is a tethered vehicle that is towed behind the AUSS support craft at a depth of approximately 150 feet. EARS is used to transmit and receive the acoustic signals used by the AUSS vehicle and AUSS support ship for communication and navigation.

During normal operations, the AUSS vehicle may descend to the bottom in one of two ways: (1) propelled to the bottom using its own thrusters or (2) pulled to the bottom using a weight that drags a string of equipment behind it. The string of equipment pulled by the weight consists of (starting 100 feet above the weight and moving up) a corrosive link, a Sonatech transponder with acoustic command release, torpedo float, and then the vehicle. This equipment is normally connected together using lightweight line. After the vehicle is stable at the bottom, it is released from the descent string via an acoustic command. Later, the torpedo float and the Sonatech transponder are released to be picked up on the surface by initiating an acoustic release command to the Sonatech unit.

After a dive is completed, ascent weights are released from the vehicle's nose in one of three ways:

a. Acoustic command release

b. Time release

c. Corrosive release (within 20 to 30 hours)

Another option for ascent initiation is:

d. Back up acoustic command release

When the vehicle is on the surface, a tethered nose float will normally be deployed to aid in recovery and to expose a flashing light and a radio transmitter.

The Search And Recovery (SAR) subsystems both on board the vehicle and on board the support craft consist of the following:

Subsystem	Location
Acoustic transponder	vehicle
Acoustic Link Fish Cycle Transponder Mode	vehicle
Acoustic-Tracking System	ship
Automatic flasher beacon light	vehicle
Radio transmitter	vehicle
Radio automatic direction finder	ship

III. DETAILED DESCRIPTION

a. Acoustic Command Release

The acoustic command release system consists of two electro-mechanical release mechanisms: two lead weights (37 lb each), and the normal acoustic communications channel used to communicate between the support craft and the vehicle. The release command format is peculiar to AUSS and cannot be duplicated easily.

b. Time Release

The time-release system consists of the same electro-mechanical releases and lead weights as for the command releases, and a vehicle on-board timing scheme that will release the ascent weight within 1 hour after the surface craft loses contact with the vehicle.

c. Corrosive Release

The corrosive releases are magnesium/steel releases placed in series with and below the electro-mechanical release. This should release the ascent weight 20 to 30 hours after the vehicle is launched.

d. Back–up Acoustic Command Release

A Sonatech Model NT–029 transponder serves as a back-up acoustic release command receiver on the vehicle. When the proper command code is received by this transponder, a relay is energized that causes the release of both ascent weights (and the descent weight if not previously released). For a period of 60–90 seconds after successfully receiving the command code, the transponder will respond to interrogations with double burst responses. The normal response burst (see III.e) will be followed by a 10-msec burst of 10.25 kHz after a delay of 210 msec. Sonatech Model NS–011 and NS–017 transceivers are capable of both recognizing this command verification response and of issuing the release command. The Sonatech standard command code ID number for this release command is 35. See III.e for detailed specifications on this transponder.

e. Acoustic Transponder

The Sonatech Model NT–029 transponder mentioned in III d as a back-up acoustic release command receiver also serves as a transponder for acoustic tracking. To conserve its internal battery, it normally draws power from the main vehicle power source. If this power source is not available for any reason, the transponder will automatically be powered by its own battery (which has a life expectancy of 120 days or 80,000 responses to interrogations.) Additional specifications for this transponder are provided below.

Characteristics	Specifications
Maximum Depth	22,000 feet
Receiver Characteristics	
Frequency	9 kHz
Lockout Time	2.5 ± 0.5 sec
Minimum detectable signal for 50% prob of detection	< 73 dB re 1 μPa
Recognition Time Jitter	< 0.5 msec
Transmitter Characteristics	
Frequency	13.5 kHz
Burst Width	10 msec (2 msec jitter reduction frequency followed by 8 msec of 13.5 kHz)
Jitter Reduction Freq	10.75 kHz
Source Level	>186 dB re 1μPa at 1 m
Turn-Around Time	15 ± 0.5 msec, measured from leading edge of interrogation signal to leading edge of reply pulse

f. Acoustic Link Fish Cycle Transponder Mode

Several navigation modes are incorporated into the vehicle's acoustic link subsystem. These modes are operator selectable via commands over the acoustic link. The most commonly used mode (and the default mode upon power-up and computer reset) is the fish cycle transponder mode. This mode makes it possible to track the vehicle using standard long baseline acoustic tracking techniques if the vehicle is operating in or above a compatible transponder net (as it typically will be). When in this mode, reception of an interrogation burst (10 msec of 9 kHz) will cause the vehicle to transmit (after a 5-msec turn-around delay) a 10-msec burst of 7 kHz to interrogate the transponder field. The location, response frequencies, turn-around delays, and lock-out times for transponders in the field will be provided if appropriate.

The likelihood of the vehicle being in any other navigation mode is very small. However, details of these modes will be provided if necessary.

It should be noted that the acoustic link transponder function will not be operational if the main vehicle power has been shut-off (as it should be if the vehicle computers think there is a potential battery problem). However, the acoustic transponder (III.e) will continue to function since it has its own power source to use when needed.

g. Acoustic-Tracking System

The shipboard acoustic-tracking systems for AUSS are a Sonatech NS–011 for long baseline and a Honeywell RS906 with both long baseline and short baseline acoustic-tracking capability. These systems have been set up to track the AUSS vehicle acoustic transponder, the synthesized acoustic transponder, or the synthesized AUSS vehicle pinger.

h. Automatic Flasher Beacon Light

The automatic flasher beacon light is a Novatech submersible flasher Model ST400A. This unit is activated by a pressure switch when the vehicle surfaces. If the nose float fails to deploy from the vehicle, the flasher beacon light may not be visible. Operating characteristics for the flasher beacon are shown in table A-1.

Table A-1. Flasher beacon characteristics.

Characteristics	Description
Depth Capability	24,000 feet
Luminous Intensity	35 candelas
Repetition Rate	40 flashes per minute
Operating Life	140 hours

i. Radio Transmitter

The radio transmitter is a Novatech Submersible VHF Beacon Model RF700A. This unit is activated at the surface when its antenna is no longer submerged. Operating characteristics for the radio transmitter are shown in table A-2.

Table A-2. Radio transmitter characteristics.

Characteristics	Description
Transmitter Power	200 mW rf
Frequency	160.785 MHz
Operating Life	10 days
Modulation	Pulsed CW
Depth Capability	24,000 feet

j. Radio Automatic Direction Finder (ADF)

The radio automatic direction finder is an OAR Model ADF–320. This unit is capable of direction finding on the vehicle-mounted pulsed radio transmitter. The radio direction finder can also be mounted in aircraft for air search. Operating characteristics for the radio direction finder are shown in table A-3.

Table A-3. Radio automatic direction finder characteristics.

Characteristics	Description
Directional Accuracy	3–5 degrees
Display	3-inch cathode ray tube on front panel with compass rose graduated in 5-degree increments. Line trace from center of Crt to edge indicates bearing to transmitter
Range	Line of sight or 3 nmi
Frequency Coverage	148–174 MHz
Maximum Air Speed	100 knots
Power Requirements	Unregulated 12 volts DC (10.5 to 14 volts) at 1.2 amps typical

IV. RESPONSIBILITIES AND CONTACTS

a. Support Craft Responsibility

The support craft will stay on station and attempt to track, communicate with, and recover the AUSS vehicle by any means possible during both normal and emergency search and recovery procedures. The support craft may leave the AUSS search area only when the search and recovery task (including tracking of the vehicle, if possible) has been taken over completely by another craft.

b. Test Director Responsibility

The test director shall stay on board the support craft to direct support craft involvement in search and recovery until such time that the responsibility for search and recovery is passed on to another craft. Members of the AUSS team and AUSS SAR equipment may be transferred to another craft as necessary.

The Test Director shall assure that appropriate personnel have been notified of an emergency search and recovery effort via radio, radio telephone, and/or cellular phone, and will take action to mobilize Navy assets to act as deterrents to foreign interception of the AUSS vehicle.

c. Emergency Contacts

In the event an emergency search and recovery effort is required, notification should be given immediately, with all known facts, to the following NOSC management in the order listed in table A-4.

Table A-4. Emergency notification.

Civilian:	NRaD Phone	Home Phone
Mr. J. M. Walton	553–1879	272–2340
Mr. M. W. Cooke	553–1881	447–9876
Mr. R. A. Marrone	553–1876	271–1043
Mr. N. B. Estabrook	553–1862	481–8153
Mr. I. P. Lemaire	553–3900	271–1178
Mr. John Freund	703–746–6096 (W)	703–521–4390 (H)
Mr. Allen Feller	703–746–6096 Cellular	202–484–1534 703–407–1855
Military:		
Operations Officer	553–4763	
NOSC Duty Officer (Night & weekends)	553–4621	

d. Candidate SAR Units for AUSS

Candidate SAR Units For AUSS are listed in table A-5.

Table A-5. Candidate SAR units for AUSS.

Vehicle	Capability	Contact	Depth (ft)
ATV	Tracking System compatible with AUSS. 6 TVs, 2 manipulators. Can attach recovery line. Limited search.	NOSC, Mr. Bob Watts (619) 553–1971 (W) (619) 259–7585 (H)	20,000
CURV–II	Forward-Scanning CTFM sonar, TV. 35-mm cameras. Can attach recovery line. Limited search.	NOSC, Mr. Bud Harmon (619) 553–3431 (W) (619) 566–5213 (H)	6,000
TURTLE	Forward-Scanning CTFM sonar, TV, 35-mm cameras. manned observation. Limited search. Can rig and attach recovery line.	CSDG–1 Operations (619) 553–7115, 7094 CDR Baccei	10,000
SEACLIFF	Forward-Scanning CTFM sonar, TV, 35-mm camera, manned observation. Limited search. Can rig and attach recovery line.	CSDG–1 Operations (619) 553–7115,7094 CDR Baccei	20,000

Table A-5. Candidate SAR units for AUSS (continued).

Vehicle	Capability	Contact	Depth (ft)
DSRV	Forward-Scanning CTFM sonar, TV. Manned observation. Can be fitted with Sidescan Sonar. Limited search. Can rig and attach recovery line.	CSDG–1 Operations (619) 553–7115,7094 CDR Baccei	5,000

V. SEARCH AND RECOVERY PROCEDURES

The various modes of search and recovery for AUSS are: (1) normal search and recovery; (2) search and recovery during "slow" ascent; (3) vehicle lost on the surface; (4) vehicle lost on the bottom and anchored; (5) vehicle lost on bottom and entangled; and (6) vehicle lost on the bottom, not anchored. The following procedures are presented as guidelines for location and recovery of the vehicle for the five cases given. These procedures assume the appropriate SAR gear is operational.

a. Normal Search and Recovery

The procedure outlined in table A-6 was developed by the AUSS crew during at-sea operations. It involves several levels of redundancies, and has proven satisfactory.

Table A-6. Normal search and recovery.

Step	Procedure
1	Command vehicle release through acoustic link
2	Time vehicle ascent using predetermined ascent-rate information to predict time of surfacing.
3	Position ship for underway recovery of vehicle using underwater acoustic-tracking system, and surface tracking.
4	Use OAR direction finder and lookout personnel to locate vehicle when unit surfaces.
5	Navigate ship for underway recovery of vehicle
6	Obtain vehicle nose float tether with grappling hook
7	Bring vehicle on board support craft via AUSS recovery ramp

b. Search and Recovery During Slow Ascent

Three cues to a slow ascent are (1) acoustic tracking of the vehicle ascent, (2) depth status updates through the AUSS acoustic link, (3) vehicle not on surface soon after precalculated ascent time. This case may occur due to a bottle flooding, an unknown buoyancy failure, or failure to release one or both ascent weights. Table A-7 describes the procedure that will be used if the vehicle is ascending slowly.

Table A-7. Search and recovery during slow ascent.

Step	Procedure
1	Determine ascent rate, if possible, using acoustic navigation system or acoustic link updates on depth status.
2	Take note of drift and glide to try to predict vehicle surfacing location in case acoustic communications are lost
3	Recover vehicle as in steps 3 through 7 of table A-6.

c. Search and Recovery, Vehicle Lost on Surface

If all information available to the AUSS team indicates that vehicle has surfaced, but the unit cannot be located visually or by direction finder from the surface support craft, the procedures of table A-8 will be carried out.

Table A-8. Search and recovery, vehicle lost on surface.

Step	Procedure
1	Check out OAR ADF receiver to assure operational status using spare transmitter unit
2	While conducting surface navigation search pattern, contact NOSC to initiate airborne or other search
3	Dispatch helicopter,surface, or fixed-wing craft for visual search. Use craft outfitted with appropriate ADF gear, or mount a compatible ADF unit on craft (see tables A-2 and A-3 for transmitter and receiver characteristics)
4	If possible, provide search craft with: a. Lat/long and identification of AUSS surface support craft. b. Radio frequencies and call signs for AUSS support craft c. Lat/long of predicted surfacing point for vehicle d. Time of predicted AUSS vehicle surfacing e. Predicted surface drift (used to determine support craft search pattern) f. Pictures of AUSS vehicle floating on the surface g. Pictures of surface support craft h. Copies of SAR plan
5	When located, AUSS vehicle may be brought on board AUSS support craft using normal recovery procedures.

d. Search and Recovery, Vehicle Lost on Bottom and Anchored

If all information available to the AUSS team indicates the vehicle is still on the bottom and cannot be released from the descent line, the procedures of table A-9 will be carried out.

Table A-9. Search and recovery, vehicle lost on bottom and anchored.

Step	Procedure
1	Attempt to release vehicle, torpedo float, and Sonatech transponder from 100 foot line and descent anchor by sending Sonatech release code to Sonatech transponder. This will require a swimmer when this equipment reaches the surface to separate the vehicle equipment from the descent equipment.
2	If #1 fails to return the AUSS vehicle to the surface, attempt to bring vehicle and the descent string to the surface by releasing the ascent weights on vehicle. This should render a net positive buoyancy for the vehicle and descent string of around 20 lb. This will require a swimmer to separate the vehicle equipment from the descent equipment when the vehicle reaches the surface. Note: The descent weight should be cut loose and dropped or brought on board prior to any further action.
3	After the descent string is separated from the vehicle and it is on the surface, bring the AUSS vehicle on board the support ship using a normal recovery.

e. Search and Recovery, Vehicle Lost on Bottom and Entangled

If all information available to the AUSS team indicates the vehicle is either entangled on the bottom or cannot be surfaced from or with the descent string as in d. above, the procedures of table A-10 will be used.

Table A-10. Search and recovery, vehicle lost on bottom and entangled.

Step	Procedure
1	Make emergency contacts
2	Request submersible (manned/unmanned) to investigate and free AUSS vehicle. Under most possible circumstances, a simple synthetic line cutter should be adequate to free the vehicle.
3	Provide submersible and its support craft with as many of the following items as is possible a. Lat/long and identification of AUSS support ship b. Call signs and radio frequencies for AUSS support ship c. Lat/long (best information) of vehicle on bottom d. Time and predicted glide for vehicle once released e. Pictures of AUSS in air f. Pictures of AUSS vehicle floating on the surface g. Copies of AUSS SAR plan h. OAR radio direction finder
4	When AUSS vehicle is on the surface, recover using normal recovery procedures on the AUSS support craft.

f. Search and Recovery, Vehicle Lost on Bottom not Anchored

If all information available to the AUSS team indicates the vehicle is free of entanglement and anchors, but cannot be surfaced, the procedures of table A-11 will be carried out.

Table A-11. Search and recovery, vehicle lost on bottom not anchored.

Step	Procedure
1	Make emergency contacts
2	Request submersible (manned/unmanned) to locate, investigate, and attach a lift line to the AUSS vehicle
3	Provide submersible and its support craft with as many of the following items as possible a. Lat/long of last known position for AUSS vehicle b. Lat/long and identification of AUSS support craft c. Radio frequencies and call signs for AUSS support craft d. Pictures of AUSS vehicle in air e. Pictures of AUSS vehicle floating on the surface f. Copies of AUSS SAR plan g. OAR radio direction finder
4	Bring AUSS vehicle to the surface and perform normal recovery with AUSS support craft.

VI. SEARCH AND RECOVERY PROCEDURES FOR EARS FISH

a. Search and Recovery, EARS on Bottom

If EARS is not located on the surface or if EARS is known to have descended to the bottom, the procedures of table A-12 will be carried out.

Table A-12. Search and recovery, EARS on bottom.

Step	Procedure
1	Make emergency contacts
2	Request submersible (manned/unmanned) to investigate and either free or attach lift line to EARS for recovery.
3	Provide submersible and its support craft with as many of the following as is possible
	a. Lat/long and identification of AUSS support ship
	b. Call signs and radio frequencies for AUSS support ship
	c. Lat/long (best information) of EARS on bottom
	d. Pictures of EARS in air
	e. Copies of AUSS SAR plan
4	Indicate that EARS equipment will implode in depths greater than 500 feet.

VII. EMERGENCY RECOVERY INFORMATION FOR AUSS AND EARS

a. AUSS Emergency Recovery Information

The AUSS vehicle is normally neutrally buoyant during dives. Its in-air weight is 2700 lb. If the main vehicle pressure hull is flooded, the approximate in-water weight would be 1500 lb, and approximate in-air weight would be 4200 lb.

The AUSS vehicle has two retracted lift eyes (designed to accept 1/2-inch (2 ton) shackle) on top which are bolted into the pressure hull end caps. These lift eyes are suitable for recovery. To obtain access to these lift eyes, a recovery vehicle must first depress these spring-loaded eyes into the vehicle until they bottom out (0.4 inch) then release them. (The action is identical to a ballpoint pen mechanism.) The implement used to depress the lift mechanisms should have dimensions no greater than 1.0 inch x 0.6 inch on the face that contacts the mechanism. In addition, the vehicle can be safely grasped around its cylindrical hull with lift straps. If the releasable nose float can be freed (information on release available from the AUSS test director), the polypropylene nose line can be used to raise the AUSS vehicle but not to lift it out of the water. The nose line may be used to pull the AUSS vehicle into the AUSS launcher.

b. EARS Emergency Recovery Information

EARS and its tow cable are both negatively buoyant. The in-air weight of EARS is 200 lb. If EARS is attached to its tow cable, it can be brought to the surface and brought on board with attachments to the tow cable. If EARS is parted from the tow cable, attachment to a cable at the tail of EARS may be made.

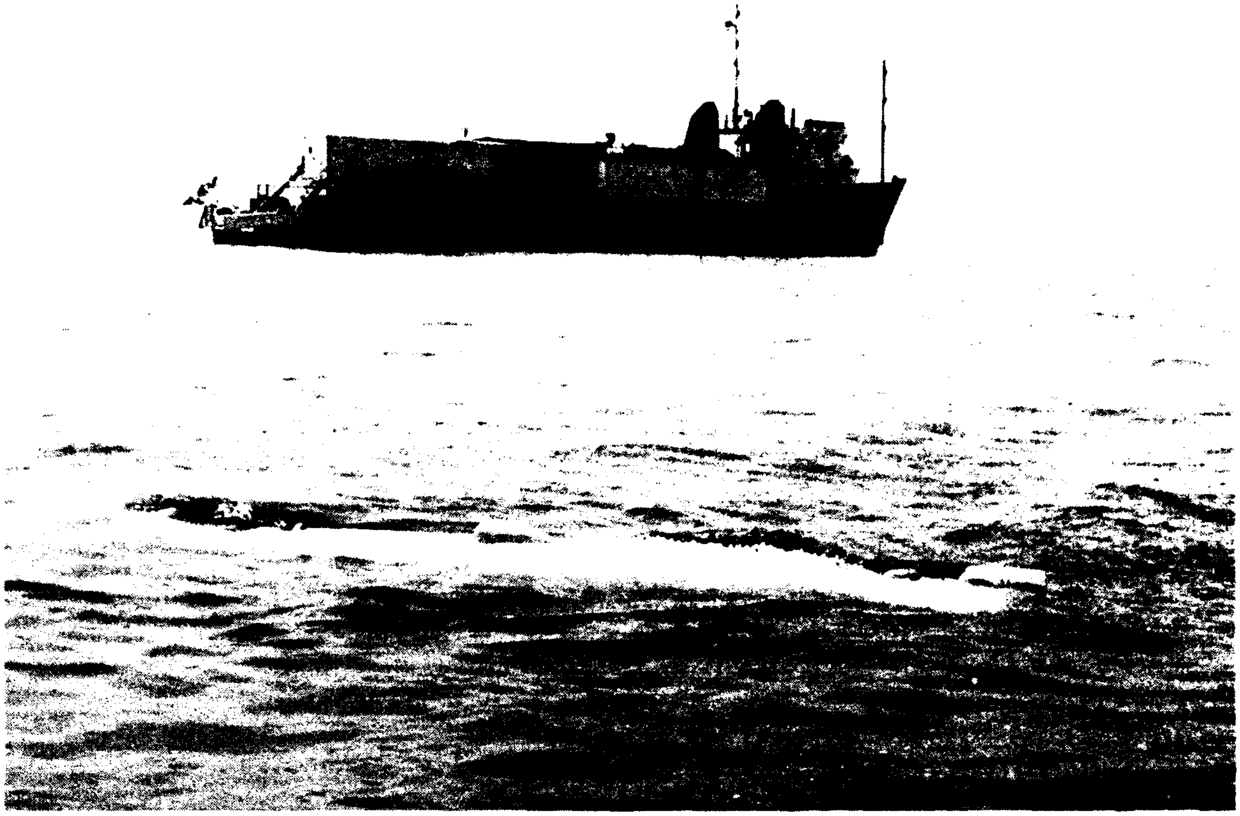


Figure A-1. AUSS vehicle and support craft (*MARSEA FIFTEEN*).

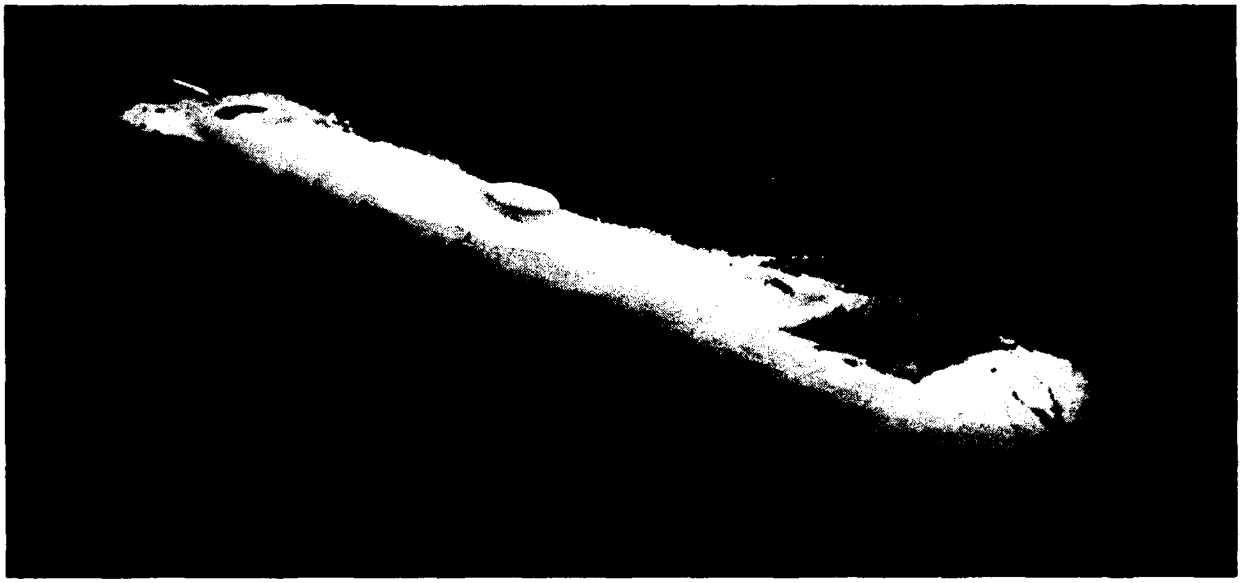


Figure A-2. AUSS vehicle on surface.

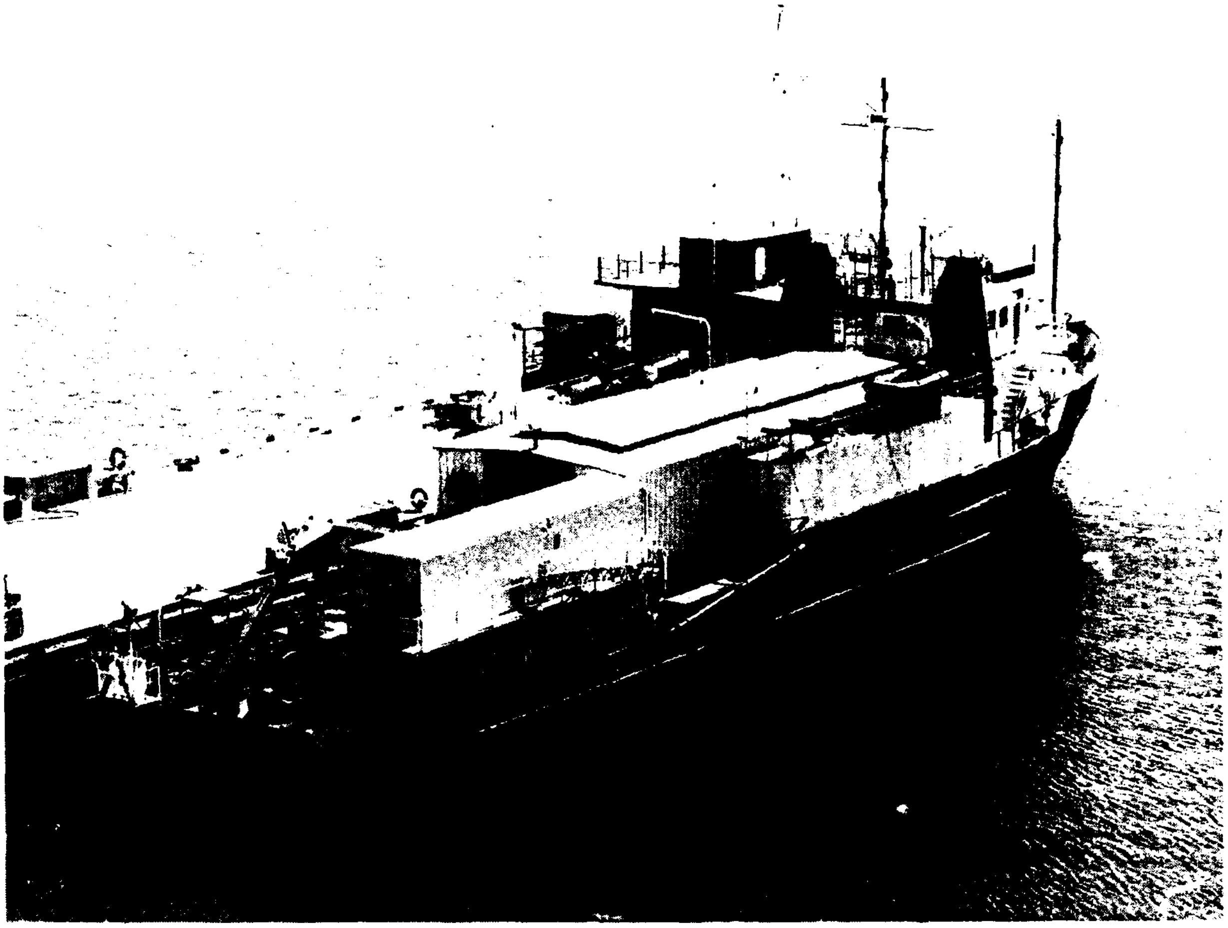


Figure A-3. *MARSEA FIFTEEN* at dock.

APPENDIX B

GENERAL DEVELOPMENT TEST DOCUMENTS

AUSS TEST PLAN SYNOPSIS

INTRODUCTION

The Advanced Unmanned Search System (AUSS) program will culminate in *delivery* of a complete deep-ocean search system to the Submarine Development Group One. This delivery system will significantly improve the reliability of and speed of search conducted by the Navy in water depths down to 20,000 feet.

The complete AUSS will be air transportable, and can be installed on ships of opportunity such as oceanographic and offshore supply ships. Deployment to operational status of AUSS to anywhere in the world will be accomplished in less than 5 days.

This test plan synopsis is meant to provide an outline of important autonomous underwater vehicle (AUV) technology to be tested and search demonstration testing planned for the AUSS. The primary test and demonstration is of an integrated autonomous untethered vehicle search system conducting supervisory-controlled search with immediate contact evaluation.

BACKGROUND

AUSS has been designed specifically to do search. The design has resulted from an exhaustive search systems analysis, tradeoffs, and subsystems testing.

The AUSS consists of an untethered vehicle, a launch and recovery ramp, a maintenance van (also used for transportation of the vehicle), and a control van.

A unique feature of the AUSS (critical to its efficiency in performing search) is its proven high-data rate acoustic link. This acoustic link is designed for vertical transmissions through the water, and handles the high-digital-data rate of 4800 bits per second (bps) required for the AUSS search mission. The acoustic link allows an operator in the control van and the untethered vehicle to communicate with each other in near-realtime. The vehicle performs search scenarios at high speed, and sends the search sensor data to the operator's display screen. The operator is able to interpret the sensor data during the mission, and "supervise" the activity of the vehicle.

This supervisory control of the vehicle allows AUSS to perform immediate contact evaluation in which contacts (sonar anomalies) made with the AUSS side-looking sonar (SLS) are immediately evaluated with the Charge-Coupled Device (CCD) television camera. Several SLS contacts and CCD contact evaluations can occur during a single dive.

On-board navigation of the AUSS vehicle is accomplished with an integrated Doppler/gyro compass system. This navigation system is used to autonomously follow SLS search patterns and CCD camera photomosaic search patterns. The on-board navigation system also allows the vehicle to autonomously "close" a target position and hover at that position for contact evaluation. A forward-looking sonar (FLS) in the nose of the vehicle is used to confirm relative positions of the vehicle and targets it pursues for contact evaluation.

TEST APPROACH

The success of the AUSS test program has been founded in stepwise lab, bay, and eventually sea testing of subsystems on the AUSS vehicle. After each step along the way, time is taken to integrate solutions to technical and operational problems determined during the previous step as well as integrating improvements to the system. This approach will continue as the program moves into the test phase program. The program involves testing of subsystems implemented as solutions to technical problems identified during previous testing. This test series will culminate in a deep-ocean demonstration of the AUSS capability to search and evaluate targets on the sea floor. The test phases are

Phase I will be navigation systems installation tests and dockside tests

Phase II will be local San Diego subsystem tests

Phase III will conclude subsystems tests. Phase III will also include complete subsystem integration tests and search demonstration tests

Phase IV is the shallow-water check-out prior to the deep-water test phase

Phase V is the deep water AUSS search demonstration

TEST PLANS

PHASE I (Navigation systems installation tests and dockside tests)

1. Install, integrate, and calibrate navigation systems at 2,500-foot and 12,000-foot deep test locations. Navigation systems to include 3-dimensional acoustic tracking, microwave (Mini-Ranger) tracking, Global Positioning System (GPS), and Loran C.
2. Trim and balance vehicle in water.
3. Verify motor controller/thrust characteristics. Develop static thrust curves.
4. Verify operation of descent weight drop system.
5. Verify operation of ascent weight drop and surface recovery float release systems.
6. Check in-water operation of search and recovery (SAR) equipment deployment mechanism. Determine operating range characteristics of SAR equipment.
7. Demonstrate in-water operation of on-board computer interfaces with sensors and effectors.
8. Simulate on-board systems failure scenarios to demonstrate emergency processor redundancy functions.
9. Simulate tracking failure and communication failure scenarios to demonstrate vehicle transponder redundancy functions.
10. Conduct preliminary on-board Doppler navigation characteristics tests.
11. Conduct limited vehicle control system tests and validate preliminary on-board vehicle dynamics model.

PHASE II (2,500-ft and 12,000-ft test locations)

1. Demonstrate improved launch and recovery ramp system.

2. Utilize and evaluate improved descent and ascent subsystems. Determine ascent and descent rates, and vehicle ascent/descent angles.

3. Determine effect of improved signal-to-noise and improved beamforming on performance of acoustic link system.

4. Validate vehicle hydrodynamic characteristics and determine maximum horizontal and vertical velocity vectors.

5. Finalize on-board vehicle dynamics model.

6. Conduct heading hold, depth hold, altitude hold, and simple dead-reckoning navigation tests.

7. Conduct autonomous line-follow algorithm tests (used in SLS and photomosaic search pattern runs). Note: This routine depends upon the AUSS rapid update, and high-resolution Doppler sonar.

8. Conduct autonomous "go to a point and hover with standoff" algorithm (used to perform contact evaluations with camera). Note: This routine depends upon the AUSS rapid update, high-resolution Doppler sonar.

9. Test CCD camera and strobe system. Transmit CCD images (uncompressed) to surface console display.

PHASE III (2,500-ft and 12,000-ft test locations)

1. Demonstrate obstacle alert and collision-avoidance system.

2. Test sonar and television data compression system. Determine compression ratios and quality of reconstructed images displayed.

3. Conduct complete search demonstration as follows:

    a. Search utilizing SLS in large autonomously run parallel track pattern in an area where targets have been deployed.

    b. Determine accuracy of vehicle on-board autonomous Doppler navigation at ends of search legs by fixing vehicle position with long baseline acoustic tracking system.

    c. During search legs, run vehicle at 5 knots, transmit compressed SLS images, and reconstruct images at operator console.

    d. Immediately upon detecting a promising anomaly in the sonar image, surface operator commands the vehicle to the position of the suspected target for evaluation.

    e. As vehicle moves towards the target, the forward-looking sonar (FLS) is used to confirm relative positions of vehicle and target.

    f. Vehicle autonomously moves into position of target(s), and hovers within a few feet of the position(s).

    g. Surface operator will request camera images from the vehicle as it hovers over target position. The CCD camera images are taken, compressed, and transmitted to the surface where they are reconstructed and displayed to the operator.

h. Operator will request the vehicle to reposition for CCD camera transmissions from different perspectives.

i. Operator will request vehicle change in altitude to receive closer or broader look at target as vehicle hovers over it.

j. As the vehicle hovers over the target, long baseline fixes on the vehicle will be collected to accurately determine the position of the target. (Note: In previous tests, the rms error on the mean position fixes taken in this fashion was 10 feet.)

k. When the target or target field is adequately inspected and documented, and good position fixes are determined, the operator will command the vehicle to autonomously return to the search track and continue its SLS large-area search.

l. A separate photomosaic search demonstration will be run over an area where targets have been located with SLS. The vehicle will autonomously run a parallel track pattern in the area. The pattern will be run with the vehicle 100 feet above the bottom while the CCD images are collected, compressed, and sent to the surface where they are reconstructed and displayed to the operator.

m. Data will be collected from which statistics will be developed to quantify search performance of AUSS during these demonstrations. Some statistics that will be developed are

(1) Search-area rate: the rate (nmi^2/hr) at which AUSS conducts the search including the contact evaluations. The search-area rate is the best indicator of **overall** system search performance. Due to the **combination** of realtime operator in the loop, immediate contact evaluation, high-speed search, and rapid turn times, AUSS excels over other search systems in search-area rate.

(2) SLS search-area rate: the rate (nm^2/hr) at which the SLS covers the search area (this does not include contact evaluation time). By utilizing data compression and reconstruction, AUSS will optimize SLS search-area rate because the vehicle advance speed will no longer be limited by the rate at which sonar images may be sent to the surface operator.

(3) Average contact evaluation time: average time it takes to evaluate a contact. A contact evaluation starts when the SLS search is interrupted (to perform a contact evaluation) and ends when the SLS search resumes. In the past, AUSS contact evaluations during a search demonstration averaged 1/2 hour in duration.

n. An on-board vehicle data recorder will record the raw sensor data for postmission playback. This raw sensor data will be used for comparison with compression-manipulated sensor data recorded at the surface in the AUSS data logger. The data recorder and the data logger are both digital storage devices.

PHASE IV (2,500-ft tests in preparation for deep-water tests)

1. Conduct rough-water launch and recovery operations. Upgrade or improve launch and recovery gear where necessary.

2. Operate all subsystems to assure equipment is ready for deep deployment.

3. Conduct simulated deep operations. Operator interaction with the vehicle will be artificially delayed by the predicted delay time of round-trip communications to 20,000 feet. Develop procedures to adjust for any difficulties or inaccuracies encountered with this delay.

PHASE V (Deep Operations at 19,000 feet in the Hawaiian Trough, north of the island of Hawaii and east of Maui)

1. Deploy underwater acoustic-tracking system. Survey tracking system and coordinate it with GPS tracking.

2. Deploy random field of targets to bottom of ocean.

3. Conduct complete deep-search demonstration. This demonstration outline is the same as the shallow demonstration of phase III.

LISTS OF AUSS TESTS TO BE CONDUCTED

PREDOCKSIDE LAB TESTS

a. Vehicle Electronics

(Jerry and Mike to ring out and check power and signal)

1. After endbell
2. Center section/after endbell interface
3. Forward endbell
4. Center section/forward endbell interface
5. Spider
6. Center section/spider interface
7. After wet wiring
8. Center section and after endbell/after wet wiring interface
9. Forward wet wiring
10. Center section and forward endbell/forward wet wiring interface

b. Vehicle Computers Interfaces

(Vehicle computer interfaces to be checked on vehicle center section card rack)

1. Sensor/Acoustic Link
2. Main/Sensor and Acoustic Link
3. Sensor/Acoustic Link with FLS sensor data
4. Data logger********

c. Surface/Vehicle Interfaces

1. CMD/Surface AL to Veh AL/Sensor/Main
2. Main/Sensor/Veh AL go Surface AL/CMD

d. Acoustic Equipment

(Specified frequencies will be measured on spectrum analyzer)

(Close-coupled acoustic sources and receivers will be used to communicate with the transducers in these in-air tests)

(These tests will be conducted with a complete vehicle and surface electronics connected by an "acoustic link" wire.)

1. Transmit and receive acoustic link data through snails.

2. Transmit and receive acoustic link data through acoustic link transducer.

3. In LBS nav mode (nav mode ***), interrogate acoustic link transducer with 9 kHz, measure time delay of 7-kHz response at stinger.

4. In SBS nav mode (nav mode ***), interrogate acoustic link transducer with 7,*,* kHz, measure time delay of *,*,* kHz responses at stinger.

5. Interrogate backup transponder at *** kHz and measure time delay of its output at 7 kHz.

e. Sensors

1. Command CCD camera/35-mm camera/strobes to operate from control console.

2. Receive transform and display both packed CCD images and compressed CCD images.

3. With FLS dome removed, operate the FLS and inspect the pan of the FLS head through the angular settings of ±15, ±30, ±45, and ±90 degrees. Measure angles, observe limits, and look for binding and interferences.

4. Use Doppler test set to simulate Doppler operation. Observe Doppler outputs at main computer and at the control console.

5. Use deadweight tester or calibrated gage and hydraulic hand pump to calibrate the pressure transducer through the complete AUSS. Read output as part of the status display.

6. Altimeter*****

f. Propulsion

1. Apply low-speed commands and observe the thruster rotation directions for the following: forward thrust, reverse thrust, forward/yaw port, forward/yaw starboard, yaw (pivot) port, yaw (pivot) starboard, transverse up, transverse down, increase depth, decrease depth, increase altitude, decrease altitude, pitch nose down, pitch nose up.

2. Observe the action of the elevators from the following commands: elevator up, elevator down, pitch up, pitch down, increase depth, decrease depth, increase altitude, decrease altitude.

g. Emergency Functions and Search And Recovery

1. Activate float release and observe ejection of float and erection of SAR gear set. Check for binding, any safety hazards, and suitability of spring constants.

2. Operate OAR receiver at a reasonable distance to DR on the transmitter.

3. Activate the weight releases (loaded with weights) with commands from the operator console.

4. Allow the weight releases to activate as a result of a lack of communication from the surface computer.

5. Simulate a main computer failure to activate the weight releases.

6. Simulate a low-battery voltage to first signal the operator of a low voltage, then activate the weight releases.

7. Simulate an emergency processor failure to activate the weight releases.

8. Command an activation of the weight releases through the backup acoustic transponder transducer.

9. Simulate a leak detect at all sections of the leak detector using water to activate the weight releases.

10. *Backup battery tests***

PHASE I DOCKSIDE TESTING

(Flight recorder required to obtain data)

(Communications will be made through a cable from a surface CMD computer and surface AL computer to the vehicle AL computer. This cable will be married to a strength member and floats)

a. Buoyancy and trim

1. Determine and add weight required such that vehicle (no SLS transducers) is very slightly positively buoyant.

2. Adjust pitch trim of vehicle by shifting batteries.

3. Record all of above for future modifications and adjustments (if required).

b. Weight shifter and ascent weights

1. Exercise weight shifter to determine pitch stability and cb–cg.

2. With weight shifter weight fully aft, drop one, then two nose weights and observe pitch angles obtained.

3. Pitch vehicle nose up to 90 degrees (by any combination of means), activate ascent weight release, and slowly decrease pitch angle to observe maximum angle at which nose weights will fall out of vehicle. If the weights are not free due to a single release command, repeat release commands while decreasing pitch angle.

4. With nose weights in place, pitch nose down using full excursion of the weight shifter. Record results.

5. Release nose weights with weight shifter weight fully forward (to see what will happen if weight shifter is stuck forward and we want to ascend).

c. Float release and SAR gear

1. Swimmer activate float release at surface. (ascent weights should be absent for this test).
2. Observe angle of antenna and strobe with respect to the water surface. Adjust later if necessary.
3. Operate OAR receiver from small boat or NOSC pier to DF on vehicle antenna.
4. Pull lines over antenna/strobe to check depression of mechanism and for potential catch points.
5. Drag vehicle away from float to check for easy payout of line.

d. Thruster tests

(Vehicle should be fully submerged for these tests)

1. Measure full thrust of both main thrusters on 100% with load cell, line, and pulley system.
2. Decrease thrust in 5% increments to develop static thrust curves.
3. Repeat steps 1 and 2 for reverse thrust.
4. Repeat steps 1 and 2 for vertical up thrust.
5. Repeat steps 1 and 2 for vertical down thrust.
6. With vehicle connected only to a "free" tether, provide a step function main forward thrust command for a few seconds and record the Doppler velocity.
7. Repeat step 6 for vertical up thrust.
8. Repeat step 6 for vertical down thrust.
9. Repeat step 6 for port and starboard yaw.
10. Repeat step 6 for pitch up and pitch down with vertical thrusters.

e. Control Functions

1. Perform heading hold at a variety of headings.
2. Operate in dynamic pitch trim.
3. Use depth hold to move to a variety of depths.
4. Use altitude hold to move to a variety of altitudes.
5. Using compass and time, perform a few short GO DR runs.
6. Observe outputs from Doppler during various GO DR runs.
7. Using compass and Doppler, perform a few short GO runs.

8. Combine some GO runs with Hover-at-a-Point routine.

9. Run short restrained versions of at-sea functions to assure they don't blow up (i.e., spiral descent, mosaic (if available) etc.).

f. Sensors

1. Operate forward-looking sonar (FLS). Obtain images of pilings etc. from a variety of angles throughout the 180-degree scan, and as much as possible, throughout the vertical extent of the beam. Look for distortion and interference resulting from the hemispherical dome or electronics.

2. Operate CCD camera. In low visibility, maintain altitude close to bottom, use ambient light. In high visibility, maintain higher altitude, use strobes, operate at night.

3. Transmit packed CCD images and reconstruct.

4. Transmit compressed images and reconstruct, if possible.

SHALLOW VEHICLE TESTS

a. Descent/Ascent (100 ft)

b. Emergency Functions (100 ft)

c. Control/Navigation

d. Acoustic Link/Tracking (2500-ft water, vehicle safety-lined to 100 ft)

PHASE II SEA TESTS

(First dive to 2500 feet will be untethered because we will be ready for an untethered dive before we go)

(Most of the phase II sea tests will be done in 2500 feet of seawater. If all goes well, transponders and targets will be deployed in 12,000 feet where a series of demonstrations similar to those done in 2500 feet will be conducted)

a. Launch and Recovery and Vehicle Handling Systems

1. Exercise handling system at sea. Determine improvements if any.

2. Exercise launch and recovery system at sea. Determine improvements if any.

3. For descent, exercise both descent weight, float, and transponder, **and** spiral descent routine.

4. For ascent, drop both weights, but on some bright calm days, ascend dropping only one weight, and ascend with trim weight in full forward position with both weights dropped.

5. Use new concepts for deployment of descent string and grabbing for float line.

b. Dynamics Tests

1. Perform heading hold at a variety of headings.

2. Operate in dynamic pitch trim.

3. Use depth hold to move to a variety of depths.

4. Use altitude hold to move to a variety of altitudes.

5. Using compass and time, perform a few short GO DR runs.

6. Observe outputs from Doppler during various GO DR runs.

7. Using compass and Doppler, perform a few short GO runs.

8. Combine some GO runs with Hover-at-a-Point routine.

9. Determine maximum speed forward, up, and down during speed runs using main and vertical thrusters.

10. Determine maximum yaw rate port and starboard.

11. Determine maximum pitch rate using vertical thrusters in step responses in both directions.

12. Conduct step response runs for forward speed change, heading change, pitch change, depth change (high and low speed), and altitude change.

13. Conduct runs to fill out matrix of accelerations resulting from changes in thrusts. The three independent variables are initial thrust, thrust change, and initial velocity. The dependent variable is acceleration. These matrices will be developed for both horizontal and vertical accelerations, and pitch, and yaw. These data are used to improve the accuracy of the vehicle model.

14. Conduct mosaics if available.

c. Sensors

1. Operate forward-looking sonar (FLS). Obtain images of targets from a variety of angles throughout the 180-degree scan, and as much as possible, throughout the vertical extent of the beam. Look for distortion and interference resulting from the hemispherical dome or electronics.

2. Transmit packed CCD images and reconstruct.

4. Transmit compressed images and reconstruct if possible.

d. Search Demonstrations

LABORATORY TESTS (PREDOCKSIDE AND PREPHASE I)

a. Surface Computers Hardware

1. Verify CMD (operator command console computer) dedicated console keyboard is compatible with all required user inputs
2. Exercise control of surface acoustic link by CMD
3. Demonstrate communications between CMD and surface acoustic link (AL)
4. Send vehicle depth information from CMD to NAV and observe appropriate values on display at Honeywell/Seatrac**available sometime during dockside**
5. Demonstrate various boot/reboot modes in surface computers (no user login)
    a. All from Ethernet dedicated file server
    b. CMD from fast ROM or RAM disk (measure time to reboot)*40 sec as of 3–30–90*
    c. NAV from hard or floppy disk
    d. Measure times for reboots for all computers and boot modes
6. Verify operation of all nondedicated display interfaces
    a. Image Display #1—any of three different images from IMG computer
    b. Image Display #2—any of three different images from IMG computer
    c. Image Display #3—any of three different images from IMG computer
    d. VCR monitors—must accept any of three different images: (1) from IMG computer, (2) data logger image, or (3) CMD status display
    e. Nondedicated (switchable) display monitor—must accept any of three different images: (1) from IMG computer, (2) data logger image, or (3) CMD status display

b. Verify CMD Processor

1. Displays all command menus
2. Assembles all AUSS vehicle commands
3. Reflects commands entered in the queue status indicator
4. Sends all commands to the vehicle via the acoustic link
5. Verifies vehicle status information is displayed in appropriate locations on formatted display
6. Verifies error messages are correctly displayed
7. Uses FRD command to request flight recorder data and verifies data displayed reflects the conditions set in vehicle software. Verifies FRD format
8. Verifies current vehicle sensor messages are correctly displayed
9. Verifies all uplink and downlink sensor data are relayed to the IMG processor from the CMD via RS–232 serial link

c. Verify IMG Processor

(Sensors are CCD camera, FLS, starboard SLS, port SLS)

1. Unpacks image data from all sensors and displays it on any of the three image displays
2. Decompresses image data from all sensors (except FLS) and displays it on any of the 3-image displays
3. Portions of images can be zoomed at any image display
4. Pseudocolor or grey scale can be designated independently at the 3-image displays
5. Automatic or custom linear contrast enhancement can be performed independently on any image display
6. All ASCII information from CMD is relayed to the LOG processor
7. Any images can be stored on command in files on the network server disk

d. Verify "interim" Log Processor

1. Records all uplink and downlink ASCII data from IMG on server disk
2. Records all NAV data from NAV processor on server disk
3. Recalls and displays any image stored by the IMG
4. Plots flight recorder data on CRT and or navigation plotter
5. Plots realtime or recorded vehicle Doppler position
6. Plots realtime or recorded sensor image area coverage

e. Vehicle Electronics

(Jerry and Mike R. to ring out and check power and signal)

1. After endbell
2. Center section/after endbell interface
3. Forward endbell
4. Center section/forward endbell interface
5. Spider
6. Center section/spider interface
7. After wet wiring
8. Center section and aft endbell/after wet wiring interface
9. Forward wet wiring
10. Center section and forward endbell/forward wet wiring interface
11. Test GFI with built-in test feature

12. Determine emergency battery endurance under load (gyro, emergency processor, and backup transponder)

13. Fully discharge/recharge emergency battery

14. Measure current draw for system with

    a. CCD on/off

    b. CCD thermal cooler on/off

    c. Doppler on/off

    d. Compass on/off

    e. Nav computer on/off

    f. All vehicle subsystems on

15. While conducting 14 above, make electrical noise measurements at all sensor preamps and the acoustic link preamp

f. Vehicle Computers Interfaces

(Vehicle computer interfaces to be checked on vehicle center section card rack)

1. Sensor/Acoustic Link

2. Main/Sensor and Acoustic Link

3. *Sensor/Acoustic Link with* FLS sensor data

4. Data logger********

5. Show that if the EP/center bit buss fails, message is sent to the surface console

6. Show that if after bit buss fails, message is sent to the surface

7. Show that if the main computer goes down, the EP resets it**not done as of 3–31–90****

8. Show that if the sensor computer goes down, the main computer resets it***not done as of 3–31–90***********9–11 below to be implememted before dockside when software prom control implemented in sensor computer*************

9. Show that if the acoustic link computer goes down, the sensor computer resets it

10. Show that if the image manipulation computer goes down, the sensor computer resets it

11. Show that if the digital signal processor goes down, the sensor computer resets it

g. Acoustic Equipment

(Specified frequencies will be measured on spectrum analyzer)

(Close-coupled acoustic sources and receivers will be used to communicate with the transducers in these in-air tests)

(These tests will be conducted with a complete vehicle and surface electronics connected by an "acoustic link" wire)

1. Check power output and thermal load of sonar and acoustic link power amps and preamps (in place in the vehicle) while hooked up to dummy loads. Assure that signals are amplified at right levels

2. Transmit acoustic link data through close-coupled source at acoustic link transducer and verify signal presence at acoustic link receiver

3. Transmit and receive acoustic link data through snails

4. Upon power up, check acoustic link default values*****Walton to get with Osborne,Mackelburg,McCracken,Watson,Held to decide values*****

5. Check operation of acoustic link noise monitor and try to determine noise floor value (noise monitor is DC equivalent of RMS noise on acoustic link channel)*****need before dockside tests start*****

6. Transmit and receive acoustic link data in async mode (receiver locks to 11.33-kHz sync provided by surface/vehicle source-Doppler correction not possible in this mode)

7. Transmit and receive acoustic link data in sync mode (receiver locks to 11.33-kHz sync provided in acoustic link transmission-Doppler correction possible in this mode)

8. Test Doppler corrector. Record acoustic link transmission on tape recorder at one speed, play back transmissions into acoustic link receiver at other speeds. Do this for both uplink and downlink

9. Command tone reset (20-sec long 9 kHz), and observe cold boot of all vehicle computers

10. Test dual (redundant) and independent acoustic link transmissions at 1200 and 2400 bps per sideband channel

11. In LBS (fish cycle) nav mode, interrogate acoustic link transducer with 9 kHz, measure time delay of the 7 kHz response at stinger***stinger amplifier no–existent as of 3–20–90**

13. In SBS nav mode, interrogate acoustic link transducer with 7 kHz, measure time delay of 7,10,*,*,*** kHz responses at stinger (if not possible with close coupled transducers, measure by injecting 7 kHz electronically and measuring responses electronically).

14. Interrogate backup transponder at 9,11 kHz and verify its outputs at 11,11.5,12,12.5,13,13.5 kHz. (frequencies are selectable by a switch internal to the unit)

h. Sensors

1. Command CCD camera/35-mm camera/ strobes to operate from control console. To determine camera shutter/ strobe sync, construct test setup that allows strobes to illuminate all or part of CCD/35-mm fields of view in a dark room (at night?), command a CCD/35-mm/strobe picture command, and investigate illumination.

2. Receive transform and display both packed CCD images and compressed CCD images (do with canned data, and then actual image data when possible)

3. Command picture series. Verify shutter cycles at appropriate times.***no TV operations commands are in system as of 3–31-90******

4. With FLS dome removed, operate the FLS and inspect the pan of the FLS head through the angular settings of ±15, ±30, ±45,and ±90 degrees. Measure angles, observe limits, and look for binding and interferences

5. Check operation of FLS, SLS by using a close–coupled transducer hooked to a transponder circuit, which transponds at same frequency as FLS, SLS output.***this will not be possible until the end of April******

6. Measure for appropriate gains in sonar circuits by injecting signals at transducer input locations and measuring outputs

i. Propulsion

1. Apply **momentary** low-speed commands and observe the thruster rotation directions for the following: forward thrust, reverse thrust, forward/yaw port, forward/yaw starboard, yaw (pivot) port, yaw (pivot) starboard, transverse up, transverse down, increase depth, decrease depth, increase altitude, decrease altitude, pitch nose down, pitch nose up

2. Observe the action of the elevators from the following commands: elevator up, elevator down, pitch up, pitch down, increase depth, and decrease altitude

j. Emergency Functions and Search and Recovery

1. Manually release float and observe ejection of float and erection of SAR gear set. Check for binding, any safety hazards, and suitability of spring constants

2. Operate OAR receiver at a reasonable distance to DR on the transmitter

3. Activate the weight releases (loaded with weights) with commands from the operator console

4. Allow the weight releases to activate as a result of a lack of communication from the surface computer (main computer initiates releases)

5. Demonstrate that the EP will activate the weight releases if the main computer fails to reboot

6. Simulate low-battery voltages to first signal the operator of a low voltage, then activate the weight releases (demonstrate release will activate from either the main or EP)

7. Simulate a low-weight-release capacitor voltage at each of the weight release capacitors to activate the weight releases (demonstrate releases will activate from either the main or EP)

8. Command an activation of the weight releases through the backup acoustic transponder transducer

9. Simulate a leak detect at all sections of the leak detector using water to activate the weight releases (demonstrate releases will activate from either the main or EP)

10. Simulate a low-emergency-battery voltage to activate the weight releases (demonstrate releases will activate from either the main or EP)

11. *backup battery tests***

k. Navigation Equipment

1. Mechanically align the vehicle compass on center line of vehicle

2. Swing compass (technique not identified yet). Any help here Rick Marrone?

3. With vehicle level (use accurate level to measure), adjust pitch and roll pendulometers for zero indicated pitch and roll at console and at the flight recorder

4. Pitch vehicle to two measured pitch angles (one nose down, one nose up) and calibrate output of pitch pendulometer indicated at the console and at the flight recorder

5. In conjunction with 3 above, command vehicle to statically trim and assure that the weight shifter moves in the proper direction for nose down and nose up cases

6. Roll vehicle in stand to two measured-roll angles (one to port, one to starboard) and calibrate output of roll pendulometer indicated at the control console and at the flight recorder

7. Check yaw rate sensor: Hang vehicle from overhead crane. Spin vehicle on axis and record yaw rate and heading in flight recorder. Use rate of change of compass heading values to verify flight recorder values for yaw rate

8. Check pitch rate sensor: Hang vehicle from overhead crane. Pitch vehicle on axis and record pitch rate and pitch in flight recorder. Use rate of change of pitch pendulometer values to verify flight recorder values for yaw rate

9. Use Doppler test set to simulate Doppler operation. Observe Doppler outputs at main computer and at the control console

10. Doppler altimeter

Ver 2, 1 MAY 90
JMW

PHASE I DOCKSIDE TESTING

(Flight recorder required to obtain data)

(Preliminary communications will be made through a cable from a surface laptop computer directly to Howard's main vehicle computer. This cable will be married to a strength member and floats)

(Later tests will require utilization of the same umbilical wire to simulate the acoustic link channel)

(To be staged from Scripps Marine Facility where the water depth will be from 15–20 feet deep)

a. Weight, Buoyancy, and Trim

1. Vehicle Weight

Lift vehicle with digital load cell in lift rig. Record overall vehicle weight.

2. Net Buoyancy

Add 100 lb (water weight) to vehicle and lower all into water with load cell in lift rig. Let soak, record in-water weight of all.

3. Pitch Trim

Using results of 2. above, determine weight required to render vehicle slightly positively buoyant. Place this amount in bag hanging from a sling around vehicle, and slide fore or aft until vehicle is pitch-trimmed. Remove vehicle from water to adjust batteries in hull and/or add weights to trim the vehicle. Record all of above for future modifications and adjustments.

b. Weight Shifter, Descent Weight Release, and Ascent Weights

1. Weight Shifter

a. Exercise weight shifter to determine pitch stability and cb–cg.

b. With ascent weights in place, pitch nose down using full excursion of the weight shifter. Record result.

2. Ascent Weight Release

With weight shifter weight fully aft, drop one, then two ascent weights and observe pitch angles obtained.

3. Descent Weight Release

With ascent weights absent and weight shifter weight still fully aft, attach line from descent weight release eye to weight on bottom and haul vehicle down until fully submerged. Record angle. Activate descent weight release. If eye does not release, reset release and try lesser pitch angles.

4. Emergency Ascent Weight Release Cases

a. Pitch vehicle nose down to 90 degrees (by any combination of means), activate ascent weight release, and slowly decrease pitch angle to observe maximum angle at which ascent weights will fall out of vehicle. If the weights are not free due to a single release command repeat release commands while decreasing pitch angle.

b. Release ascent weights with weight shifter weight fully forward (to see what will happen if weight shifter is stuck forward and we want to ascend.)

c. Float Release and SAR Gear.

1. Float Release

Swimmer activate float release at surface. (ascent weights should be absent for this test).

2. SAR Gear Erection

Observe angle of antenna and strobe with respect to the water surface. Adjust later if necessary.

3. Radio Direction Finding

Operate OAR receiver from small boat to DF on vehicle antenna. Find range limitation in this configuration. Continue this test while splashing water on antenna, and submerging vehicle to just below the antenna base.

4. Potential Fouling of SAR Equipment

Pull lines over antenna/strobe to check depression of mechanism and for potential catch points.

5. Float Line Payout

Drag vehicle away from float to check for easy payout of line.

d. Thruster Tests

(Vehicle should be fully submerged for these tests)

(Record AL noise on flight recorder during these tests)

1. Main Thrusters

a. Measure full thrust of both main thrusters on 100% with load cell, line, and pulley system.

b. Decrease thrust in 10% increments to develop static thrust curves.

c. Repeat steps 1 and 2 for reverse thrust.

2. Vertical Thrusters

a. Repeat steps 1a and 1b for vertical up thrust.

b. Repeat steps 1c for vertical down thrust.

3. Doppler Velocity And Main Thruster Step Functions

a. With vehicle connected only to a "free" tether, provide a step function main forward thrust command for a few seconds and record the Doppler velocity.

b. Repeat step 3a for port and starboard yaw.

4. Vertical Thruster Pitch Tests

a. With vehicle connected only to a "free" tether, command the vehicle to pitch up (vertical thruster step function burst).

b. With vehicle connected only to a "free" tether, command the vehicle to pitch down (vertical thruster step function burst).

5. Vertical Thruster Step Functions

a. With vehicle connected only to a "free" tether, provide a step function vertical thrust down command for a few seconds.

b. With vehicle connected only to a "free" tether, provide a step function vertical thrust up command for a few seconds.

6. Static Rudder Position Adjustment

Thrust vehicle forward with both 100% port and starboard thrust. Adjust static rudder position to determine adjustment sensitivity. Set for straight line running at end of test.

e. Control Functions

1. Heading Hold

Perform heading hold at a variety of headings.

2. Dynamic Pitch Trim

Operate in dynamic pitch trim.

3. Depth Readout

a. Verify console depth readout and flight recorder depth are zero with vehicle on surface.

b. Verify console depth readout and flight recorder depth are 15 feet at 15 feet of depth.

4. Altitude Readout

Verify console altitude readout and flight recorder altitude are 15 feet when the vehicle is 15 feet off the bottom.

5. Depth Hold

Use depth hold to move to a variety of depths.

6. Altitude Hold

Use altitude hold to move to a variety of altitudes.

7. GO DR Runs

Using compass and time, perform a few short GO DR runs, observe outputs from Doppler during various GO DR runs.

8. GO Runs

Using compass and Doppler, perform a few short GO runs.

9. Hover-at-a-Point

Combine some GO runs with Hover-at-a-Point routine.

10. At-sea Functions Integrity

Run short restrained versions of at-sea functions to assure they don't blow up (i.e., spiral descent, mosaic (if available) etc.).

f. Sensors

1. Forward-Looking Sonar

Operate forward-looking sonar (FLS). Obtain images of pilings etc. from a variety of angles throughout the 180-degree scan, and as much as possible, *throughout the vertical extent of the* beam. Look for distortion and interference resulting from the hemispherical dome, or electronics.

2. CCD Camera

a. Operate CCD camera. In low visibility, maintain altitude close to bottom, use ambient light. In high visibility, maintain higher altitude, use strobes, operate at night.

b. Transmit packed CCD images and reconstruct.

c. Transmit compressed images and reconstruct if possible.

g. Acoustics

1. Noise Floor

Measure noise floor on acoustic link noise monitor with all vehicle thrusters and acoustic devices off.

2. Acoustic Link Noise Monitor

a. Measure noise on acoustic link noise monitor with main thrusters on 100% (during D. Thruster Tests).

b. Measure noise on acoustic link noise monitor with indivi [illegible] oustic devices on (FLS, SLSs, Doppler).

c. Reset range of acoustic link noise monitor if necessary.

APPENDIX C

PREREQUISITE DEVELOPMENT TESTING PLANS

JMW
Ser 941/ –
20 July 1990

MEMORANDUM

From: Jim Walton, Code 941

To: AUSS team

Subj: Dockside Vehicle Control Systems Test Plan

Encl: (1) Dockside Control Test Plan

1. The objectives of the next dockside test will be to evaluate the performance of the vehicle operating in the various hover control modes, and gather information critical to adjusting the software used in the hover modes if necessary.

2. Enclosure (1) is the test plan for these tests.

JIM WALTON

copy to:
94 (information only)
941
941 (Cooke, Held, Jones, Kono, Osborne, Rutkowski, Tallerino, Uhrich, Walton, file)
943 (Watson, McCracken, Mackelburg)

DOCKSIDE CONTROL TEST PLAN

1. **Trim Vehicle**

   a. Hang bags below after thruster and forward camera mount

   b. Launch vehicle and have divers fill bags with weights until vehicle is near neutral and trim.

   c. Remove vehicle from water to move the weights inside of vehicle fairings.

2. **Doppler and Heading drift**

   a. Launch vehicle and leave attached to crane

   b. Observe Doppler N/S position readout for 5-min flight

3. **Doppler N/S Position Output While Underway**

   a. Disconnect from crane

   b. Pull vehicle with lines on approx N course thru measured distance

   c. Pull vehicle with lines on approx S course thru measured distance

4. **Hover Heading Control**

   a. Read vehicle heading and initiate heading hold at that heading

   b. Command vehicle to step to heading 90 degrees < present heading

   c. Command vehicle to step to heading 181 degrees > present

   d. Command vehicle to step to heading 179 degrees > present

5. **Hover Depth Control**

   a. Command vehicle to hold depth 3 ft under surface

   b. Command vehicle to hold at a depth approx 5 ft above bottom

   c. Command vehicle to hold depth 3 ft under surface

6. **Hover Altitude Control**

   a. Command vehicle to hold altitude at present altitude

   b. Command vehicle to hold altitude 5 ft from bottom

   c. Command vehicle to hold an altitude approx 3 ft under surface

7. **Hover Pitch Control (vehicle at surface)**

   a. Command vehicle to hold 0-degree pitch

   b. Command vehicle to hold +10-degree pitch

   c. Command vehicle to hold –10-degree pitch

8. Hover Pitch/Depth Control

a. Command vehicle to 3-ft depth

b. Command vehicle to hold 0-degree pitch

c. Command vehicle to hold +10-degree pitch

d. Command vehicle to hold –10-degree pitch

9. Hover Pitch Control/Altitude Control

a. Command vehicle to hold at an altitude 3 ft under surface

b. Command vehicle to hold 0-degree pitch

c. Command vehicle to hold +10-degree pitch

d. Command vehicle to hold –10-degree pitch

10. Hover At A Radius From a Point (direct Doppler driven)

(vehicle at surface)

a. Command vehicle to hover wrt point x ft (start with x=10 ft) ahead of it.

b. Command vehicle to hover wrt point y ft (start with y=20 ft) away and at 90 degree relative heading

11. Hover At A Radius From a Point (Doppler–updated estimator driven)

(vehicle at surface)

a. Command vehicle to hover wrt point x ft (start with x=10 ft) ahead of it.

b. Command vehicle to hover wrt point y ft (start with y=20 ft) away and at 90 degree relative heading

12. Static Pitch Trim

a. Run trim weight to after stop and record vehicle pitch angle

b. Run trim weight to forward stop and record vehicle pitch angle

JMW
7-24-90

AUSS TRACKING SYSTEMS TEST

OBJECTIVES

1. To conduct a "shake down" cruise for the *MARSEA FIFTEEN* with AUSS/ATV installations.

2. To provide *MARSEA FIFTEEN* crew training on typical AUSS cruise.

3. To test handling, deployment, operation, and recovery of transducer pole with both ATV and AUSS tracking transponders installed.

4. To test handling, deployment, operation, and recovery of AUSS EARS batfish.

5. To determine if all of the AUSS bottom transponders deployed in OPAREA 37-03 are operational.

6. To test the Honeywell RS906 tracking system in the long baseline (LBS) and the short baseline (SBS) mode.

7. To test the NS-011/Thorn tracking system realtime in LBS mode integrated with GPS.

8. To test the SeaTrac integrated navigation system integrating LBS and GPS tracking of the ship and SBS tracking of bottom-installed transponders.

9. To test the operation of the batfish tracking LBS while moving at high speeds.

PROCEDURES

1. Transit To Station

Sail to center of net, approximately lat 32° 58′ N, long 117° 31′ N. Head into seas for deployment of transducer gear.

2. Transducer Pole

Deploy transducer pole and secure while maintaining slight headway into seas.

3. Batfish

Deploy batfish (ship must be underway for deployment, and must maintain headway as long as batfish is deployed).

4. Turn On Transponder Field

Continue heading into seas at minimum headway as turn-on codes are applied to ocean-bottom transponders.

5. LBS Tracking Experiments

As soon as transponders are on and responding, conduct LBS tracking experiments as described below:

ENCLOSURE (1)

a. LBS tracking of ship with batfish using Honeywell system.

b. LBS tracking of ship with pole and NS–11/Thorn system.

6. SBS Tracking Experiments

During LBS experiments, conduct SBS experiments as described below:

a. SBS tracking of bottom-mounted transponders with interrogations initiated at the batfish, transponds received at pole-mounted Honeywell array.

b. SBS tracking of bottom-mounted transponders with interrogation initiated at ATV transducer on pole (from NS–11) and transponds received at transducer pole-mounted Honeywell array.

7. Acoustic Coverage Experiments

Continue 5 and 6 above while running patterns defined by Tracking system operators via van-to-bridge communications. These will typically include transponder field center crossings, and maximum coverage experiments where the ship will be required to run "boxes" up to 300 feet outside the box defined by the bottom transponder field.

8. Speed Tests

If time permits, operate with batfish deployed and transducer pole recovered. Conduct speed runs up to 6 knots and evaluate LBS operation and coverage at high speed.

JMW
Ser 941/–
31 July 1990

MEMORANDUM

From: Jim Walton, Code 941

To: AUSS team

Subj: Launch, Recovery, and SAR tests plan

Encl: (1) Launch, Recovery, and SAR Test Plan

1. Enclosure (1) is the test plan for AUSS launch, recovery and surface search and recovery.

JIM WALTON

copy to:
94 (information only)
941
941 (Cooke, Held, Jones, Kono, Osborne, Rutkowski, Tallerino, Uhrich, Walton, file)
943 (Watson, McCracken, Mackelburg)

7–26–90

LAUNCH, RECOVERY, AND SAR TESTS PLAN

OBJECTIVES

1. To provide crew and AUSS team training in AUSS launch and recovery process.

2. To test operation of AUSS launch and recovery system, and determine improvements and adjustments to be made to it.

3. To determine maximum range of AUSS radio beacon ADF SAR gear. Novatech beacon on AUSS, Ocean Applied Research, Inc. (OAR) receiver.

4. To define any "holes" in the transmit beam pattern of the Novatech RF transmitter on AUSS.

5. To define any shadowing by the ship or "holes" in the receive beam pattern at the OAR RF receiver.

6. To determine what effects, if any, a partially submerged rf beacon will have on direction-finding capability.

PROCEDURES

At the dock on the day before at-sea testing

1. Insert ascent weights, but do not latch into release mechanism. Tie ascent weights in place with line around vehicle through eyes at bottom of weights.

2. Lift vehicle into bay and trim.

3. Manually release and recover ascent weights while AUSS vehicle is in the water.

4. Haul AUSS vehicle into launcher.

4. Make necessary adjustments to launcher equipment.

5. Release SAR gear and float in launcher, tape float into place to be released later by small boat.

At–sea

1. Steam to southern extreme of operations area (lat 32° 32′ N, long 117° 12′ W) and head ship into seas.

2. Launch small rubber boat with NOSC driver, NOSC frequency packset radio, and two AUSS team members on board. One AUSS team member must be dressed out as a swimmer.

3. Overboard launcher (with AUSS in it) and observe any potential interferences.

4. Continue to maintain ship's headway into the seas, adjust speed per test director's needs while AUSS team observes launcher performance.

ENCLOSURE (1)

5. Release AUSS from launcher.

6. Recover launcher.

7. Bring ship around and pass near vehicle. Note GPS positon of vehicle and time.

8. Head "North" with ship toward *****Lat,***Long while personel in small boat attach safety line to vehicle, release float and erect SAR gear.

9. Continue on specified northerly heading while observing performance of OAR ADF receiver.

10. When maximum apparent range of OAR receiver is reached, transit back toward vehicle until reliable ADF operation is observed and rotate ship to identify any "holes" or shadowing.

11. Turn ship into seas and maintain position.

12. Have small boat rotate AUSS vehicle 360 degrees, reporting over the radio when they start rotation, and when they complete rotation. Observe operation of OAR receiver, and note time of any discrepancies in performance.

13. Have swimmer from small boat sit on nose of AUSS vehicle such that vehicle submerges until Novatech antenna is wet. Note performance of ADF receiver at ship.

14. If performance of receiver is degraded in 12 above, have ship close in on vehicle until performance is reliable.

15. Have ship close in on vehicle/small boat position while small boat crew pulls float out and away from vehicle.

16. Have small boat clear away from vehicle while ship moves into vehicle grappling position. Note GPS position and time.

17. Grapple vehicle float line, and head ship at slow speed into seas for recovery (Use trolling gears if available).

18. Recover AUSS.

19. Recover small boat personel and small boat.

20. Return to NOSC.

JMW
Ser 941/–
16 August 1990

MEMORANDUM

From: Jim Walton, Code 941

To: AUSS team

Subj: AUSS 500-foot Deep Test Plan

Encl: (1) AUSS 500-foot Deep Test Plan

1. Enclosure (1) is the test plan for AUSS 500-foot deep test.

JIM WALTON

copy to:
94 (information only)
941
941 (Cooke, Held, Jones, Kono, Osborne, Rutkowski, Tallerino, Uhrich, Walton, file)
943 (Watson, McCracken, Mackelburg)

JMW
8–16–90

AUSS 500-FOOT DEEP TEST PLAN

OBJECTIVES

1. To evaluate the performance and dependability of the acoustic link system (in the 500-foot geometry).

2. To evaluate the performance and dependability of two different tracking systems tracking the AUSS vehicle in long baseline fish cycle mode (in the 500-foot geometry).

3. To define improvements and adjustments necessary in the acoustic link and the fish cycle systems prior to conducting vehicle dives to 2500 feet.

4. To track the vehicle in ultrashort baseline using the vehicle transponder (yellow banana).

5. To experiment with passive tracking of the AUSS vehicle at the surface ship.

6. To obtain underwater CCD images of the descent weight.

7. To command (via the acoustic link) the release of the descent weight.

8. To command (via the acoustic link) the release of the ascent weights.

9. To record and recover from the flight recorder the pitch angles during ascent.

10. To record and recover from the flight recorder the rates of ascent from the depth transducer during ascent.

11. To observe the result of the nose float release during ascent.

12. To perform a normal AUSS vehicle launch and recovery with the upgraded launcher, including improvements since the last dive.

PROCEDURES

Refer to figure C-1 for final in-water rig.

Dockside

1. Close vehicle using prelaunch checklist. Leave the compass off.

2. Shift weight shifter weight to center of its travel.

3. Launch vehicle and trim with lead weights.

4. Remove nose float and tie it (or equivalent flotation) into styrofoam cup locker

5. Haul recovery line up launcher, and engage vehicle with docking cart. Make adjustments to cart catch if necessary.

6. Recover vehicle into ramp, observing performance of winch.

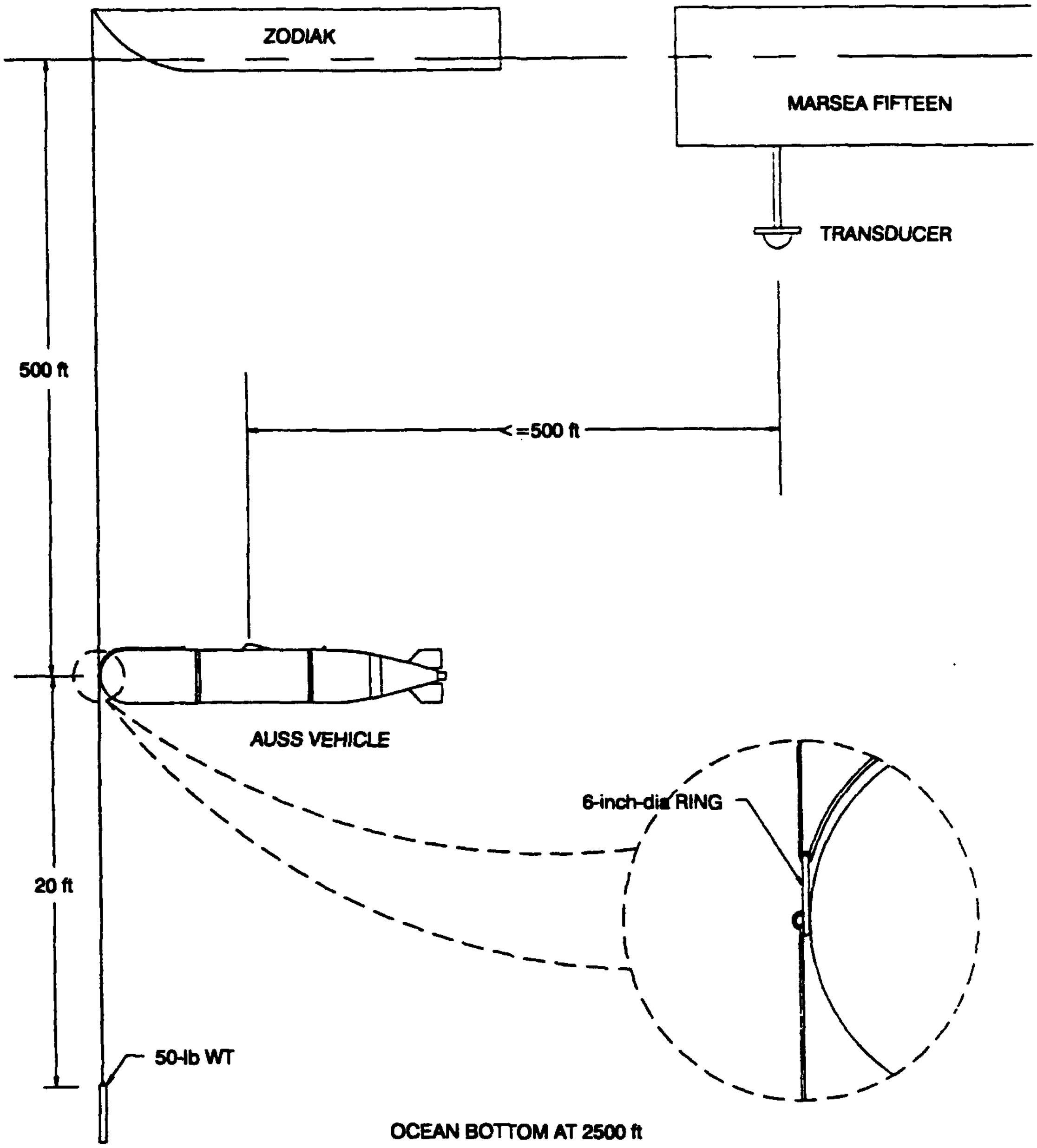


Figure C-1. 500-ft test configuration.

Predive

1. Install Novatech flasher and radio beacon with fresh batteries, and set up SAR erection system to deploy flasher and beacon, and float.

2. Remove safety line from ascent weights, and remove any safety equipment from SAR erection system.

3. Conduct prelaunch check (use prelaunch checklist).

4. Install descent weight release eye assembly. Tie 6-foot length of 1/4-inch line into descent weight release eye. Terminate other end of 6-foot line with a bowline knot. Tape this line to the vehicle to avoid tangles during launch.

5. In zodiac, place two lines rigged and laid into buckets as follows:

   a. line one—500-foot line (1/4-inch nylon) firmly secured at one end (bottom of bucket) to bow of zodiac. Tie the other end (top of bucket) into 1/2-inch-diameter bar stock ring provided (this ring should be wrapped with scotch 88 tape to protect the vehicle). Tie approximately 4 ft of 1/4-inch nylon line from the ring to a 3/8-inch shackle.

   b. line two—20-foot line (1/4-inch nylon) at one end (top of bucket) terminate with 50-lb weight. The other end (bottom of bucket) will be left free and tied later.

At–sea

1. Upon arrival on-station, head ship into seas and deploy transducer pole.

2. Turn on bottom transponders

3. Move ship to the center of the net.

4. Head ship into seas and launch small boat. Man small boat with driver, swimmer, and radio operator with radio. Two pairs of leather gloves and a sharp knife for cutting line will also be on board. All gear from 5 above will also be on board.

5. Conduct radio check with bridge, small boat, and deck radio operators.

6. While still heading ship into seas, make slight headway (approximately 2 knots), and launch AUSS vehicle.

7. Once vehicle is launched, maintain standoff between transducer pole and vehicle of approximately 500 feet (measured with optical range finder). The person with the range finder will use a radio to advise the bridge of range between the pole and the vehicle when possible during the test. (The technique we expect to use is to have the Captain keep the small boat around 350 ft dead ahead while headed into the seas.)

8. To aid in maintaining standoff to vehicle, track vehicle transponder (yellow banana) as soon as possible using Honeywell ultra short baseline.

9. Move zodiac over to vehicle, and rig vehicle as follows:

   a. Attach 3/8-inch shackle of line one to forward lift point.

   b. Untape 6-foot line coming from descent release, and run it through 1/2-inch-bar stock ring of line one.

   c. Tie the free end of line 2 into the bowline in the 6-foot line.

   d. Lower 50-lb weight of line 2 until almost to 6-inch ring.

   e. Transfer load to line one, making sure 6-inch ring bears on the descent weight release, and does not slip past knot in line one. Do not allow line to slack from this point on.

   f. Lower vehicle with line one until load is taken by small boat.

   g. Drift.

10. Communicate with the vehicle via the acoustic link.

a. Attempt to statically trim the vehicle with the weight shifter.

b. Use dynamic trim if necessary.

c. Request status at 2400/4800 bps, and dual and independent.

d. Take a CCD image of the descent weight, which should be in the field of view 20 feet below the vehicle.

11. Track vehicle from ship using fish cycle with the Thorn/NS-011 system and the Honeywell system.

12. Track vehicle from ship using the acoustic link ultrashort baseline mode.

13. Conduct experiments in passively tracking the AUSS vehicle using Thorn/NS–011 system.

14. Determine the greatest separation between the ship and the vehicle at which commands to the vehicle will be received, tracking in the various modes is possible, and communications from the vehicle can be received at the ship.

15. Move the ship to a position just inside the maximum range of the acoustic link command link and command the vehicle to:

a. Release the descent weight. (have zodiac personnel confirm that line has slackened some.)

b. Release the ascent weights. (have zodiac personnel confirm that vehicle is on its way *to the surface)*

16. As vehicle ascends, zodiac personnel should try not to affect the ascent trajectory of the vehicle. Once vehicle is on the surface, zodiac must haul in 500 ft of line to the vehicle maintaining enough tension so the line does not foul the float line or the vehicle.

17. Zodiac personnel will disconnect shackle from vehicle, and untangle any lines until vehicle is floating on surface with nose float released, and ready for normal vehicle recovery.

18. Conduct normal AUSS vehicle recovery.

19. Recover zodiac personnel, equipment, and zodiac.

3900
Ser 941/72–90
11 September 1990

MEMORANDUM

From: Jim Walton (Code 941)

To: AUSS Team

Subj: AUSS Descent String Test

Encl: (1) AUSS Descent String Test Plan

1. Enclosure (1) is the test plan for AUSS Descent String.

JIM WALTON

Copy to:
94 (info only)
941
941 (Cooke, Held, Jones, Kono, Osborne, Rutkowski, Schwager, Tallerino, Uhrich, Walton, files)
943 (Watson, McCracken, Mackelburg)
946 (Thorn)
9622 (Wilson)

AUSS DESCENT STRING TEST PLAN

OBJECTIVES

1. To evaluate the performance and dependability of the acoustic link system with the vehicle at 2500-foot depth.

2. To evaluate the performance and dependability of two different tracking systems tracking the AUSS vehicle in long baseline fish cycle mode with the vehicle at 2500-foot depth.

3. To gather relative tracking accuracy data for four methods of tracking the AUSS vehicle: RS906 fish cycle, Thorn fish cycle, Thorn Relay tracking, and Thorn passive.

4. To compare the performance of the acoustic link and tracking systems when connected to the transducer at the batfish, and to the transducer on the pole.

5. To define improvements and adjustments necessary in the acoustic link and the tracking systems prior to conducting free (untethered) vehicle dives.

6. To track the vehicle in ultrashort baseline using the vehicle transponder (yellow banana).

7. To conduct long-term Doppler output drift tests (random walk) with the vehicle nearly fixed in hydro space at 100-foot altitude.

8. To study the performance of the GPS system with more than 4 space vehicles available versus 4 space vehicles available.

9. To command (via the acoustic link) the release of the descent weight.

10. To command (via the acoustic link) the release of the ascent weights.

11. To record and recover from the flight recorder the pitch angles and pitch rates during vehicle ascent.

12. To record and recover from the flight recorder the depth record from the depthometer during vehicle ascent.

13. To mark the position of the vehicle in the launcher when located properly for launch.

14. To measure the clearance between the rubber bumper on the docking cart and the bottom of the vehicle.

15. To provide an assembled vehicle to the mechanical team for lifting and servicing the forward and after vertical motors after the dive.

16. To photograph AUSS at-sea operations. In particular, the vehicle floating on the surface with and without the float released, and at-sea pictures of the *MARSEA FIFTEEN*.

PROCEDURES

(Refer to figure C-2 for final in-water rig.)

Predive

1. Install Novatech flasher and radio beacon with fresh batteries, and set up SAR erection system to deploy flasher and beacon, and float.

JMW
9/12/90

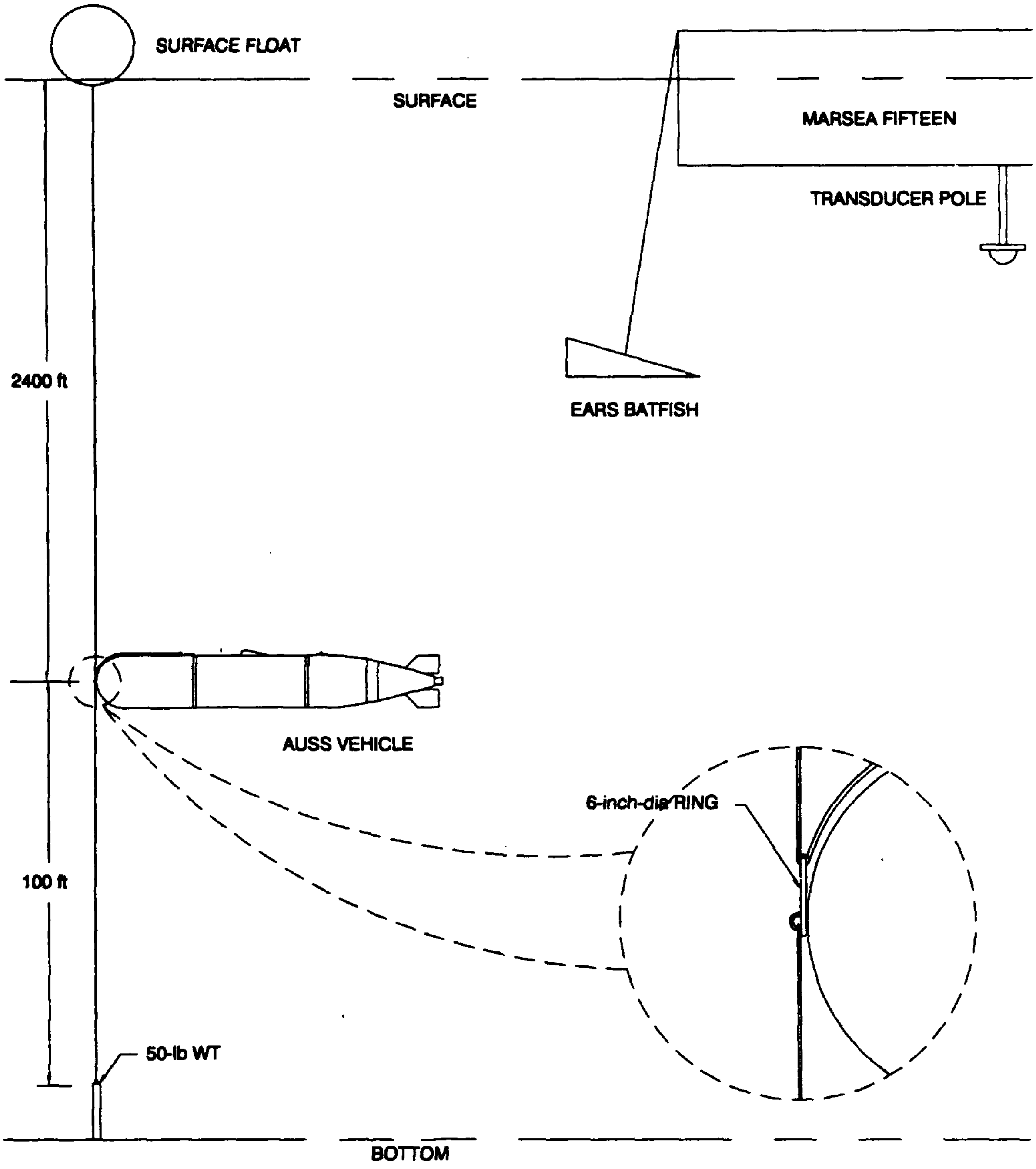


Figure C-2. Ocean bottom at 2500-ft configuration.

ENCLOSURE (1)

2. Remove safety line from ascent weights, and remove any safety equipment from SAR erection system.

3. Conduct prelaunch check (use prelaunch checklist to the extent possible).

4. Leave weight shifter weight centered.

5. Install descent weight release eye assembly. Tie 6-foot length of 1/4-inch line into descent weight release eye. Terminate other end of 6-foot line with a bowline knot. Tape this line to the vehicle to avoid tangles during launch.

6. In zodiac, place two lines rigged and laid into buckets as follows:

   a. Line one—2500 foot line (1/4 inch nylon) firmly secured at one end (bottom of bucket) to bow of zodiac. Tie the other end (top of bucket) into 1/2-inch-diameter bar stock ring provided (this ring should be wrapped with scotch 88 tape to protect the vehicle). Tie approximately 4 ft of 1/4-inch nylon line from the ring to a 1/2-inch shackle.

   b. Line two—100-foot line (1/4 inch nylon) at one end (top of bucket) terminate with 50-lb weight. The other end (bottom of bucket) will be left free and tied later.

At–sea

1. Upon arrival on-station, head ship into seas and deploy transducer pole.

2. Turn on bottom transponders.

3. Move ship to the center of the net.

4. Head ship into seas and launch zodiac. Man zodiac with driver, swimmer, and radio operator/photographer with radio and camera. Two pairs of leather gloves and a sharp knife for cutting line will also be on board. All gear from 6 above will also be on board.

5. Conduct radio check with bridge, zodiac, and deck radio operators.

6. Maneuver zodiac to take at-sea pictures of the *MARSEA FIFTEEN* at various angles.

7. Recover the photographic equipment from the zodiac.

8. Move vehicle from maintenance van to launcher. Measure clearance between vehicle and bumper on docking cart.

9. Mark launcher and crane track with marks that will help relocate vehicle in launcher for launch position.

10. While still heading ship into seas, make slight headway (approximately 2 knots), and launch AUSS vehicle.

11. Once vehicle is launched, deploy EARS batfish. Maintain ship headway from this time until EARS is recovered.

12. To aid in maintaining standoff between ship and vehicle during vehicle descent, track vehicle transponder (yellow banana) as soon as possible using Honeywell ultrashort baseline.

13. Move zodiac over to vehicle, and rig vehicle as follows:

a. Attach 1/2-inch shackle of line one to forward lift point.

b. Untape 6-foot line coming from descent release, and run it through 1/2-inch bar stock ring of line one.

c. Tie the free end of line 2 into the bowline in the 6-foot line.

d. Lower 50-lb weight of line 2 until almost to 6-inch ring.

e. Transfer load to line one, making sure 6-inch ring bears on the descent weight release, and does not slip past knot in line one. Do not allow line to slack from this point on.

f. Lower vehicle with line one until it slacks (indicating weight is on the bottom.)

g. Tie surface float on to top of line one, and cut off excess line if necessary.

h. Recover zodiac crew (recover EARS for this if necessary), and take small boat in tow.

14. Communicate with the vehicle via the acoustic link.

a. Attempt to statically trim the vehicle with the weight shifter.

b. Use dynamic trim if necessary.

c. Request status at 2400/4800 bps, and dual and independent.

d. Exercise the STOP and ESP commands.

e. Send a tone reset.

f. Collect acoustic link noise monitor data from the transmitted status and the flight recorder.

g. Set flight recorder to record Doppler raw data and compass reading during entire dive.

15. Track vehicle from ship using fish cycle with the Thorn/NS–011 system and the Honeywell system.

16. Track vehicle from ship using the acoustic link ultrashort baseline mode.

17. Conduct experiments in passively tracking the AUSS vehicle using Thorn/NS–011 system.

18. Conduct experiments in tracking the AUSS vehicle in the Thorn/NS–011 relay mode.

19. Move the transducer connection for the acoustic link and tracking systems between the transducer pole and the batfish to compare performance.

20. Connect the Thorn system to operate independently on the transducer pole (without going through the AUSS circuitry).

21. Have the zodiac crew board the zodiac, and station zodiac near the surface float.

22. Move the ship to a position at least 1000 feet from the small boat and the buoy and command the vehicle to:

a. Release the descent weight. (have zodiac personnel confirm that line has slackened some.)

b. Release the ascent weights. (have zodiac personnel confirm that vehicle is on its way to the surface)

23. As vehicle ascends, zodiac personnel should try not to affect the ascent trajectory of the vehicle. Once vehicle is on the surface, zodiac must haul in 2500 ft of line to the vehicle maintaining enough tension so the line does not foul the float line or the vehicle.

24. Zodiac personnel will disconnect shackle from vehicle, and untangle any lines until vehicle is floating on surface with nose float released, and ready for normal vehicle recovery.

25. Conduct normal AUSS vehicle recovery.

26. Recover zodiac personnel, equipment, and zodiac.

27. Wash vehicle, move it into the maintenance van, and hook it to the umbilical (leave closed).

28. Recover flight recorder data on Doppler raw data during entire dive, compass heading during entire dive, and depth, pitch, and pitch rate during ascent.

APPENDIX D

SAMPLE OF BACKGROUND DEVELOPMENT TEST PLANS

JMW
9-4-90

AUSS PERFORMANCE CHARACTERIZATION AND QUANTIFICATION TESTS OBJECTIVES

OBJECTIVES

1. Demonstrate that the AUSS vehicle has the capability to

   a. Operate at 20,000 feet of seawater

   b. Run in a straight line at speeds up to 5 knots

   c. Turn vehicle 180 degrees within 2 minutes

   – With 0 speed of advance

   – With the initial condition of maximum speed in a straight line

   d. Ascend at a rate of 2 ft per second (ft/s) with the initial condition of maximum speed in a straight line.

   e. Descend at a rate of 2 ft per second with the initial condition of maximum speed in a straight line.

   f. Ascend at a rate of 1 ft per second with near-zero advance rate

   g. Descend at a rate of 1 ft per second with near-zero advance rate

   h. Stop within 100 feet with the initial condition of full forward speed

   i. Hover within a 50-ft-diameter circle for 2 minutes

   j. Hover at a specified depth ± 5 feet for 2 minutes

   k. Transit at 5 knots while maintaining a specified depth ± 5 feet for 2 minutes

   l. Hover at a specified altitude ± 5 feet for 2 minutes

   m. Transit at 5 knots while maintaining a specified altitude ± 5 feet for 2 minutes

   n. Hold a specified heading ± 15 degrees for 2 minutes

   o. Transit at 5 knots while holding a specified heading ± 15 degrees for 2 minutes

   p. Operate with hotel load (thrusters and sensors secured) for 10 hours on the same battery pack (without recharging)

   q. Operate at 5 knots for 8 hours on the same battery pack (without recharging)

   r. Autonomously follow predescribed search patterns appropriate for side-looking sonar search

   s. Autonomously follow predescribed search patterns appropriate for photomosaic search

   t. Descend in a weight-assisted mode to 20,000 feet within 1 hour

   u. Ascend to the surface from 20,000 feet within 1 hour

2. Demonstrate that a reliable acoustic communication at 4800 bits per second (bps) can be received by the surface ship from the vehicle while the surface ship is within and to the maxi-

mum extent of a 90-degree-included-angle cone above the vehicle. Worst case bit error rate not to exceed 10**–5.

3. Demonstrate that a reliable acoustic communication at 1200 bps can be received at the vehicle from the surface ship while the vehicle is within and to the maximum extent of a 90-degree-included-angle cone below the surface ship. Worst case bit-error rate (ber) not to exceed 10**–5.

4. Demonstrate that the geodetic position of the vehicle while hovering can be determined within an error circle with diameter equal to 10 meters using long baseline (LBS) acoustic tracking.

5. Demonstrate that the position of the vehicle in global coordinates can be determined within an error circle equal to 100 meters by integrating surface ship tracking with short baseline (SBS) acoustic tracking of the vehicle.

6. Demonstrate that the vehicle consistently deploys ascent weights upon command to initiate the ascent of the vehicle to the surface.

7. Demontrate that the vehicle consistently deploys a recovery float on a line, a flashing light, and trackable radio beacon when it reaches the surface at the completion of a dive.

8. Demonstrate that the vehicle radio beacon is trackable out to ranges to 1 mile when deployed from the surface-floating vehicle.

9. Demonstrate that the vehicle is capable of automatically initializing an ascent to the surface in a fail safe mode under the conditions of:

   a. Loss of acoustic communications with the surface ship

   b. Low-battery voltage

   c. Low voltage in an individual cell of the battery pack

   d. Voltage drop in the ascent weight solenoid activation capacitors

   e. Leak detection in the main electronics housing

   f. Loss of the main computer function

10. Demonstrate that the vehicle battery can be exchanged at sea within 1.5 hours from the time when the vehicle is recovered and secured in the launcher to the time when the vehicle is relaunched.

11. Demonstrate that the vehicle battery can be recharged at sea in the vehicle maintenance van battery room.

12. Demonstrate that the vehicle can be launched and recovered in seas up to sea state three.

3900
Ser 941/79–90
25 September 1990

MEMORANDUM

From: Jim Walton (Code 941)

To: AUSS Team

Subj: AUSS Acoustic Link, Tracking, and Hover Controls Tests

Encl: (1) AUSS Acoustic Link, Tracking, and Hover Controls Tests Plan

1. Enclosure (1) is the AUSS Acoustic Link, Tracking, and Hover Controls Tests Plan.

JIM WALTON

Copy to:
94 (info only)
941
941 (Cooke, Held, Jones, Kono, Mackenzie, Osborne, Rutkowski, Schwager, Tallerino, Uhrich, Walton, files)
943 (Watson, McCracken, Mackelburg)
946 (Thorn)
661 (Nickerson)

AUSS ACOUSTIC LINK, TRACKING, AND HOVER CONTROLS TESTS PLAN

OBJECTIVES

Acoustic Link and Tracking

1. To evaluate the performance and dependability of the acoustic link system with the vehicle at 2500-foot depth.

2. To evaluate the performance and dependability of two different tracking systems tracking the AUSS vehicle in long baseline (LBS) fish cycle mode with the vehicle at 2500-foot depth.

3. To gather relative tracking accuracy data for the four methods of tracking the AUSS vehicle, namely: RS906 fish cycle, Thorn fish cycle, Thorn Relay tracking, and Thorn passive.

4. To compare the performance of the acoustic link and tracking systems when connected to the transducer at the batfish, and at the transducer on the pole.

5. To define improvements and adjustments necessary in the acoustic link and the tracking systems prior to conducting free (untethered) vehicle dives

6. To track the vehicle in ultrashort baseline (USBL) using the vehicle transponder (yellow banana).

7. To study the performance of the Global Positioning System (GPS) with more than 4 space vehicles available versus 4 space vehicles available.

8. To command (via the acoustic link) the release of the descent weight.

9. To command (via the acoustic link) the release of the ascent weights.

Controls

1. To conduct long-term Doppler output drift tests (random walk) with the vehicle nearly fixed in hydrospace at 100-foot altitude.

2. To record and recover from the flight recorder the pitch angles and pitch rates during vehicle ascent.

3. To record and recover from the flight recorder the depth record from the depthometer during vehicle ascent.

4. To test hover depth control.

5. To test hover heading control.

6. To test hover altitude control.

7. To test hover pitch control.

8. To test hover pitch/depth control.

9. To test hover pitch/altitude control.

10. To test hover at a radius from a point (direct Doppler driven).

11. To test hover at a radius from a point (Doppler-updated estimator driven).

12. To test the GO command.

13. To test the GO dead-reckon command.

PROCEDURES

(Refer to Figure D-1 for final in-water rig.)

PREDIVE

1. Install Novatech flasher and radio beacon with fresh batteries, and set up SAR erection system to deploy flasher and beacon, and float.

2. Remove safety line from ascent weights, and remove tie straps from SAR erection system.

3. Conduct prelaunch check (use prelaunch checklist to the extent possible). Use ascent weight stems and descent weight eye to test ascent and descent weight releases.

4. Install ascent weights.

5. Leave weight-shifter weight centered.

6. Check out Sonatech transponder for transponder descent string and arm weight release. Check interrogate and release codes.

7. Rig transponder descent string with float, rings, sonatech transponder, and 100-pound weight.

8. Move vehicle out to launcher and install snails.

9. Deploy float and check new recovery catch line length. Adjust catch clearance if necessary.

10. Reinstall float and line.

11. Rig float end of transponder descent string to descent weight release eye.

ON STATION

Equipment Deployment

1. Upon arrival on–station, head ship into seas and deploy transducer pole.

2. Turn on bottom transponders.

3. Move ship to the center of the net.

4. Head ship into seas, make slight headway (approximately 2 knots), and launch AUSS vehicle with weighted descent equipment including float, transponder, and descent weight.

5. Once vehicle is launched, deploy EARS batfish. Maintain ship headway from this time until EARS is recovered.

6. Track vehicle transponder (yellow banana) as soon as possible using Honeywell ultra-short baseline (USBL).

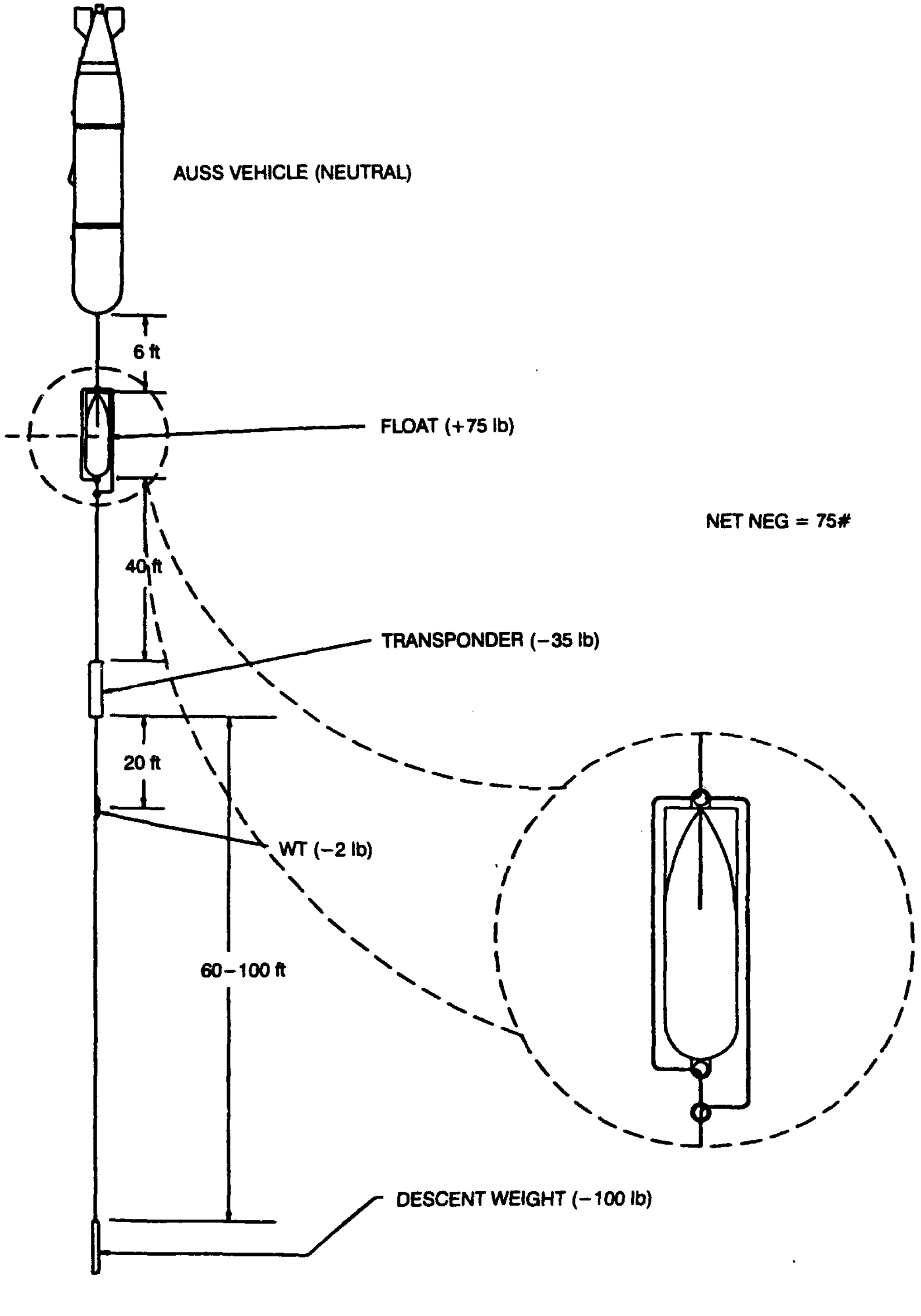


Figure D-1. AUSS vehicle on descent string.

Acoustic Link

7. Communicate with the vehicle via the acoustic link.

    a. Statically trim the vehicle with the weight shifter.

    b. Use dynamic trim if necessary.

    c. Request status at 2400/4800 bps, and dual and independent.

    d. Exercise the STOP and ESP commands.

    e. Collect acoustic link noise monitor data from the transmitted status, and the flight recorder.

    f. Set flight recorder to record Doppler raw data and compass reading during entire dive.

Tracking

8. Track vehicle from ship using fish cycle with the Thorn/NS– 011 system and the Honeywell system.

9. Track vehicle from ship using the acoustic link USBL mode.

10. Conduct experiments in passively tracking the AUSS vehicle using Thorn/NS–011 system.

11. Conduct experiments in tracking the AUSS vehicle in the Thorn/NS–011 relay mode.

12. Move the transducer connection for the acoustic link and tracking systems between the transducer pole and the batfish to compare performance.

13. Connect the Thorn system to operate independently on the transducer pole (without going through the AUSS circuitry).

Controls

14. Release AUSS vehicle from transponder descent string.

15. Observe pitch angle, and correct for zero pitch with weight shifter if necessary.

Enclosure

16. Hover Depth Control

    a. Command vehicle to hold at depth indicated in most recent status update.

    b. Command vehicle to hold at a depth 30 feet above the depth it is at.

    c. Command vehicle to hold depth 30 ft below the depth it is at (return to original depth).

17. Hover Heading Control

    a. Read vehicle heading and initiate heading hold at that heading.
    b. Command vehicle to step to heading 90 degrees < present heading.
    c. Command vehicle to step to heading 181 degrees > present.
    d. Command vehicle to step to heading 179 degrees > present.

18. Hover Altitude Control

    a. Command vehicle to hold altitude at present altitude
    b. Command vehicle to hold altitude 30 ft above original altitude
    c. Command vehicle to hold original altitude

19. Hover Pitch Control

    a. Command vehicle to hold 0-degree pitch
    b. Command vehicle to hold +10-degree pitch
    c. Command vehicle to hold –10-degree pitch
    d. Command vehicle to hold 0-degree pitch

20. Hover Pitch/Depth Control

    a. Command vehicle to hover at present depth
    b. Command vehicle to hold 0-degree pitch
    c. Command vehicle to hold +10-degree pitch
    d. Command vehicle to hold –10-degree pitch
    e. Command vehicle to hold 0-degree pitch

21. Hover at a Radius from a Point (direct Doppler driven)

    (vehicle at surface)

    a. Command vehicle to hover wrt point x ft (start with x = 10 ft) ahead of it.

    b. Command vehicle to hover wrt point y ft (start with y = 20 ft) away and at 90 degree relative heading

22. Hover at a Radius from a Point (Doppler-updated estimator driven)

    (Vehicle at surface.)

    a. Command vehicle to hover wrt point x ft (start with x=10 ft) ahead of it.

    b. Command vehicle to hover wrt point y ft (start with y=20 ft) away and at 90 degrees relative heading

Recovery and Post Dive

23. Command release of transponder and float from 100-lb weight and recover.

24. Command weight shift to fully aft and command release of ascent weights.

25. Conduct normal AUSS vehicle recovery.

26. Wash vehicle, move it into the maintenance van, and hook it to the umbilical (leave closed).

27. Recover flight recorder data on Doppler raw data during entire dive, compass heading during entire dive, and depth, pitch, and pitch rate during ascent.

3900
Ser 941/ –90
17 Oct. 1990

MEMORANDUM

From: Jim Walton (Code 941)

To: AUSS Team

Subj: AUSS Transit Controls Tests

Encl: (1) AUSS Transit Controls Tests Plan

1. Enclosure (1) is the AUSS Transit Controls Tests Plan.

JIM WALTON

Copy to:
94 (info only)
941
941 (Cooke, Held, Jones, Kono, Mackenzie, Osborne, Rutkowski, Schwager, Tallerino, Uhrich, Walton, files)
943 (Watson, McCracken, Mackelburg)
946 (Thorn)
661 (Nickerson)

AUSS TRANSIT CONTROLS TESTS PLAN

OBJECTIVES

GO DR Command

1. To test the operation of the vehicle GO DR command.
2. To test closed loop dynamic control of pitch and depth/altitude using the elevator.
3. To test the switch into the two options of "high current mode" *at the conclusion of the* GO DR command.
    a. The existing heading option (vehicle remains on heading it was on during command)
    b. The previous heading option (vehicle returns to heading it was on prior to receiving command).

Preliminary Vehicle Characteristics

1. To determine where to place the crossover between low speed vertical thruster depth/altitude control, and high speed elevator depth/altitude control.
2. To measure maximum speed of the vehicle, and the long term accuracy of the Doppler.
3. To determine the stopping time and distance of the vehicle for the obstacle-avoidance system (OAS).
4. To determine the turning radius of a full-speed turn.
5. To collect step-function-response data in yaw for high speeds.
6. To collect step-function-response data in depth for high speeds.
7. To collect step-function-response data in altitude for high speeds.
8. To collect overall vehicle bulk-modulus data.

GO Command

1. To test the operation of the vehicle GO command.
2. To investigate the accuracy of the vehicle navigation system in the GO mode.
3. To exercise and flight record the "trajectory" portion of the GO command.
4. To test the switch into the three options of "basic vehicle mode" at the conclusion of the GO DR command.
    a. The existing heading option (vehicle remains on heading it was on during command)
    b. The previous heading option (vehicle returns to heading it was on prior to receiving command).
    c. The hover at a point with standoff option.

Vehicle Symmetry

1. To determine if the vehicle is hydrodynamically symmetric when running straight forward.

ENCLOSURE (1)

2. To determine if the main-propulsion propellers are matched.

3. To determine if the main-propulsion motors are matched.

Vehicle Model Matrix

1. To develop a vehicle on-board matrix model of empirical values of acceleration as a function of vehicle forward velocity and commanded thrust, $a = f(V,Tc)$.

PROCEDURES

PREDIVE

1. Install Novatech flasher and radio beacon with fresh batteries, and set up SAR erection system to deploy flasher and beacon, and float.

2. Remove safety line from ascent weights, and remove tie straps from SAR erection system.

3. Conduct prelaunch check (use prelaunch checklist to the extent possible). Use dummy ascent weights and descent weight eye to test ascent and descent weight releases.

4. Install ascent weights.

5. Leave weight shifter weight centered.

6. Check out Sonatech transponder for transponder descent string and arm weight release. Check interrogate and release codes.

7. Rig transponder descent string with float, rings, sonatech transponder, and 100 pound weight. (See figure D-1 for final rigging.)

8. Move vehicle out to launcher and install snails.

9. Rig float end of transponder descent string to descent weight release eye.

ON STATION

Equipment Deployment

1. Upon arrival on–station, head ship into seas and deploy transducer pole.

2. Turn on bottom transponders.

3. Move ship to the center of the net.

4. Head ship into seas, make slight headway (approximately 2 knots), and launch AUSS vehicle with weighted descent equipment including float, transponder, and descent weight. (See figure D-1 for final rigging.)

5. Track vehicle transponder (yellow banana) as soon as possible using Honeywell USBL.

6. Once vehicle is launched, deploy EARS batfish. Maintain ship headway from this time until EARS is recovered.

Preliminary Vehicle Adjustments

7. When vehicle has reached a stable position on the descent string, move trim weight to level vehicle if necessary.

8. Turn on Doppler sonar, and start collecting doppler data in flight recorder. Try to get a minimum of 25 minutes of Doppler data flight recorded while vehicle is hanging on descent string.

9. Conduct quick tracking and acoustic link checks to assure operation.

10. Collect CCD images of descent line, transponder and weight. Transmit images to surface in low and high resolution. After this, collect CCD images when possible between controls tests.

11. Release vehicle from descent line after no more than 30 minutes of descent string work.

12. Trim vehicle with trim weight if necessary.

13. Put vehicle in basic mode holding present depth and heading it was on when attached to the descent string.

GO DR Command

14. Hold existing depth and heading and thrust for 20 seconds at 30% thrust on both mains, no vertical thrusters. At end of run, basic vehicle mode should be existing heading, and hold depth.

15. If all goes well in previous step, repeat and run for 2 minutes.

16. Repeat last step and run at 100% thrust.

17. Give a GO DR command for 2 minutes at 100% thrust that takes the vehicle to a depth 20 feet less than initial depth, and on a heading which is 90 degrees from its present heading. At completion of command, have vehicle return to the heading it was on before the command.

Preliminary Vehicle Characteristics

18. Crossover

a. Attempt to depth control the vehicle with vertical thrusters only while thrusting forward with both mains at 10, 20, 30, 40, 50% thrust.

b. Attempt to depth control the vehicle with elevators only while thrusting forward with both mains at 20, 30, 40, 50, 60, 70% thrust.

19. Maximum vehicle speed and Doppler accuracy:

a. Determine direction of current while on descent string or by drift test.

b. Operate close enough to bottom to get good Doppler velocity.

c. Run parallel and into current at 100% thrust in GO DR for 10 minutes.

d. Obtain at least five LBS fixes on vehicle after it has come up to speed during this run, and log the time the fixes were made.

e. Repeat b through d with the vehicle running with the current.

20. Stopping time and distance

a. Operate close enough to bottom to get good Doppler velocity.

b. Run at 100% thrust for 3 minutes perpendicular to current in GO DR.

c. At end of 3 minutes, have vehicle reverse thrusters full for 3 minutes.

21. Turning radius

a. Operate close enough to bottom to get good doppler velocity.

b. Run at 100% thrust for 3 minutes perpendicular to current in GO DR.

c. At end of 3 minutes, have vehicle commanded to a heading 180 degrees from present on another GO DR with 100 % thrust.

22. Yaw step functions

a. Repeat 21 for 80, 60, 40, 20% thrust.

b. Repeat 22a for 90-degree turns.

23. Depth step functions

a. Run at 100% thrust for 3 minutes.

b. After 3 minutes, have vehicle change depth by 50 feet.

c. Repeat for (thrust,depth change) = 80,50 60,50 40,50%

24. Altitude step functions

a. Run at 100% thrust for 3 minutes.

b. After 3 minutes, have vehicle change altitude by 50 feet.

c. Repeat for (thrust,altitude change) = 80,50 60,50 40,50%

25. Vehicle bulk modulus

a. During the same dive, depth hold at 2500,2000,1500,1000 feet.

GO Command

Note: Conduct GO tests at random angles with respect to the current.

26. Command the vehicle to go to a position at the same depth as the present position, and 50 feet straight ahead. Send information to vehicle as range and bearing to target and depth. Use 0 trajectory. Basic vehicle mode at end of command to be existing heading.

27. Command the vehicle to go to a position 30 feet higher than the present position, and 500 feet directly abeam of the vehicle. Send information to vehicle as N/S, E/W coordinates of target and altitude. Use 0 trajectory. Basic vehicle mode at end of command to be previous heading.

28. Command the vehicle to go to a position at the same depth as the present position, and 500 feet directly astern. Send information to vehicle as N/S, E/W coordinates of target and altitude. Have vehicle go on a trajectory 30 feet above beginning depth. Basic vehicle mode at end of command to be standoff 10 feet from target position.

Vehicle Symmetry

29. Place vehicle at least 150 feet above the bottom.

30. Conduct drift test to determine direction of current.

31. Line vehicle axis parallel to current.

32. Give vehicle GO DR command on same heading as current with 100% thrust for 3 minutes.

33. Give vehicle utility command to hold depth and to run both main thrusters 100% for 3 minutes, followed by command for 0% thrust on starboard and 100% on port main for 3 minutes more.

34. Give vehicle utility command to hold depth and to run both main thrusters 100% for 3 minutes, followed by command for 100% thrust on starboard and 0% on port main for 3 minutes more.

35. Repeat (in later dives if necessary) above steps under vehicle symmetry for (a) propellers switched, (b) propulsion motors switched.

Vehicle Model Matrix

36. Conduct drift test to determine direction of current. Run all model matrix tests perpendicular to the current. (See table D-1.)

37. Move vehicle to position at least 150 feet from bottom, and at extremity of transponder net.

38. Make the following runs, allowing 3 minutes for the vehicle to reach a steady state at each setting. Give vehicle utility command to hold depth and to run both main thrusters at the percent thrusts in the table below.

Table D-1. *Percent thrust settings for both main thrusters.*

RUN #

1	0 80	10 0	0 90	20 0	0 100	30	0	40	0	50	0	60	0	70	0
2	0 –80	–10 0	0 –90	–20 0	0 –100	–30	0	–40	0	–50	0	–60	0	–70	0
3	100 20 100	90 100 –60	100 10 100	80 100 –70	100 0 100	70 100 –80	100 –10 100	60 100 –90	100 –20 100	50 100 –100	100 –30	40 100	100 –40	30 100	100 –50
4	–100 –20 –100	–90 –100 60	–100 –10 –100	–80 –100 70	–100 0 –100	–70 –100 80	–100 10 –100	–60 –100 90	–100 20 –100	–50 –100 100	–100 30	–40 –100	–100 40	–30 –100	–100 50

APPENDIX E

SAMPLE OF DEVELOPMENT DIVE PLANS

JMW
11–28–90

AUSS DIVE 5 PLAN

PRECLOSE

1. Install tissue in pressure vessel to detect moisture.

DOCKSIDE

1. Trim vehicle
2. Adjust antiroll unit on launcher

ON DESCENT STRING

1. Flight record descent
2. 1/2–1 hour max on string
3. Trim with weight
4. Flight record Doppler data for random walk
5. Track in passive mode
6. Track in relay mode
7. Exercise new frequency-shifted acoustic link
8. Try singular and string of commands
9. CCD image of transponder?
10. Note heading just prior to release for current direction

SONAR SCANS IMMEDIATELY AFTER RELEASE

1. Drift and trim
2. Using Doppler and tracking, determine heading back to descent string
3. Hold depth and heading determined above, and do FLSs of descent string

ALTITUDE HOLD STEPS

1. Hover at radius
2. Altitude steps, +3, +10, +30, –3, –10, –(down to 50-ft altitude).

CCD/HOVER

1. Hover at radius, 50-ft altitude
2. CCD images, fan off and on

3. Lower altitude if necessary

COMMAND STRINGS

1. Send command strings of 2, 3, 4, 5 commands to vehicle.

COMMANDS/TONE RESET WHILE TRANSITING

1. Transit and heading hold at 20% bias thrust
2. Send commands to change heading, depth, bias thrust, Stop, ESP
3. Tone reset while transiting

GO DR/GO/PRELIM. VEHICLE CHARACTERISTICS

(See test plan.)

SONAR CONTACT EVALUATION/HOVER AT RADIUS EVALUATION

1. Use FLS to close target at known positions
2. Hover at radius over target
3. Obtain and record several tracking fixes while hovering
4. Take multiple CCD images, note vehicle drift using images

TARGET SURVEY

1. Close and hover at all known targets
2. Get at least 10 good-tracking fixes at each target

ASCENT

1. Make sure ascent is flight recorded

OPENING PRESSURE VESSEL

1. Make sure Walton is involved
2. Plan opening to avoid dripping water on tissues inside vessel

JMW
02–06–92

AUSS DIVE 33 PLANS

SPECIAL PREDIVE PREPARATIONS

1. Add 7-lb total lead weight to port side of vehicle inside hull.

2. Do preclose checkout and close vehicle by noon the day before dive.

3. Also do in-water trim test in the afternoon before dive.

4. Accurately measure out all lines on the descent string for Stan's OAS tests.

5. Remove Doppler sensor polyethylene cover.

6. If time allows before launch, do head-to-head comparison of GPS/GPS differential/LBS tracking of ship for "box" pattern.

7. Use new prelaunch command that sets the delay before a down transmission is requested, and sets the elevator to a 5-degree down angle (default value).

DESCENT STRING TESTING

Preliminaries

1. Assure acoustic link operation.

2. Turn on CCD cooler.

3. Turn on Doppler sonar.

OAS/Trim

4. Before trimming vehicle, note pitch and send OAS commands to look at bottom/water column returns.

5. Trim vehicle, note roll angle (7-lb lead has been added on port side).

6. While trimming vehicle, continue OAS commands to look at bottom/water column returns.

Baseline Doppler

7. Test two modes of Doppler sound-speed correction (imposed 5,000 ft/sec, and imposed corrected sound speed (based upon depth and temperature).

8. Implement preferred sound-speed source.

9. Zero rate sensors-FRD rate sensor outputs

10. Zero Doppler

11. Collect 10 minutes of "quiet" Doppler data

12. Zero Doppler

CCD Performance

13. Take CCD image of descent string and float to examine noise on CCD image (thrusters are off)

14. Send 256 x 256 x 8 CCD bias images.

15. Send 256 x 256 x 8 CCD dark images.

Doppler Performance

16. Zero Doppler

17. FRD rate sensor outputs, Doppler positions, acoustic link noise, and pitch for time period in which #3 thru #16 were accomplished.

18. Zero Doppler

19. FRD Doppler positions for the time period in which # 17 was accomplished. Zero flight recorder.

Release/Trim

20. Zero Doppler

21. Release from descent string

22. Trim vehicle using new static trim mode (new mode operates while the vehicle is in dynamic trim).

OAS of Descent String

23. Move 50 feet down-current from descent string coordinates (0,0).

24. Head into current at altitude of descent string float.

25. Image descent string with OAS.

26. Repeat 24 and 25 for ranges of 100, 200, 300...feet from the descent string.

HOVER CONTROL LOOPS/OBSTACLE-AVOIDANCE MANEUVER

1. Transmit status every 5 seconds.
2. Do hover altitude hold with 50-foot altitude step. Collect and plot status data for:
    (1) Altitude
    (2) Depth
    (3) Forward and After vertical thruster control levels
3. Do hover depth hold with 50-foot depth step. Collect and plot status data for:
    (1) Altitude

(2) Depth

(3) Forward and After vertical thruster control levels

4. Change status update back to every 15 seconds.

5. Begin GO towards waypoint at which DOPPLER ACCURACY run will start. Inflict obstacle avoid maneuver. Continue to destination.

6. FRD data from 5 and clear flight recorder.

DOPPLER ACCURACY

1. Run vehicle on pattern (use GO to waypoints), which is a square with 3000–4000 feet on a side.

2. Track using fish cycle for ship and vehicle.

3. Dump flight recorder and plot Doppler path.

4. Clear flight recorder.

SLS AND CONTACT EVALUATION TESTS
(Also Strobe Illumination Field and OAS of Target)

1. Perform SLS search patterns. Use 2000-foot-long legs, 500-foot-range scale, and 0% overlap (100% coverage).

2. Complete three legs.

3. Obtain as many fish cycle fixes as possible during each turn.

4. Upon contacting a strong target (we want a car), pause vehicle, and mark target. Then conduct the following tests:

Current Direction and Downcurrent Positioning of Vehicle

(1) GO to a hover heading at 150 feet from target.

(2) Use target-closing routine with two FLS scans to determine a good down-current vehicle position for target closure. **Write down both the position of the target and the vehicle position calculated. Enter this information in the log.**

(3) Update Doppler position of target using FLS target marking.

(4) GO to computed 30-foot down-current position and heading hold into current.

Bias Thrust Closing of Target

(5) Close target using heading into current, bias thrust, FLS, and picture series. Use low resolution/medium compression.

(6) Retransmit best picture of series with high resolution/low compression.

(7) Confirm position of target using CCD target marking.

OAS of Target and CCD Illumination Field

(8) GO to position determined in (2) and hover at heading into current.

(9) Obtain FLS scan.

(10) Use FLS scan to verify target position or update target position and vehicle heading.

(11) Hold heading and take CCD images and OAS images while altitude hovering at 20,30,40,50...feet. This is done to determine illumination field, how far off the bottom the strobes still illuminate the bottom, and OAS bottom and target image characteristics.

(12) Stan will continue some experiments with OAS based upon data collected above at this time.

Hover At Radius Closing of Target

(13) GO to position determined in (2) and hover at heading into current.

(14) Obtain FLS scan.

(15) Use FLS scan to verify target position or update target position.

(16) GO to hover at 10-foot radius from target and take picture series.

(17) Use CCD target marking to update target position.

(18) Use GOs with hover at 10-foot radius to maintain hover over target.

(19) If hover is good, take fish-cycle fixes of target position.

5. Send, continue, and finish SLS pattern.
6. Dump flight recorder data.
7. Clear flight recorder.

QUIET PHOTOMOSAIC/ DOPPLER & LBS

1. Do a photomosaic with no CCD images.
2. Lanes to be 200-feet long, with 40-foot altitude. Make three turns.
3. Update fish cycle as frequent as possible to compare with Doppler.

QUIET SLS/ DOPPLER & LBS

1. Do a SLS pattern with no sensor acoustic link data.
2. Search pattern to be same as in previous SLS search pattern
3. Update fish cycle as frequent as possible to compare with Doppler.

TARGET SURVEY

1. Use SLS search to find, close, and hover at all targets.
2. Get at least 10 good-tracking fixes at each target.

3. Take lots of CCD images, transmit and record good ones at highest resolution.

Note: If trouble occurs with noise on CCD camera, conduct these CCD CAMERA TESTS.

1. Move vehicle to 30-foot altitude.

2. Take CCD image with vehicle in altitude and heading hover.

3. If image in 2 exhibits noise experienced in dive 31, take CCD images under the following conditions:

    a. Secure both vertical motors.

    b. Turn on forward vertical propulsion motor with manual thrust command (1–10% thrust only).

    c. Secure forward vertical motor and turn on after vertical propulsion motor with manual thrust (1–10% thrust only).

    d. Devise other experiments as required.

BULK MODULUS AND SONAR SCANS IN WATER COLUMN

1. See 25a of GO/GO DR test plan for bulk modulus experiment.

2. During bulk modulus experiment, do sonar scans at high altitudes.

ASCENT

1. Look for up elevator angle (should be 9 degrees) and resulting pitch angle in any status updates during ascent (some of Howard's new software).

2. Make sure ascent is flight-recorded.

JMW
11-18-91

AUSS 12 kft OPAREA TRANSPONDER NET INSTALLATION AND CALIBRATION TEST PLAN

PREDICTED OPAREA LAYOUT

```
POS2****** (2nmi)****** POS3
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
(2nmi)       POS5      (2nmi)
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
  *                       *
POS1****** (2nmi)****** POS4
```

POSITION	LAT (N)	LONG (W)	XPONDERS	kHz INTR,RESP	ON, REL
POS1	31° 00′ 56″	119° 03′ 26″	LBS1	7,15	A E
POS2	31° 02′ 55″	119° 03′ 30″	LBS2	7,15.5	B F
POS3	31° 02′ 58″	119° 01′ 12″	LBS3	7,16	C G
POS4	31° 01′ 00″	119° 01′ 00″	LBS4,	7,16.5	D H
POS4			LBS1990	7,13	C –
VARIABLE	*	*	FISH	9,7	E A

OBJECTIVES

1. Relocate AUSS 12-kft operations area (OPAREA) (near areas identified as Trieste Operations Area, and BUMP 12-k OPAREA.)

2. Relocate transponder deployed by Walton and Osborne from the Research Vessel *DeSteiguer* on 20 February 1990.

3. Collect sound-velocity profile information.

4. Calibrate *MARSEA FIFTEEN* deep fathometer for 12-kft operations.

5. Complete bathymetric survey of AUSS 12-kft OPAREA (initiated during *DeSteiguer* cruise).

6. Evaluate tracking performance using *MARSEA FIFTEEN* transducer pole and AUSS batfish.

7. Evaluate ultrashort baseline (SBS) performance at 12-kft location with *MARSEA FIFTEEN*/AUSS equipment.

8. Deploy "fish cycle" transponder at a variety of locations and depths in an attempt to predict future AUSS fish cycle performance in this OPAREA.

9. Determine proper transponder anchor-line lengths for the AUSS scenario in this OPAREA.

10. Deploy four transponder net at 12-kft spot.

11. Survey net using AUSS Thorn/NS11 system.

12. Survey net using ATV DP10/NS11 system.

13. Evaluate long baseline (LBS) and fish cycle performance using the AUSS and ATV systems in the 12-kft OPAREA.

14. Test operations of *MARSEA FIFTEEN* satellite communications system from 12-kft OPAREA.

15. Deploy sonar target and survey target in LBS coordinates.

16. Test deployment and retrieval of AUSS launcher in open ocean high sea states (if they exist).

PROCEDURES

1. Transit (approx 140 nmi) from NOSC, San Diego, to GPS lat 31° 01′ N, long 119° 01′ W. This should be position POS4 on diagram.

2. Deploy transducer pole and begin bathymetry.

Note:Deploy batfish if any of the following steps cannot be accomplished due to acoustics.

3. Turn on transponder deployed from *DeSteiguer* (LBS1990). If LBS1990 cannot be turned on, deploy LBS4 at POS4 with 200-ft anchor.

4. Launch XBTs and use data to determine sound-velocity profile and average sound velocity.

5. Attempt to make ship passes over POS4. Use minimum range values obtained to determine water depth and compare with fathometer.

NOTE: During the following steps, continue to collect bathymetry, annotating chart with time to correlate with GPS fixes.

6. Transit from POS4 to POS2 and deploy the fish xponder with 100 feet of anchor line.

7. Do fish cycle experiments and continue to collect bathymetry while transiting from:

    POS2 TO POS1
    POS1 TO POS3
    POS3 TO POS4
    POS4 TO POS1
    POS1 TO POS2
    POS2 TO POS3

8. If bathymetry looks good, do the following deployments in order:

    LBS3 AT POS3
    LBS4 AT POS4
    LBS1 AT POS1
    LBS2 AT POS2

9. Survey net by following ship navigation pattern provided by Pat Osborne. It is important to continue bathymetry during this time.

10. While Pat reduces the survey data, Walt Bacino will use the ATV system to look at the net. He will define ship navigation at this time.

11. Conduct the following experiments at various extents of and outside the net:

    a. Pole tracking
    b. Batfish tracking
    c. Thorn/NS11 with a&b
    d. Honeywell with a&b
    e. ATV DP10/NS11
    f. Honeywell SBS
    g. Speed runs while tracking with pole
    h. Speed runs while tracking with batfish

12. Recover fish xponder and redeploy near POS5 with target.

13. Survey in fish xponder.

14. Repeat as much of 11 as possible.

15. Use ship's satellite communications to report results of experiments.

16. Deploy launcher if high sea state exists.

17. Return to San Diego.

APPENDIX F

SAMPLE OF DEMONSTRATION DIVE PLANS

JMW
05–11–92

AUSS DIVE 39 PLANS

SPECIAL PREDIVE PREPARATIONS

1. Leave Doppler cover off for this dive.

2. Attach Portable Test Range (PTR) 14-inch thin wall stainless steel sphere on a line tied into the descent weight when preparing the descent string.

3. Set elevator prelaunch command to a 13-degree down angle.

4. Change flight recorder sample rate of the acoustic noise to 1/2 second for acoustic link receive level data collection.

DESCENT STRING TESTING

Preliminaries

1. Assure acoustic link operation.

2. For descent string geodetic position determination, collect SBS fixes usable for average position calculation and/or range arc data for position determination.

3. *Turn on CCD cooler.*

4. Turn on Doppler sonar.

5. Turn on hard disk vehicle data logger.

6. Turn on 35-mm camera.

7. Trim vehicle.

8. Take CCD image of descent string.

9. Zero-rate sensors – FRD-rate sensor outputs.

10. Zero Doppler.

Release/Trim

11. Note heading vehicle has vaned to on-descent string, write in log.

12. Zero Doppler.

13. Release from descent string.

14. Trim vehicle.

FLS of 14-inch Sphere

1. Move vehicle down-current of descent string and hover at 50-foot radius, 10-foot altitude. Obtain FLS scan of 14-inch sphere on bottom.

2. Check use and accuracy of FLS target marking on 14-inch sphere.

SLS SEARCH AND CONTACT EVALUATION/TARGET SURVEY/35-mm TESTS/HIGH ALTITUDE CCD ILLUMINATION TEST

1. Starting near the descent string, perform 8,800-ft x 9,000-ft SLS search cells consisting of 5- x 8,800-foot long legs with 1,800 feet between legs (1,000-foot range scale (2,000-ft swath) with 110% coverage). The minimum number of these will be one, the maximum will be (very optimistically) three.

   a. The first cell is centered on lat 32° 36.94′ N, long 117° 30.43′ W (Epilaurd site).

Note: Before beginning of the 2nd and 3rd SLS patterns, check the Doppler by closing the descent string and using FLS target marking. Update Doppler only if absolutely necessary.

   b. The second cell is centered on lat 32° 38.3′ N, long 117° 31.2′ W (Watts site).

   c. The third cell is centered on TBD by Oscar.

2. Obtain SBS fixes whenever possible and **during each turn.**

3. SLS target mark all "small" targets as determined by their return. These will be investigated after SLS search as necessary.

4. Upon contacting each strong target, pause vehicle, and mark target.

Then:

(1) After pause, obtain resume coordinates from IMG processor.

(2) GO to a position 75 feet from the target and hover at 30-foot altitude and 75-foot radius with respect to the target.

(3) Use 250-ft range scale FLS scan to verify target position and update target mark.

(4) GO to a position 30 feet from the target and hover at 30-foot altitude and 30-foot radius with respect to the target.

(5) Use 125-ft-range scale FLS scan to verify target position and update target mark. (repeat at 10-foot altitude if necessary).

(6) GO to a position 10 feet from target coordinates and hover at 30-foot altitude and 10-foot radius with respect to target.

(7) At the first target contacted, take 20 CCD and 35-mm images at 30-foot altitude (this will be used for determining the development process later).

(8) When hovering over the bomber target, determine the altitude limit for a good image (illumination dependent). This requires getting images at as high an altitude as is possible.

(9) Collect SBS and range arc fixes on vehicle hovering over target as required and record fixes.

(10) Send Resume with coordinates obtained from step (1).

PHOTOMOSAIC OF BOMBER

1. At the start point of the photomosaic, hover at a radius while obtaining 10 good SBS fixes on the vehicle. Enter the vehicle heading in the log just prior to terminating the hover at radius. (the vehicle heading should be stable and should be 180 degrees from the local bottom water current direction).

2. Plan a photomosaic that will cover all of the bomber.

3. If there are problems with the photomosaic, try photomosaic in which the legs run strictly perpendicular to the current direction determined above.

4. If possible, obtain SBS fixes during the photomosaic and photomosaic turns.

5. Obtain 10 good SBS fixes while the vehicle is hovering at 10-foot radius at the end of the photomosaic.

ASCENT

1. Set up ascent command for maximum up elevator angle of **9 degrees**.

JMW
05–26–92

AUSS DIVE 41 PLANS

SPECIAL PREDIVE PREPARATIONS

1. Use Doppler cover for this dive.
2. Set Seatrack coordinates such that 14-inch sphere position is (0,0).
3. Set elevator prelaunch command to a 13-degree down angle.
4. Change flight recorder sample rate of the acoustic noise to 1/2 second for acoustic link receive level data collection.
5. Launch vehicle as near as possible to 14-inch sphere previously deployed in search area.

DESCENT STRING TESTING

Preliminaries

1. Assure acoustic link operation.
2. For descent string geodetic position determination, collect SBS fixes usable for average position calculation and/or range arc data for position determination.
3. Turn on CCD cooler.
4. Turn on Doppler sonar.
5. Turn on hard disk vehicle data logger.
6. Turn on 35-mm camera.
7. Trim vehicle.
8. Take CCD image of descent string.
9. Zero-rate sensors – FRD-rate sensor outputs.

Release/Trim

10. Note heading vehicle has vaned to on descent string, write in log.
11. Zero Doppler.
12. Release from descent string.
13. Trim vehicle.

FLS of 14-inch Sphere

1. Move vehicle 100 feet down-current of expected position of sphere and hover at 100-foot radius, 25-foot altitude. Obtain 250-foot-range scale FLS scan of 14-inch sphere on bottom.

2. Target mark sphere position with FLS, and zero Doppler at sphere target mark position.

SLS SEARCH AND CONTACT EVALUATION/TARGET SURVEY/35-mm TESTS

1. Move vehicle to Doppler position (0 ft north ,3600 ft east).

2. Run single leg SLS run at heading 180 degrees. Use 1000-foot-range scale, and hold vehicle speed at 3.5 knots. Use SBS to follow vehicle with ship.

NOTE: If noise is still evident in SLS image, stop SLS run, and move vehicle to a 180-degree search leg with east coordinate = 4100 ft.

3. SLS target mark all "small" targets as determined by their return. These will be investigated after SLS search as necessary.

4. Upon contacting bomber target, pause vehicle, and mark target. Set up for P.R. sequence to be used in video tapes as described below:

(1) After pause, obtain resume coordinates from IMG processor.

(2) GO to a position 75 feet from the target and hover at 35-foot altitude and 75-foot radius with respect to the target.

(3) Use 250-ft-range scale FLS scan to verify target position and update target mark.

NOTE: (4) and (5) are optional depending upon Doppler and sonar and target marking performance.

(4) GO to a position 30 feet from the target and hover at 35-foot altitude and 30-foot radius with respect to the target.

(5) Use 125-ft-range scale FLS scan to verify target position and update target mark. (repeat at 10-foot altitude if necessary).

(6) GO to a position 10 feet from target coordinates and hover at 35-foot altitude and 10-foot radius with respect to target.

(7) Collect a limited number of CCD and 35-mm pictures of the bomber.

(8) Collect SBS and range arc fixes on vehicle hovering over target as required, record fixes, update Doppler to match Seatrack coordinates for bomber based upon the SBS/ range arc fixes.

PHOTOMOSAIC OF BOMBER

1. At the start point of the photomosaic, hover at a radius while obtaining 10 good SBS fixes on the vehicle. Enter the vehicle heading in the log just prior to terminating the hover at radius. (The vehicle heading should be stable and should be 180 degrees from the local bottom water current direction).

2. Plan a photomosaic that will cover all of the bomber. Run legs that are perpendicular to the current direction determined above. Use 15–20-foot altitude if possible.

3. If possible, obtain SBS fixes during the photomosaic and photomosaic turns.

4. Obtain 10 good SBS fixes while the vehicle is hovering at 10-foot radius at the end of the photomosaic.

NOTE: Repeat (6), (7), and (8) above if photomosaic takes more than 30 minutes.

DEBRIS FIELD

1. Conduct unlimited speed SLS on 180-degree course starting from bomber. Use 1000-foot-range scale. Use SBS to follow vehicle with ship. After the extent of the debris field is determined using SLS and the largest of the chunks in the debris field are marked, close a large item in the debris field. Use the same target-closing tactics as used in the bomber.

2. Target mark using CCD on the large chunk, and conduct a photomosaic over the debris field. Altitude of the photomosaic should be 15–20 feet if possible (to get detail on the smallest of targets).

3. Check the target mark on the big chunk for Doppler drift. Update Doppler with big chunk coordinates if necessary.

SABALO

1. Leave the debris field on heading of approximately 165 degrees (Oscar to refine this heading in situ).

2. Scan during transit to submarine site using 1000-foot-range scale, 100-foot altitude. Follow vehicle with ship using SBS.

3. This run is to be about 5 nmi (approximately 32,000 feet), and will therefore, take at least an hour. This means that 16–20 amp-hours will be consumed during the transit alone. The size of the search grid at the submarine site will be determined based upon the amount of energy left in the battery.

4. When the submarine is contacted, follow contact evaluation and optical documentation similar to bomber.

5. Hover on the submarine and mark its position using SBS and range arc.

6. Conduct photomosaic over submarine if battery energy allows it.

ASCENT

1. Set up ascent command for maximum up elevator angle of **9 degrees.**

APPENDIX G

SAMPLE OF DEVELOPMENT TEST REPORTS

JMW
7-25-90

TRACKING SYSTEM TEST REPORT

NOTES, PROBLEMS ENCOUNTERED, TASKS ASSIGNED

1. Port Engine problems; had to restart in middle of channel. Chief Engineer turned it down, once just outside entry to harbor. Ran on starboard engine only for periods of time on way out. Symptom is that coolant expansion tank is spitting water, tank is surging. At 0900, Chief Engineer does not have diagnosis, says that worst case is cracked head; running at 900 rpm.

2. Need tie back on fan-fold doors on maintenance van – Harold

3. Need longer 7/8-in-dia wire rope on launcher trolley (in-haul cable). Length should be at least 6 ft greater than we have now – Harold

4. Launcher trolley system is not controllable. 110 V is available in box, but variable speed control does nothing, and trolley continues to haul in – Stegman

5. Calculate loads on transducer pole and mounts, determine maximum speed limitation with pole down in present configuration, and redesign upper mount and pivot (objective max speed 10 knots) – Jones

6. Batfish – Jones or Rutkowski
   a. Cover hole in front
   b. Wetsuit rubber on id of baffle, glue it in
   c. Open up hole for connector access so connector is not stressed.
   d. Tie down exterior wiring, possibly cover wiring to protect from water drag.

7. Move intercom in bridge closer to helm wheel.

8. Repair interface between compass and speed log in helm.

9. Add swivel to EARS cable sheave– Jones

10. Coat EARS hand winches with water repellant – Jones

    JW's suggestion – LPS–3, heavy oil

    Drew's suggestion – Water Displacing (AMLGUARD) wax-like when dry

    8030–01–041–1596, MIL–C85054A(AS) Type 1 (spray can)

    8030–01–045–4780, MIL–C85054A(AS) Type 2 (quart, brush on)

12. Operation of EARS L/R system requires three people: One at winch, one to watch and give signals, and one to levelwind.

13. EARS cable needs to be inspected and repaired – Rutkowski

14. EARS cable needs to be measured and marked to know how much cable is out – Rutkowski

15. Install bottled water station in control van – Rutkowski

16. GFI for launcher winch unit – Stegman

17. GFI for all exterior use wiring – Stegman

18. Get GPS P-Code or differential – Cooke

19. Elevate/enclose/shroud AUSS hydraulic units to protect from salt water.

20. Protect air-conditioners from destruction from salt spray/immersion – Jones

21. When possible, undercoat maintenance van to avoid rust out – Jones

RESULTS

1. Maximum range to farthest transponder with reliable tracking with Thorn system (ship speed = 4 knots) – 3600 yards, intermittently out to–4200 yards

1a. Honeywell – tracked out to 8000 ft. (farthest xponder).

2. All transponders are in place and responded to turn–on codes. For codes B and A, it took 4 to 5 blasts of code in a row to get them to come on. A = 1, 11.5, B = 2, 12 kHz, C = 3 and 4, 12.5 and 13 kHz. 3 and 4 came up immediately while at center of northern edge of net holding headway into seas with bow thruster. 1 and 2 came up while steaming on a line from 2 to 3 at about 4 knots.

3. Minimum ship speed with both mains at idle = 4 knots, ships log and GPS/Seatrack in agreement.

4. Thorn's system can reliably track LBS even when bow thruster is in use.

5. Osborne is trained on Thorn system LBS tracking of ship. Thorn needs to go on first "fish cycle" test.

6. Maximum range of SBS (with today's temp profile) was

reliable–another day**************

intermittent–another day**************

7. Electrical noise on batfish overshadowed acoustic noise – must fix.

8. Bow thruster almost wipes us out (Thorn system) while we are in net. With trolling gear in (around 1.5 knots), transducer pole is very good, very quiet. At normal speed (4.0–5.0 knots) transducer pole is "good" for noise – these are not measurements, but qualitative due to listening to NS–011.

9. Stand-alone GPS track and LBS (Thorn) tracks may be as close as 30 yards. Loran was off from LBS track as far as 300 yards.

10. With 5 satellites up, tracking was degraded to about 100 yards dither. With 4 satellites up, dither was down to around 5 yards.

JMW
AUG. 22,1990

500-FOOT AUSS TEST REPORT
(AUSS DIVE 1)

VEHICLE HANDLING AND LAUNCH AND RECOVERY

1. Vehicle opens and closes easily on new carts.

2. New electronics chassis tray on top of center section works well. Needs a place to hang it out of the way – Harold

3. Saddles stabilize the vehicle very well. Need to modify stabilizing arms so their length can be varied in place – Harold

4. Manual hoists and manual transfer of the vehicle on I-beams are inconvenient, especially at sea. Need air or electric drives for these – Walton, Harold

5. Launcher installation is rolled with respect to the van and the rails. This creates an interference between the vehicle and the launcher during vehicle transfer. Solution to this problem is putting a shim under the port side pillow block – Harold

6. When raising and lowering the vehicle at the launcher and the cart locations, the vehicle needs guides to stabilize it – Walton, Jones

7. We grappled the float line on the third try. We'll get a thrower on the control van after platform the next time.

TEST RIGGING AND PROCEDURES

1. Test rigging went as explained in the test plan. Mike R. and James did the work out in the small boat. They said it went so well that they would be willing to do it down to 2500 ft.

2. I added one conservative measure, I tied a line to the vehicle and passed it off to the small boat before we launched.

3. Radio communications were handled at three locations–the bridge, small boat, and control van. I did not have a person with an optical range finder at the transducer pole as described in the test plan, but the range finder was in the small boat. I had them read off ranges to the transducer pole periodically over the radio so both the bridge and the van knew the range. This process worked very well.

SUPPORT SHIP AND SHIP HANDLING

1. There was no down time resulting from ship problems.

2. The bow thruster was secured during the acoustic link and tracking systems portion of the testing to avoid bubbles in the water at the location of the transducer pole.

3. During station-keeping maneuvers, bubbles interfered at the transduer pole as a result of the reversing of the ship's main propellers. This will not be a problem when the vehicle is deeper

and we can remain underway at all times and not back down. We will also be able to use the transducer at the batfish for the LBS and acoustic link.

4. The Captain made four runs at the approach to vehicle recovery: one planned dry run, two where we missed with the grappling hook, and the final capture.

TRACKING

1. We were able to track the vehicle tranponder (yellow banana) using the Honeywell ultrashort baseline (USBL) with reasonable dependability, but with unreasonable accuracy. The ranges calculated by the Honeywell SBS were incorrect by as large a factor as 2 when compared to the Thorn/NS–011 fish-cycle tracking. Team members guessed the Honeywell SBS was "on" 50% of the time. Since this was oddball geometry, we will not pursue quantitative analysis of the SBS any further at this time, but will look at it closer when we are operating at 2500 feet.

2. Both the Thorn and the Honeywell systems were able to track the vehicle in long baseline (LBS) fish cycle. The Thorn system was more dependable, and more adaptable since it can track with as few as two bottom transponders for the two cycles of the fish-cycle tracking. The Honeywell appears to have a software problem in the fish-cycle processing.

3. A problem that affected the performance of both tracking systems in the fish cycle during this test was when the vehicle sent out the 7-kHz tone, it didn't always trigger the net. Whenever the net was triggered in the fish cycle, the Thorn system got good fixes.

4. In some cases, the vehicle missed the 9-kHz interrogation from the surface entirely. Jim Thorn will investigate this problem by reviewing tracking data files he collected during this dive.

5. To the best of my knowledge, this seatrip was the first time that "passive tracking" of a submersible has been demonstrated realtime at sea. Jim Thorn switched from tracking in the fish-cycle mode to the "passive mode" without missing a beat. The accuracy achieved seems to be good also. In the passive mode, Thorn's system used GPS to fix the position of the ship, and listened for the vehicle's interrogate frequency and then the responses to this interrogate by the transponder net to fix the vehicle's position.

SURFACE CONSOLES AND COMPUTERS

1. The surface command computer (CMD) appeared to drop some of the data it received through the acoustic link channel. These were data originating at the main vehicle computer, handled by the sensor computer, passed to the acoustic link, and handed to the CMD at the surface. It turns out that the problem existed in the main computer in that semicolons were not being appended to the end of data before being handed to the sensor computer.

2. Files from the Seatrac system being written to the server could not be accessed until after these files were closed. Since this is a problem internal to the Seatrac software and we do not have access to their high-level code, the situation will exist as long as we depend upon Seatrac for integrated navigation. Interim solutions to this problem are: Open and close files frequently. Obtain the Seatrac data from the printer port.

ACOUSTIC LINK

1. Acoustic link performance was not what we had hoped during this test. It was, in fact, an oddball geometry that we had not had experience with. But a major objective of this test was to

see if the new acoustic link and configuration was going to work at all. In satisfying this objective, we found that the acoustic link will work, and found some problems we will be fixing before the next dive.

2. The acoustic link performed well only when the surface transducer was somewhere within 200 feet of the zodiac which was nearly directly above the vehicle. Since the vehicle was 500 feet deep, this did not satisfy the 45-degree half-angle cone requirement defined for operations of the acoustic link.

3. Two problems for which solutions are being pursued were identified as a result of this test. (1) The stinger transducer was not "blanked" during this test so that any noise in circuits leading to it became acoustic noise in the water. Since this was noise right at the vehicle, the acoustic signal to noise at the vehicle acoustic link transducer was affected adversely. (2) There were two different "tonals" that showed up within the acoustic link electronics that adversely affected the signal to noise of the acoustic link electronics.

So, the only downlink signals that would survive the noise environment at the vehicle and be recognized at the vehicle would have to be very strong, such as signals emanating from a source very close to the vehicle.

VEHICLE ELECTRONICS AND COMPUTERS

1. In the prelaunch check, it was determined that the weight shifter could not be stopped in an arbitrary position (such as in the center), and would stop only after it reached the forward or after microswitch. Since we had no way we could tell if it would "trim" the vehicle (with the vehicle pitch as feedback), we took the conservative way out. Since we needed a reasonably level vehicle during the dive, the weight was centered prior to the dive by running the weight shifter until the weight was in the center and then turning the vehicle power off. When the vehicle was turned back on, and throughout the test, the weight remained centered. The pitch of the vehicle during the test was less than ± 15 degrees, but varied due to its direct connection to the zodiac bobbing on the surface. The ability to invoke the stop and ESP commands during the next dive will allow us to use the weight shifter in the fashion it is supposed to be used with confidence that we can trim the vehicle no matter what happens.

2. Early in the dive, the after bit buss got out of synchronization with the rest of the system. As a result, the acoustic link channel got clobbered with uplink transmissions filled with error messages relating to the after bit buss. The cloud of error messages was so thick that most other transmissions could not get through from either the up or the downlink. To salvage the dive, we maneuvered the ship very near the zodiac, and got a good transmission down to the vehicle—a message within the transmission successfully "turned off" the aft bit buss. The phrase "turned off" actually means that communications to and from the after bit buss were discontinued.

JMW
9–20–90

DESCENT STRING TEST REPORT
(AUSS DIVE 2)

Refer to the Descent String Test Plan for the procedures and objectives planned for this dive.

INTRODUCTION

Every once in a while, a Project Engineer needs a "difficult" day to reassure himself that he can make the right decisions under adverse conditions. Unlike previous dives, I cannot go down the list of objectives and tell how they were met. Instead, I can say that several were met only after working around many problems. A major value of the dive can be found in the lessons learned as a result of postdive analysis and discussions, and some of the subsequent testing and analysis catalyzed by the dive. Some facts and some guesses resulting from some investigative work has led me to believe that the following dive synopsis pretty well describes what happened during the dive. While reading the synopsis, be assured that I have taken a look at all of the problem areas you will observe, and they are being worked out for the next dive evolution.

DIVE SYNOPSIS

Due to foggy conditions, the visibility during transit to and at the operations area (OPAREA) was severely reduced. On the way out, it was discovered that the OAR ADF receiver was working improperly. When the transducer pole for the Honeywell USBL was deployed, the Honeywell system ceased to operate. When we attempted to load the ascent weights, the release mechanisms were jammed. An erroneous excessive battery current error message (which showed up only after the vehicle checkouts were complete and the vehicle was being readied for transfer the launcher) occupied the acoustic uplink channel nearly full time. The combination of these conditions, of course, led me to delay the launch.

When I gave the go ahead to launch, the fog had lifted some, the OAR receiver appeared to be operating properly (we did some rewiring), the weight releases had been loosened up (we found that steel parts had been used in them instead of stainless steel and they had corroded), we had defeated the erroneous error message and it had not come back for quite some time, and I had traded the ability to track the vehicle in USBL for the ability to relocate it where it would be "anchored" (see test plan).

Although time was marching into the afternoon and the fog had not completely lifted, I had the small boat and crew deployed for photos and launch. The launch went smoothly as did the descent line rigging and the lowering of the vehicle to the bottom. Unknown to me at the time, the vehicle overshot the anchor weight line (fact as shown in postdive analysis of flight recorder data), and may have gotten tangled in the line (guess) when the weight hit the bottom. The weight reached the bottom at 1445.

Soon after the vehicle was on the bottom, the acoustic uplink channel began screaming repeatedly at us with the erroneous high battery current message we thought we had conquered. This made it nearly impossible to communicate with the vehicle or perform the tracking experiments we desired. Eventually, we were able to get some "tricky" commands through to the vehicle that defeated the erroneous error message long enough to conduct limited tracking experiments.

After some time and great effort was spent obtaining questionable results of the tracking system (so much communications sound was in the water that the tracking system performance was most certainly adversely affected), we got commands through to turn on the Doppler sonar, increase the uplink data rate to 4800 bits per second (bps), and to trim the vehicle from a nose down angle of 11 degrees to a nose down angle of 4 degrees. Further trim was not possible since the trim weight was against the stops at this point.

For 22 minutes (16:22:30–16:44:30) the vehicle was relatively level, and Doppler data were collected (meeting a test objective), but postdive review of the data showed that the resolution of the flight recorder data need to be greater to allow development of random walk statistics.

At the end of this 22-minute period, and for an unknown reason, the vehicle (probably the main vehicle computer) fired the descent and ascent weight releases. Only one of the ascent weights came free, and the descent line remained snagged on the vehicle. The vehicle pitch went to 58 degrees nose up, the roll angle went to 20 degrees, and the vehicle remained at this attitude for the remainder of the dive.

Starting at 16:44:30 (when the weight releases were purposely fired) and until the end of the dive, the frequent 4800 bps communications from the vehicle were strong and reliable as long as the ship was astern of the vehicle (within the beam of the vehicle acoustic link transducer). The uplink transmissions were weak and usually not detected at the surface console (we could hear the transmissions coming through the speaker) when the ship was ahead of the vehicle. Tracking and downlink communications were still difficult due to the monopoly the uplink was holding on the acoustic channel.

Throughout the dive, unplanned 9-kHz "auto-interrogations," and unplanned 9-kHz tone resets occurred. The interrogations from the vehicle did in fact set off the transponder net, and the tone resets did in fact reset the vehicle, which means the on-board computers were rebooted. The tone reset is evidenced by the vehicle returning to what is called the basic vehicle mode where the tracking mode is set, the acoustic link is set to 2400 bps, and the Doppler is turned off.

To end the dive, we sent descent and ascent weight release commands to the vehicle and the vehicle returned acknowledge and command completion responses back to us for both commands. Of course, nothing happened since the vehicle had already released what it could earlier. I had the small boat crew grab the surface buoy, pull the buoy and 50 feet of its tether on board, and then release the buoy and line. At the completion of this maneuver, the vehicle ascended to the surface.

Upon surfacing at 19:25, the flasher was quite visible, and the OAR ADF immediately began indicating. By maneuvering the ship, it was found that the OAR indicated the bearing to the vehicle not in the "analog" fashion it was able to achieve just prior to launch, but in a binary fashion such that the bearing to the vehicle was shown only as either directly to starboard or directly to port of the ship. The recoveries of the vehicle, small boat, and transducer pole went smoothly in the dark.

STATUS ASSOCIATED WITH THIS SEATRIP

Acoustic Link

1. Reliable 4800-bps uplink transmissions are possible from 2500 feet of seawater with the upgraded vehicle system. Reliable 4800-bps uplink transmissions are possible with the vehicle in the launcher. When the vehicle is in the maintenance van and hooked up to the umbilical, RS–232 in the umbilical running next to snails in the hut rides on the transmission so that one of the acoustic link channels is incapacitated. To work around this shortcoming, the capability to xmit 2400 bps on this channel can be checked out before the vehicle is closed.

Vehicle Computers

1. The potential still exists for premature weight releases that would end the dive. Investigations into this dive have not defined the reason the releases were activated; no direct solution to the problem has been prosecuted. Even so, work is being done to reduce the likelihood of premature releases due to loading on the bit buss, or tone resets.
2. The newly implemented elevator software operated properly for the duration of the dive.
3. The bit buss operated all day without indicating any fatal problems.
4. Activation of the tone reset did not activate the weight releases as it had previously.
5. The resolution of the flight recorded raw Doppler data needs to be increased.

EARS

1. The batfish location is better than the transducer pole location for LBS acoustic tracking and acoustic link functions. To achieve an acceptable noise level at the batfish transducer, 250 feet of batfish cable was let out. According to the manufacturer's literature, with the 250-ft scope and at the speed (3 knots) we were running, the batfish was towing at around 180-ft depth.

Vehicle Handling, Launcher, Rigging, and Operations

1. The launcher is still misaligned with respect to the overhead saddles.
2. The clearance between the launcher docking cart bumper and the bottom of the vehicle during transfer to and from the maintenance van is 2.5 inches.
3. The vehicle can be easily lowered from a zodiac boat on a line down to 2500 feet of depth.
4. When lowering the vehicle to the bottom, the velocity at which it is being lowered should be slowed just prior to reaching the bottom to avoid entanglement.

JMW
Oct.2,1990

AUSS DIVE 3 TEST REPORT
(FIRST FREE DIVE)

INTRODUCTION

The dive conducted 28 and 29 September is the first dive where the AUSS vehicle was operated free of any lines or descent equipment. The objectives of the test and the procedures followed are in my test plan memo "Acoustic Link, Tracking, And Hover Controls Tests", Ser 941/79-90.

The sea trip consumed 29 hours, starting at 0500 Friday, when we left the Scripps pier, until 1000 Saturday, when we tied up to the pier. The trip results are a mixture of milestones, successful at-sea troubleshooting, and definition of areas that require further work.

ACCOMPLISHMENTS

Acoustic Link

1. The acoustic downlink operated almost flawlessly. Nearly all commands were received and acknowledged by the vehicle.

2. Down transmissions and 2400-bps up transmissions were reliably carried and decoded by the acoustic link regardless of the position of the ship within the vehicle acoustic link beam pattern. This suggests that the acoustic link beam pattern "holes" we experienced in the past have been eliminated. To demonstrate this, I had the ship steer patterns that encircled the vehicle while it was still attached to the anchored transponder descent string.

3. Although 4800-bps up communications were possible, they were not reliable. Unfortunatly (but also fortunately since it's easy to fix) the cause of the degradation in the 4800-bps communications can be blamed on electrical noise in the EARS batfish receive circuitry. The EARS cable is in bad shape and scheduled for replacement this week, and we are planning to remove the suspected noise source (110 Vac in the tow cable, which powers a dc power supply in EARS) and supply dc voltage to the batfish through the cable instead. Other fixes to the 4800-bps communication problem could be increasing the output power of the acoustic link at the vehicle to maximum (from the present 25 watts to 100 watts), and increasing the gain of the pre-amp in the EARS batfish to improve the signal to noise there. Neither of these measures should be required for 2500-foot operation as long as the noise source is removed, but they will be important for deeper operations.

4. Auto-tracking transponder interrogations and tone resets did not occur during this dive! Improvements have been made in the acoustic link since the previous dive such that the effect of the tonals that interferred with the dive have been reduced.

Tracking

1. A new acoustic link mode has been added to the vehicle to allow tracking in the "passive" mode with the Thorn/NS011 tracking system. During the dive, this mode worked better than the

fish cycle and the relay modes, and more improvements to it are in the works. In this mode, when a series of acoustic link transmissions are completed, the vehicle automatically sends out a 7-kHz interrogation pulse to the bottom transponder net. The Thorn system uses surface tracking (GPS or MiniRanger) to fix the position of the ship. The computed position of the ship along with the NS011 time differences between receiving the 7 kHz and the transponder replies are used by the Thorn system to find the solution for the position of the vehicle.

2. The repaired Honeywell USBL system was reliable as backup tracking system during this dive. During the previous dive, the Honeywell system completely failed on us. During postdive investigations, we found out the connector going to the Honeywell SBS transducer had failed and flooded. We remachined the transducer bulkhead and rebuilt the cable to accommodate DG Obrien connectors, and the system worked well during this dive.

Bit Buss

The bit buss system worked quite well during this dive. Since this was the first completely "free" dive, I made sure all emergency functions were in place in the vehicle system, including all of the bit buss emergency processor functions. There are several emergency conditions in which the bit buss emergency processor will cause the release of the ascent weights. For 6 hours (the length of this dive), none of these conditions existed, and the bit buss did not fail and cause the weight drop. This is a major milestone since less than a month ago, the reliability of the bit buss would have allowed maybe a 6-minute dive instead of a 6-hour dive. Hats off to Howard for coming so far in so little time under so much pressure.

Transponder Descent String

1. The transponder descent string used to pull the vehicle to the bottom was successfully deployed for the first time.

2. The vehicle descent-arresting float appears to have descended nose down, and when the transponder was commanded to release, the float came to the surface nose up. This float trip is due to a little rope trick that had never been tried before and it worked great.

3. While still attached to the descent string, the vehicle leveled out nicely. The vehicle released from the descent string without a hitch.

Vehicle Handling, Launch, and Recovery

For normal launch and recovery, everything in this area has become routine. I did an "abnormal" recovery, and it didn't go too badly either. The abnormal recovery involved connecting a line between the vehicle's forward lift eye and the docking cart and pulling the vehicle up the ramp.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

Flight Recorder

1. Only the first 45 minutes of this 6-hour dive were flight recorded.

2. The flight recording ended when a command was sent to the vehicle to change the flight recorder update rate.

3. Investigations have shown there are problems in both the surface and vehicle software.

4. Software fixes have been identified and implemented, and will be tested during the bay test on Thursday, 4 Oct.

Control Systems

1. The hover controls (heading, depth, altitude, pitch) were stable and "solid" during the dockside controls tests.

2. None of the hover controls were "solid" during this sea test.

3. A dockside test is scheduled for Thursday, 4 Oct to try out and flight record the control loops and any "fixes" we might conjure up.

4. Since flight recorder data are not available for the period of time the controls tests were run, the nature of the controls problems is not known. The only observations made are of the status updates of heading, depth, altitude, and pitch during the dive. The vehicle status is updated only every 15 seconds.

5. Two theories, which focus upon instability, have been tested and disproven on Jimmy's simulator. One theory was that delays introduced in the sensor output sampling caused an instability. The other theory was that the rate sensor zero adjustment was off.

6. One more theory we are exploring is that the bit buss introduces noise glitches that corrupt the sensor inputs to the control loops.

Float Release

1. The float release jammed during this sea trip.

2. Jimmy has dissected the float release mechanism, and found two deficiencies that are being eliminated.

3. The release shaft can get cocked if the assembled release mechanism pieces move with respect to each other. This relative motion can occur because the pieces are assembled with bolts through holes with tolerance. To fix this, interference pins are being installed throughout the assembly.

4. The spring plunger, which bears against the diaphragm, is poorly designed and can get hung up under some circumstances. A redesign is being implemented in the machine shop.

Ascent Weight Releases

1. Two problems with the ascent weight release system have been corrected.

2. The starboard weight could be jammed into the spectra fairing cone. To solve this, the weights have been shaved so that the top of the weights come in contact with the weight socket before the sides come in contact.

3. The weight release mechanisms did not always latch properly when the weight was loaded. First, the mechanism had been put together with steel pins that had corroded and jammed it up. These steel pins have been replaced with stainless steel pins. Second, the mechanism required an

interference with the top of the inserted weight pin to close the jaws that retain the weight assembly. The tolerances were not tight enough for this to operate reliably. The interference mechanism function has been replaced by a plunger driven by a leaf spring.

Strobes

1. Both strobes leaked, and were electrically inoperable at the end of the dive. The strobe housings had been successfully pressure tested before the electronics and optics were installed in them.

2. Inspection of the disassembled strobes has shown they were improperly assembled with too much silicon grease (this grease is some stuff we had never seen before). There was very little water in each strobe, which also supports low-pressure excessive o-ring grease failure.

3. With excessive o-ring grease, the o-ring (at low pressure) does not seat properly due to grease interference. At higher pressure, the o-ring will be displaced inward, displacing the grease and sealing properly. This explains why the strobes were only partially flooded.

4. The strobes will be properly assembled prior to the next dive. Mark Rasmussen has found the damaged components in the strobes and is replacing them.

Electronics and Software

1. A false high-battery current alarm still shows up from time to time. This is a particularly difficult problem to troubleshoot since it has never shown up in the lab. It has only shown up when the vehicle is closed and we are communicating over the acoustic link. Further, there has been only one occasion when this has occurred when the vehicle was not submerged.

2. We believe this dive was terminated by a false leak detect alarm. The vehicle still thought it had a leak when we brought it on board. We are exploring the possibility of this being caused by either condensation or metal debris on the leak detector.

CONCLUSIONS

1. The performance of the AUSS acoustic link in dive 3 is already superior to any performance of the AUSS acoustic link, and solutions to its problem areas have been defined and are being worked on.

2. Long baseline tracking of AUSS in dive 1 was more consistent than in any AUSS prototype dive, and improvements have been defined and are in the works.

3. Even with the shortcomings of the bit buss system, the computer systems on board this vehicle and at the surface appear to be more robust than on the previous system. During this dive, the computer systems did not require any resets or tone resets.

4. Due to intelligent structuring and management of the AUSS technical development and tests, the progress per dive and lessons learned during the dives have both been maximized.

JMW
Oct.19,1990

AUSS DIVE 4 REPORT

INTRODUCTION

The three previous dives were: 500-foot test, descent string test, and Dive 3 (the first free-swimming test that was the acoustic link and tracking portions of the AUSS Acoustic Link, Tracking, and Hover Controls Tests Plan).

The primary objectives of this dive were achieved. The objectives pertain to hover controls and are 1 through 11 in the controls portion of the AUSS Acoustic Link, Tracking, and Hover Controls Tests Plan, NOSC Ser 941/79–90.

A major milestone of this dive is that for the first time, the mechanical, launch and recovery, and SAR systems worked well enough that neither a small boat nor a swimmer was required during this sea test.

ACCOMPLISHMENTS

Control Systems

1. Prior to this sea test, two dockside tests were conducted to work out the problems in the hover controls.

2. All hover control loops were successfully tested during this dive.

3. Plots have been made from vehicle flight recorder data for step function changes made in the heading, depth, and altitude.

4. Flight recorder data have been analyzed for the period the vehicle was in hover at a radius.

5. The heading control loop is very well behaved, with the main thrusters maintaining heading within ± 1 degree by producing differential thrusts within an envelope no greater that 20% of maximum thrust. Step function heading changes of varying magnitude produced less than 2 degrees of overshoot in all cases.

6. Depth control steps produced no more than 6 feet of overshoot for varying-sized depth command steps. Depth was held to ± 1 foot requiring vertical motor thrusts within ± 50% of full thrust. Pitch was maintained to within ± 1 degree while the vehicle was holding depth, but pitched to a maximum amount of 5 degrees during a depth change. The average dynamic pitch angle during depth hold was 2 degrees nose up.

7. The vehicle altitude (obtained from the Doppler sonar) needs to be averaged or filtered to obtain satisfactory altitude hold. Altitude hold can be used, but it is coarse. Altitudes were held to within ± 8 feet, and the vertical thrusters were receiving thruster commands of ± 100% throughout the altitude hold tests. During altitude hold, the pitch angle was held within ± 3 degrees around an average value of 5 degrees nose up. The maximum change in pitch during an altitude step was 12 degrees. Jimmy has taken the raw Doppler-produced altitude data (from the

vehicle data logger) and simulated a 10-sample averager and used it in the vehicle control simulation. The simulation shows the vehicle will respond to altitude changes with a 5-second delay, and will have a satisfactory altitude hold. The 5-second delay is acceptable since this is a hover control loop that will not be used at advance speeds greater than about 1.5 knots.

8. The new hover at a radius algorithm worked remarkably well on its maiden voyage. The vehicle was commanded to hover with a 10-foot standoff from a vertical line. A postdive plot of flight recorded Doppler coordinates show an average standoff of around 12 feet for a 1-hour period. Since the Doppler sonar head is 10 feet aft of the CCD camera on the vehicle, the camera head was an average of 2 feet away from the objective. The maximum Doppler coordinate offset was within 30 feet, which means the CCD camera was never farther away from the objective than 20 feet. Some "stiction" existed in the main propulsion drives during this dive, which (due to deadband) may account for some of the larger excursions from the objective. An improved design involving plastic bearings has been implemented on the main propulsors, and should improve the hover at a radius even more for the next dive. Unfortunately, the Doppler drift is unknown for this period of time because the LBS tracking data for the period was not successfully stored.

Electronics and Software

1. I was concerned that the first launch attempt of the prior sea test may have been terminated because of a grounding problem either due to a short in the strobes or commoning the signal and power grounds to the chassis. To prove that this was not true for this trip, we put the vehicle in the launcher and lowered it into the water until the strobes and the after endbell were wet. We monitored the vehicle through the snails during this experiment. Once I was convinced that neither of these items were a problem, we launched.

2. All the singular commands sent to the vehicle during this dive and recognized by the vehicle worked properly.

3. When command strings were sent to the vehicle (commands that were chained together), the second command token was tossed out such that none of the commands were executed. The command tokens tell what the commands are. This problem is being rectified for the next dive.

Bit Buss

1. The bit buss system worked well during this dive.

2. On a few occasions, bit buss errors were detected, but the vehicle system recovered from the situation each time.

Float Release

1. Final improvements to the float release were implemented and tested prior to this sea test.

2. The float release can get "cocked" if improperly installed, so proper installation procedures have been defined.

3. The float release and antenna erection system operated properly on two occasions during this sea test.

Ascent Weight Releases

1. Final ascent weight release improvements were implemented prior to this dive.

2. The ascent weights were successfully dropped twice during this sea test. One drop was due to a leak detect indication probably triggered by conductive debris on the forward center pressure vessel leak detector. The second drop was due to a leak detect indication probably triggered by saltwater on the after center section pressure vessel leak detector.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

Strobes

1. Only one strobe was wired-in going into this dive. It operated (as evidenced in the CCD image), but may not have operated fully within the time in which the CCD camera shutter was

2. Stan Watson is adjusting the CCD camera shutter speed such that the strobes' illumination time is completely within the time when the camera shutter is open.

3. More water was found in the nonfunctional strobe. Design improvements that will improve both seals associated with the window end of the strobes are being implemented.

Flight Recorder

1. We "made" the flight recorder work on this dive. This is evidenced in the large amount of controls data we have collected and plotted.

2. To make the flight recorder work, we started it up before the dive, and did not mess with it during the dive. The reason for this is that in previous dives, the sending of an FRS command (flight recorder sample rate command) effectively discontinued the flight recorder function.

3. The FRS command allows us to increase the sample rate for periods of high interest. Since the compromise we made during this dive was to leave a high sample rate throughout the dive, the random access memory for the flight recorder wrapped around after 8 hours, and we lost some of the data from the dive.

4. It was also learned, during tests before the dive, that when a flight record clear command (clears all flight recorder memory away) is sent, you must wait until the next flight recorder node before any data are recorded. Since the nodes are 1/2 hour apart, you may have to wait as long as 1/2 hour before data are recorded.

5. We are troubleshooting the FRS and clear software problems and will hopefully have solutions before the next dive. To improve upon the wrap around problem, the flight recorder RAM has been increased by 50 percent.

Cooling

1. During the last two dives, temperature-indicating strips have been in place throughout the vehicle.

2. Two observations of significance have been made.

a. The temperature rise from the "cool" air at the inlet to the computer fans at the bottom of the computers to the exhaust air at the top of the computers is 10 to 15 degrees.

b. The "cool" air at the inlet to the computers is 10 to 15 degrees higher than the air in the endbells.

3. The temperature rise through the computers makes sense, but the air at the cool side is not as cool as it should be. To improve upon this, fans have been installed that suck cool air from the endbell region and blow it toward the bottom of the computers.

CONCLUSIONS

This dive was a major milestone. All the hover control loops worked, and all but the altitude control loop (which is being improved) worked very well. I must give credit to Jimmy Held for his diligence in developing a mathematical model of the vehicle, obtaining software tools to install the model in, developing control loops (some very innovative, as in the hover at a radius), and putting the model and the loops together with the tools to refine control loops, which worked so well the first time they were used at sea. I must also give Howard McCracken credit for supporting, advising, and providing at-sea AUSS experience support to Jimmy, and for accurate implementation of the control loops.

JMW
11-28-90

AUSS DIVES 5A AND 5B REPORT

INTRODUCTION

This very ambitious dive effort was based upon the "AUSS DIVE 5 PLAN." As usual, the dive was a creative modification of the plan. In fact, there was a Dive 5a and a Dive 5b. Most of the objectives were met during Dive 5b, but I am writing these notes to cover the events of both dives.

ACCOMPLISHMENTS

Pressure Hull

1. Prior to this test, freon and helium leak tests were conducted on the AUSS vehicle pressure vessel in an effort to find the source of saltwater found in the pressure vessel. Both tests indicated that the pressure vessel was sound and did not have even the most minute level of leakage. With this information, we pressed forward and made Dive 5.

2. During the preclose preparations of the pressure vessel, we inserted toilet tissues around the inside surface of the pressure vessel near the two titanium/graphite epoxy glue joints. This was done in an effort to pinpoint the location of saltwater intrusion if it were to occur. When the pressure vessel was carefully opened at the end of the dive, it was discovered that **no** saltwater had leaked into the pressure vessel.

Doppler Sonar

1. During this dive, the vehicle moved from 0 altitude to altitudes as high as 1000 feet several times. The drop out of the Doppler sonar with the particular bottom type existing was consistently around 250 feet.

2. Doppler data were collected in the flight recorder for future random walk investigations for at least 8 minutes during Dive 5a, and for 45 minutes during Dive 5b.

Acoustic Link

1. **Intervention Commands.** We were able to communicate with the vehicle while it was transiting during this dive. This was possible due to efforts made since the last dive to protect the vehicle acoustic link receive system from electrical noise, which occurred while the main thrusters were running.

2. **Dual Frequency.** The dual frequency (one frequency for the up channel (11.33 kHz), and one frequency for the down channel (10.989 kHz)) acoustic link system worked on its maiden voyage. The objectives of switching to dual frequency were to (a) avoid false carrier and (b) to avoid a "double ping" that occurred when the vehicle was in navigation mode 3.

3. **False Carrier Detect.** The acoustic link must periodically stop transmitting (go quiet) and go into the receive mode to listen for a down transmission. The presence of a carrier is the means

by which the acoustic link knows there is a down transmission. When the vehicle detects the presence of the acoustic link down channel carrier frequency, up transmissions are held off until carrier goes away. When the same frequency was used for up and down channel carrier, reverberations from the up channel created a "false carrier detect," which would temporarily hold off uplink transmissions. Use of the dual frequency system appears to have solved this problem.

3. **Double Ping.** In navigation mode 3 (passive-tracking mode), the vehicle sends out a ping to interrogate the bottom transponder field when the vehicle has completed an up transmission. Previously, when a transmission was completed and a ping sent out, a reverberated carrier from the transmission would be interpreted as a down transmission. Failure to obtain synchronization with the ficticious down transmission would cause the vehicle to reenter the receive mode and send out a ping. This might occur several times in a row. Use of the dual frequency appears to have solved this also.

CCD Camera and Strobes

1. We obtained our first clean charge-coupled device (CCD) images during this dive.

2. CCD images obtained during the dive show that we have adequately synchronized the camera and the strobes, and that the noise in the images is at an acceptable level.

3. The first image was of the line from the vehicle nose to the transponder in the descent string. A section of the line and the white foam ring of the transponder (which was around 50 feet below the vehicle at the time) were discernible in the image transmitted and stored at both low and high resolution.

4. Several low-resolution bottom images were transmitted and stored for altitudes of 0 to around 80 feet. Nothing of interest appeared to be in the images since they were taken randomly.

5. Both strobes operated throughout the dive, and gave reliable illumination for all CCD pictures taken.

Forward-Looking Sonar

1. We obtained our first forward-looking sonar (FLS) sonagrams of the water column and the ocean bottom ahead of the vehicle. No obvious targets have been defined, but valuable information on required sonar gain adjustments and noise sources affecting the sonagram was collected.

2. Jerry Mackelburg plans to lower the time-varied gain and increase the overall gain of the FLS prior to the next dive for improved performance.

3. The power amplifier worked well for many sonar pings, and appears to be protected by the circuitry added since the last dive.

4. The major cause of noise in the sonagrams has been determined to be the operation of the main thrusters. This may be related to the short to seawater resulting from the failure at the after vertical motor connector (see Electrical/Electronics under Problems... below). For the next dive, a relay that will allow connecting the negative side of the battery to chassis ground will be implemented for experiments in how this affects noise in the sonar and the acoustic link.

Command Strings

1. **Success.** During this dive, it was demonstrated several times that multicommand strings were successfully communicated to the vehicle.

2. **Previous Dive.** During the previous dive, it was not possible to communicate a string of commands to the vehicle and have the vehicle prosecute any of the commands in the string. Control of the vehicle was accomplished by communicating one command at a time.

3. **Definition and Solution of the Problem.** It was found that the first character of the header that defines the second command in the string was being dropped. The software was improved to correct this problem.

Tracking

1. **Inverted Long Baseline.** I believe the handiest way to track the AUSS vehicle in a real search scenario where a large area is to be covered is by an "inverted long baseline" approach first described by Jim Held. The inverted long baseline approach does not require three or four bottom-mounted transponders to be deployed and surveyed in for each square mile or so of territory to be covered. The technique relies upon the ship to become a moving transponder instantly surveyed in by GPS or MiniRanger at positions where the range between the ship and the vehicle have been determined.

The ultimate implementation of inverted LBS involves mixing of the LBS ranging with the Doppler sonar information to give vehicle position fixes for a moving vehicle. This implementation is a bit down the road for us, so I proposed to Jim Thorn that we collect data on inverted LBS tracking of a stationary vehicle, and look at how to minimize the time to obtain accurate inverted LBS stationary vehicle fixes.

The stationary vehicle version of the inverted LBS does not involve Doppler data, and is strictly a calculation of the vehicle position based upon ranges to it from position fixes of the ship on the ocean surface. In a search scenario, a fix of this sort would be made when the vehicle is hovering just prior to running a search pattern, and another fix would be made when the pattern is completed. Depending upon the accuracy and drift of our Doppler, a reasonable size for the search pattern described here could be 1 nmi^2.

A large amount of data were collected to help demonstrate this version of the inverted long baseline concept. Jim Thorn has reduced some of the data and claims that the concept is sound. "Stationary vehicles" consisted of the vehicle on the descent string, the descent string transponder, and the bottom-mounted transponder net.

2. **Relay-Tracking Mode.** The relay-tracking mode (surface tracking with GPS, MiniRanger, or Loran mixed with vehicle-to-surface direct range and vehicle-to-transponders to surface total distance to give a vehicle position fix) worked "to perfection" during this dive according to Thorn.

3. **Passive-Tracking Mode.** The passive-tracking mode (interrogation of transponder net originates at the vehicle at the end of vehicle transmissions) only worked about 10% of the time. It appears that the surface tracking receiver has difficulty deciphering the returns from the transponder net from the reverberation of the acoustic link.

Solutions to this problem are to either increase the frequency of the transponder net out of the acoustic link band, or increase the time delay between the end of the vehicle up transmission and the tracking ping.

4. **Pseudopassive Mode.** The Honeywell RS906 operator can wait for a quiet time in the vehicle up transmissions, and send an interrogation to the vehicle acoustic link transponder. The Thorn passive-tracking system looks at the resulting chain of events including the transpond ping at the vehicle and the responses of the transponder net as a passive-tracking cycle initiated at the vehicle.

This approach to tracking worked nearly 100% of the time. This supports the theory that a longer delay at the vehicle after an up transmission and before a ping should render more dependable passive tracking.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

Control Systems

1. **Hover Altitude Control Loop.** It was my intention (see plan above) to test the improved altitude control loop during this dive. But we were not able to accomplish this since we had a failure in the vertical thruster system (see Electronics/Electrical section below). With repairs to the system before the next dive, it should be possible to conduct these tests during the next dive.

2. **Transit Control Loops.** No matter what we asked the vehicle to do in the GO DR command, the elevator moved to an up position causing the vehicle to climb. This occurred when the vehicle was commanded to transit and descend, transit and fly level, and transit and ascend. Because of this problem, the GO command was not attempted since the GO command ends only when the vehicle reaches a "point" in three-dimensional space. With the elevator behavior experienced, the vehicle could never reach the objective point. To accomplish ascents and descents required to obtain objective altitudes for FLS and CCD experiments without the benefit of vertical thrusters, GO, or GO DR, manual thrusts combined with manual elevator settings were used for short bursts of time.

Electronics/Electrical

1. During the dives, we had a couple of significant electrical failures.

2. Due to a leak occurring at a Brantner connector assembly that was cross-threaded and not sealed, both vertical motors were put out of commission (a common fuse blew).

3. Near the end of the dive, both main thrusters went out of control. We believed one thruster went into full forward and the other full reverse. After the weights were released and the vehicle came to the surface, the motors were still running, causing the vehicle to go in circles on the surface. Inspection after the dive shows that a land on a bit buss board involved in the control of the motors had been blown off.

SAR Gear

At the end of dive 5b, the search and recovery (SAR) strobe and radio beacon did not deploy, and the float did not fully deploy. Both of these problems have solutions in the works. The SAR strobe and radio beacon deployment problem should be fixed by the next dive.

CONCLUSIONS

Incredible strides were made during the second dive (5b). First, we showed the pressure vessel does not have any inherent leaks. We obtained both our first forward-looking sonagrams and our first CCD images. Along with the CCD images, it was shown that the strobes are working and synchronized with the CCD camera.

Dive 5b had its problems, but the net result is a combination of optimism concerning operation of many key subsystems during the next dive, and a few good lessons learned. Barring any major failures, the next dive will be a milestone of target surveys with FLS and CCD.

JMW
10–17–91

AUSS DIVES 28 AND 29 REPORT
(Dive Date, 9–25–91)

ACCOMPLISHMENTS

Dive 28

1. Collected and recorded acoustic ping data from acoustic link transducer (special configuration) that may help define sources of reverberation and/or resonance in the vehicle.

2. Showed that LBS acoustic tracking was possible with the Thorn system using the acoustic link (AL) transducer on top of the vehicle (as opposed to the stinger transducer). The stinger still appears to be the better location.

3. After failure of the forward vertical motor, the game plan was switched to dynamic control of depth/altitude using the elevator. Several transit GO DRs (specified heading, time, and depth (or altitude)) were run. Each run was 6 minutes in length. Commands sent through the acoustic link were used to change the proportional gain of the elevator loop for each of the runs. Flight recorder data were sent through the acoustic link to the surface where they were compiled into files and plotted for on-site evaluation. This is a valuable development process available only to an AUV system with a reliable high-data-rate acoustic link that can access both control loop variables with the down link, and vehicle performance data with the up link.

Dive 29

1. All propulsion motors were run without failure throughout this dive (5.5 hr of bottom time).

2. 2400 bps of nearly error-free compressed sensor data were transmitted and displayed throughout this dive. Many CCD image screens and SLS image screens were completely error-free. Occasional "worms" (artifacts originating in vehicle processing) occurred, but at a much lower frequency of occurrence than in previous dives. This low frequency of occurrence is a result of some error (check sum) discrimination software recently installed.

3. Demonstrations of SLS pattern-following were successfully completed.

4. More transit control loop runs as in item 3 of Dive 28 were made. Flight recorder data show that depth was held to within 1 foot during some of these runs. The elevator was working very hard, moving from limit to limit trying to maintain depth and pitch angle, even during the runs where good depth control was achieved. In future dives, experiments will be conducted where the gain in the outer depth control loop is decreased to see if the elevator becomes less active. Since the depth is a type 0 loop, the penalty of lower gain will be some more offset between commanded depth and actual depth. This is an acceptable price to pay for stable elevator operation.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

Predive

1. Starboard elevator was slipping. This occurred because during elevator modifications at the shop, the coupling shaft had been turned down slightly. In an effort to rectify, the Test Director

installed shim material from the galley (tin foil) and overtightened and broke coupling bolt with allen wrench (he was hoping that the allen wrench would work (as it had in the past) as a torque limiter and break before the bolt broke). Broken bolt was extracted with easy out, and soda can shim installed with new bolt. A durable fix to this problem using a stainless steel sleeve replacement for the shaft has been implemented as of this writing.

2. During predive checkout, motors would not work. Troubleshooting and phone calls to Howard McCracken revealed an analog switch chip failure. A function of a portion of the chip is to turn off the control voltage to motors during the vehicle turn-on transient period. Turn-ons include processor resets on board the vehicle. The chip was replaced, some modifications to the circuit were made for turn-on robustness and noise immunity, and the predive checkout was restarted.

3. The acoustic link transducer did not transduce acoustics when commanded to do so. Broken wires were found in the transducer oil-filled cable and repaired.

Dive 28

1. It took two tries to release vehicle from the descent line.
2. Dive terminated due to failure in forward vertical motor.

Dive 29

1. Due to uncertainty in descent line release operation, vehicle was thrusted down to depth with the vertical motors. Both vertical motors survived this and the entire 5.5-hour dive.

2. The flight recorder was used to reliably record and recover data for both dives, but only because operational limitations were imposed. Only a limited amount of data can be extracted from the flight recorder at a time. If the limit is exceeded, the entire contents of the flight recorder are lost and not retrievable. Work will continue to define the source of this problem and correct it.

3. During recovery, the recovery line once again became entangled in the SAR gear and the SAR gear doors. This time, the SAR door actually became dislodged from the vehicle and slowly disappeared into the depths. As I write, a complete overhaul of the SAR erection system is being implemented on the vehicle.

CONCLUSIONS

What started out as a destined-to-disaster sea trip turned into a great success due to perseverance and hard work. We left the dock at 0600, and were not able to launch for the first of two dives until 2030. The delays were due to resolving problems in thruster control circuits, acoustic link wiring, elevator mechanical system, and restarts in predive checkouts. Between dives, time was taken to swap out a thruster motor.

For the two dives, 9.5 hours of bottom time were logged, and 100 Ah were drawn from the battery. The second dive was terminated only so the team and the equipment could be on hand for an important show and tell.

The major product of this sea trip is system performance data, which will be used to improve the transit depth control loop, acoustic link, photomosaic patterns, and SLS search patterns.

JMW
11–4–91

AUSS DIVE 30 REPORT
(Dive Dates, 10–31–91 and 11–1–91)

ACCOMPLISHMENTS

1. **Buoyance and Trim.** During this dive, all vehicle subsystems were in place; no syntactic foam was in the vehicle (except the recovery float); and the vehicle was easily trimmed and displaced the proper volume. (When have we ever been able to say that before?)

2. **Dive time.** Bottom time for dive 30 was 9.5 hours, and the dive was not terminated due to equipment failure.

3. **Endurance.** The battery provided 100 Ah on this dive.

4. **Propulsion Motors.** All four propulsion motors survived the 9.5 hours of operation.

5. **Cruise Control.** Dedicated step function tests for the vehicle cruise control (forward velocity control) loop were conducted for the first time. The results looked good, and this loop can be considered completed.

6. **Pause/Continue.** The use of the pause/continue capability was successfully demonstrated during an SLS run. The pause command was used to interrupt the autonomously running SLS pattern when the vehicle operator saw an interesting target on the SLS screen. The autonomous SLS search pattern was continued from where it had been interrupted after the operator sent the continue command. In between the pause and continue commands, the operator was able to guide the vehicle to successfully complete a contact evaluation of the target. It is important to note that the continue command was sent to the vehicle while the vehicle was still in the vicinity of the target.

7. **Realtime Doppler Coordinate Plot.** For this dive, Rich Uhrich implemented a near-realtime CRT plot of the vehicle position that we will continue to use. The data used for this plot were the Doppler coordinates sent up the acoustic link with each status update. This is a very useful capability, and, for instance, gave an extremely vivid display of the SLS pattern and the pause/contact evaluation/continue tracks.

8. **SAR Gear.** The new implementation of the SAR gear (radio antenna and flashing light) worked very well, and was well worth the wait! We are now using a "rocket-launcher" approach to erecting the SAR gear where the antenna and light telescope out of tubes when the vehicle reaches the surface. In the old system, the antennas pivoted up and opened hinged doors.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

1. **Descent Float Deployment.** The most visible problem associated with this sea trip was a problem that aborted our first launch attempt. The descent float is connected to the vehicle with a short line (around 6 feet), and must therefore, be launched with the vehicle on the launch ramp. During this launch attempt, the descent float caught on a ramp bumper and stayed hung up until

the vehicle slid past it. The descent float fell to the deck rollers on the launch ramp, imparting a sharp blow to the recovery float as it fell. The release stem on the recovery float was broken by this blow. The descent line transponder deployed on the descent line as usual, but we cut the descent line above the descent weight to avoid deployment of the whole mess to the bottom of the ocean. What was left were two lines in the water, and of course they tangled. We maneuvered the ship such that a command could be given to release the descent line and the ascent weights from the vehicle with the "yellow banana" (an independent transponder system on board the vehicle). After the weights and the line were away, we waited for the descent equipment and the vehicle equipment to separate due to differential drift (which they did). We then recovered the descent system and then the vehicle system using normal recovery procedures. For dive 30, a temporary fix was implemented on the recovery float release stem, and the descent float line was lengthened so it was beyond the catch point. The launch went without a problem.

2. **Transit Depth Control Loop.** Prior to launch, and also while the vehicle was on the descent string, experiments were run in which it was determined that the isolated transfer function (output/input) =(elevator angle/depth error) was not being computed properly. This precluded running the transit depth control loop experiments during this dive. These problems are being investigated and software corrections will be implemented.

3. **SLS Operation.** After a pause/continue sequence, the vehicle returns to the previous search track, but it does not return to the previous altitude (which it should). This will be fixed by software implementation.

4. **SLS Operation.** SLS pings are discontinued at the start of each turn, and should be restarted at the end of the turn. During dive 30, the pings were discontinued at the start of each turn, but the system started pinging again before the turns were complete. This will be fixed by software implementation.

5. **Photomosaic.** The photomosaic works properly along track, but it does not complete turns. This will be fixed by software implementation.

CONCLUSIONS

Three major milestones were reached during this trip:

1. The new SAR gear worked flawlessly and met our expectations on its maiden voyage. This is due to Sean Whaley's good engineering design, and I'll take credit for commissioning Sean to do the design, then lobbying to allow it to be implemented and implemented properly. What we now have is a nearly tangle-free SAR system that is easy to load and should prove to be reliable.

2. The vehicle was trim and displaced the proper volume with all subsystems in place. Jimmy Held gets the credit here. Not only is this the first time I've ever heard of a vehicle with no added syntactic foam (due to weight and displacement estimate difficulties), but this is the first time that I have seen anyone predict the design to be so close.

3. No propulsion motors failed during the entire sea trip. I know that this last-stated milestone is a sad commentary on the state of our motors, but it was nevertheless a milestone.

The SLS and photomosaic performance is improving steadily with each lesson learned, and most of the bugs in these search routines have been identified and addressed. Some of the most exciting aspects of the AUSS search approach are being implemented and demonstrated at this time. More to come next dive!

JMW
11-18-91

AUSS 12 kft OPAREA DEVELOPMENT TRIP REPORT
(Trip Dates, 11-11-91 thru 11-15-91)

(PREDICTED)/ACTUAL OPAREA LAYOUT

```
POS2 *** (2nmi)/10 kft *** POS3
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
(2nmi)/10 kft   POS5   (2nmi)/10 kft
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
 *                           *
POS1 *** (2nmi)/10 kft *** POS4
```

POSITION	XPONDERS	kHz INTR,RESP	CODE ON, REL
POS1	LBS1	7,15	A E
POS2	LBS2	7,15.5	B F
POS3	LBS3	7,16	C G
POS4	LBS4,	7,16.5	D H
POS4	LBS1990	7,13	C –
VARIABLE	FISH	9,7	E A

RESTATEMENT OF OBJECTIVES (from test plan)

1. Relocate AUSS 12-kft operations area (OPAREA) (near areas identified as Trieste Operations Area, and benthic untethered multipurpose platform (BUMP) 12-kft OPAREA).

2. Relocate transponder deployed by Walton and Osborne from the Research Vessel *DeSteiguer* on 20 February 1990.

3. Collect sound-velocity profile information.

4. Calibrate *MARSEA FIFTEEN* deep fathometer for 12-kft operations.

5. Complete bathymetric survey of AUSS 12-kft OPAREA (initiated during *DeSteiguer* cruise).

6. Evaluate tracking performance using *MARSEA FIFTEEN* transducer pole and AUSS batfish.

7. Evaluate ultrashort baseline (USBL) performance at 12-kft location with *MARSEA FIFTEEN*/AUSS equipment.

8. Deploy fish-cycle transponder at a variety of locations and depths in an attempt to predict future AUSS fish-cycle performance in this OPAREA.

9. Determine proper transponder anchor line lengths for the AUSS scenario in this OPAREA.

10. Deploy four transponder nets at 12-kft spot.

11. Survey net using AUSS Thorn/NS11 system.

12. Survey net using ATV DP10/NS11 system.

13. Evaluate long baseline (LBS) and fish-cycle performance using the AUSS and ATV systems in the 12-kft OPAREA.

14. Test operations of *MARSEA FIFTEEN* satellite communications system from 12-kft OPAREA.

15. Deploy sonar target and survey target in LBS coordinates.

16. Test deployment and retrieval of AUSS launcher in open ocean high sea states (if they exist).

ACCOMPLISHMENTS

1. **Test Plan Objectives Met.** All objectives were met with the exception of 4,5,7,16 and one-half of 6.

2. **Old Transponder Awakened.** Within one-half hour of our arrival on station, we had the 13-kHz transponder on and it was responding to our interrogations. This is the transponder that Walton and Osborne deployed near POS4 on 20 February 1990 from the Research Vessel *DeSteiguer*.

3. **What is Beyond the Extent of a Reasonable DOT Field?** The fish-cycle transponder was deployed with a 50-ft tether to its anchor near POS2. The 50-foot anchor line was used since the AUSS vehicle will be flying at least 50 ft above the bottom for much of its mission. One leg fish-cycle transponding continued throughout the descent, but quit at 300 feet above the bottom. This helped to define the limits of fish-cycle tracking at this location.

4. **What is the Size of a Reasonable DOT Field?** The fish-cycle transponder was released, recovered, and redeployed at a position about 14,140 feet from POS4 on a bearing of 315 degrees from POS4. The transponder again had a 50-foot anchor line to the bottom. The fish cycle was dependable even after the transponder anchor was on the bottom.

5. **Definition of DOT Field.** With the information collected in 4 above, we redefined the transponder net such that it is 10,000 feet on a side and oriented such that POS2 is due north of POS1 (as shown in the above figure). This makes POS2 near the position of the fish cycle transponder (about 14,140 feet from POS4 on a bearing of 315 degrees from POS4).

6. **DOT Field Deployment.** It took 2 hours total to launch the four transponders at POS1, POS2, POS3, and POS4. These transponders are releasable transponders attached to 200-foot anchor lines with 150-pound chain clump anchors.

7. **Transponder Descent Time.** The descent time for the transponders averaged 45 minutes.

8. **AUSS Net Survey.** Transponder net survey data were collected by Osborne and Geurin most of Tuesday night. These data were for the NS11/Thorn system, and were collected with the ship in the troll mode using the transducer pole.

9. **ATV Net Survey.** Early Wednesday morning, Walt Bacino took over the con of the ship and collected net survey data for the NS11/DP10 system.

10. **Target Deployment.** While Osborne, Geurin, and Bacino were reducing data, the fish-cycle transponder was brought up and redeployed at the center of the net on a 100-foot tether above a test target donated to us by M. Cooke. The fish-cycle transponder allows us to survey in the position of the target.

11. **Transponder Drift.** The releasable fish transponder was deployed three times and released twice (it is still attached to the target because sea conditions made it unsafe to recover). On two occasions when it was released and recovered at the surface, it surfaced within 200 feet of its deployment position. As stated before, it took around 45 minutes for the transponder to descend, and it probably took about that long to ascend (more on this from Osborne in the future). This shows that surface-deployed transponder target marking is reasonable in this part of the ocean.

12. **Some of the AUSS survey results:**

a. **Confidence in Data.** Less than 1% of the data collected were flyers.

b. **Consistent Data.** The 13 kHz and 16.5 kHz transponders surveyed in about 5604 feet from each other, with 8-foot difference in surveyed depth (they both have 200-foot anchor lines).

c. **Bottom Depth.** By adding the 200-foot anchor line lengths to the surveyed depths of the transponders, the bottom depths at the four corners of the net can be determined. These depths are:

POSITION	BOTTOM DEPTH (ft)
POS1	11,815
POS2	11,701
POS3	11,620
POS4	11,832

d. **General Operations Area Quality.** The acoustic environment in this area appear to be very good, and the bottom slope is mild. Looks like a good OPAREA.

13. **Communications to Shore.** We were able to communicate back to the mainland from the OPAREA (at various times) with the single sideband radio to the NOSC radio hut, with the satellite communications system, and with the NOSC VHF radio (to the NOSC operations tower).

14. **Sound-Velocity Profile Corrections.** Two expendable bathythermograph (XBT) drops were made. Chance Geurin is reducing the data to give a sound-velocity profile for the area during the surveys. This will be used to correct the survey data.

15. **Further Reporting on This Trip.** Pat Osborne and Chance Geurin will continue to reduce data from this trip, and will report more of the technical results.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

1. **Fathometer.** The fathometer did not work satisfactorily during this trip. About 1/3 of the area we are using was surveyed and determined acceptable using a precision depth recorder (PDR) by Walton and Osborne in 1990. Since the ATV team in Hawaii did use the *MARSEA FIFTEEN* fathometer at depths down to 20,000 feet, we will continue our dialog with them as well as try to determine the problem through test and evaluation. With a headset on, the operator could hear the transmit pulse as well as a faint bottom return, but the fathometer chart did not adequately display the return. The purposes of using the fathometer were: (a) to evaluate the bottom slope, and (b) to determine if there are any large obstacles or depressions that may affect the tracking acoustics, or become hazards for the vehicle. Some risk was taken in putting in the net without this information, but all information gathered so far indicates that we did not waste our time. The tracking acoustics and bottom slope both seem to be fine, and we can use the AUSS vehicle flying at high altitude to safely learn more about the existence of obstacles and depressions.

2. **Transducer Pole and Batfish Evaluation.** The batfish was not deployed during this operation. Deployment was scheduled to occur after the net surveys were completed. By the time the surveys were completed, the sea state was such that the batfish deployment was too dangerous. The transducer pole was reliably used to track the six deployed transponders. The pole, however, may not be used for any propulsion case except for the troll mode, but both engines may be engaged for maneuverability. The batfish will be evaluated at the 12-kft spot during the next deployment.

3. **Ultrashort Baseline Performance.** The USBL was not evaluated during this trip because the Honeywell system did not operate properly. This problem is being investigated at this time and will be further evaluated during operations at 2500 feet.

4. **Launch and Recovery System.** The AUSS launch and recovery system was not evaluated for high sea states during this sea trip. The sea state during the early part of the operation was less than we had already experienced in the 2500-foot spot. The sea state rapidly built to a sea state 7, and due to other operational testing in progress, we missed the opportunity to deploy during the short period when a high sea state 3 existed. We will find opportunities to use the launch and recovery system in high sea states with and without the vehicle in the future.

CONCLUSIONS

The 12-kft OPAREA is ready for use by the ATV and AUSS for deployments. ATV will be using the area in the near future, and the AUSS is expected to begin using the area in the spring months. A five-transponder navigation field is in place and surveyed relative to each other. Osborne and Geurin are reducing data such that in the very near future, we will have geodetic positions for the transponders.

The bottom slope in the OPAREA is mild, and the acoustic environment is good for both the AUSS and ATV tracking systems. This, along with the excellent results obtained with BUMP in this general area, leads me to believe that the acoustic link will operate well also.

A bottom target useful to both the AUSS and ATV testing is in place and surveyed near the center of the transponder net.

JMW
11–22–91

AUSS DIVE 31 REPORT
(Dive Dates, 11–21–91 and 11–22–91)

ACCOMPLISHMENTS

1. **Dive Duration.** This was our second longest dive, and it lasted 14 hours (bottom time). The dive was terminated by operator command, and there were no vehicle system failures during this time. There were, as will be noted later, some problems with new versions of software.

2. **Battery Endurance.** The battery provided 150 Ah to this dive.

3. **Transit Depth and Altitude Control Loops.** Everyone has heard over and over again that we had not been able to control the vehicle in dynamic pitch (elevator control of pitch with the vehicle underway). Well, this trip is the one where Jimmy (using Howard's software and some unique AUSS acoustic link communications capabilities) slew this final vehicle control dragon.

The dynamic pitch control loop is an inner loop used within the transit depth control loop and the transit altitude control loop. The dynamic pitch control loop is a subset of the problems we have had in controlling the vehicle. The problems, or empirical observations collected at sea were:

a. The elevator angle of the underway (transit) vehicle varied in an oscillatory fashion. The elevator would swing between the upper and lower mechanical limits where it would "saturate" at ± 13 degrees.

b. The pitch angle of the transit vehicle varied in an oscillatory fashion swinging between pitch angles as great as ± 30 degrees.

c. The vehicle transit depth and altitude varied in an oscillatory fashion with the oscillation magnitude being several feet to 10s of feet.

The elevator angle is used to control the pitch angle. The pitch angle along with the thrust of the main propulsion motors is used to control the depth or altitude.

During this dive, the vehicle was commanded to transit through the water with its pitch and depth (or altitude) under elevator control. Information on depth, altitude, advance speed, pitch, and elevator angle was collected in the vehicle on-board flight recorder. This flight recorder data were accessed by surface operators through the acoustic link, and then plotted for analysis while the vehicle remained at depth. Once the data were analyzed, the acoustic link was again used to send the vehicle corrections to gain factors in the control loops. The vehicle was again commanded to transit through the water under elevator control. This iterative process continued until the vehicle was stable for the transit depth and altitude control loops.

A simplified synopsis of the sequence leading to stable control of the depth and altitude follows:

a. The proportional gain of the outside depth control (and altitude control) loop was lowered until the loops were stable.

b. The depth (or altitude) rate feedback gain was adjusted until the overshoot exhibited in a depth (or altitude) step was minimized.

The final outcome of these tests is that

a. The pitch of the vehicle during dynamic pitch control at speeds between 2 and 5 knots is stable and is maintained to within ± 1 degree.

b. The depth of the vehicle during transit depth runs at speeds between 2 and 5 knots is stable and is maintained to within ± 1 foot.

c. The altitude of the vehicle during transit altitude runs at speeds between 2 and 5 knots is stable and is maintained to within ± 5 feet.

4. **Hover Depth Control Loop.** The hover depth control loop was upgraded to a type 1 from a type 0 with the addition of an integrator. With this upgrade, the vehicle was able to hover in depth to ± 1 foot of a commanded depth.

5. **Hover Altitude Control Loop.** The hover altitude control loop was upgraded to a type 1 from a type 0 with the addition of an integrator. With this upgrade, the vehicle was able to hover in altitude to ± 1 foot of a commanded altitude.

6. **Side-Looking Sonar Target Marking.** Rich Uhrich's new routine for SLS target marking was tested. The objective of the target-marking routine is to give the vehicle operator the ability to determine the position of a target (in vehicle Doppler coordinates) from the SLS sonagram. To accomplish this, the position of the vehicle when the target was ensonified must be known, and the horizontal range and bearing to the target must be known.

Every 16th SLS ping, the vehicle sensor computer sends to the surface a ping line number and a time associated with that ping. When the sensor computer sends up this information, it "asks" the main vehicle computer to send to the surface the latest Doppler coordinate position for the vehicle along with the time that the Doppler coordinates were obtained. The altitude and heading of the vehicle is also sent to the surface at this time.

When a target position is desired, a cursor on the SLS screen is moved to the target image to "mark" it. The image computer determines the ping line number and the slant range from the vehicle track to the target using the marked cursor position.

Given the ping number, the image computer interpolates (based upon time) the vehicle altitude, position, and heading for that ping number. With this information, the horizontal range and bearing to the target is calculated, and then the Doppler coordinates of the target are determined.

During Dive 31, a target was marked on the SLS screen. Upon seeing a target image appear, the operator commanded the vehicle to pause (see Dive 30 notes for pause/continue descriptions). With the vehicle paused and hovering, the operator moved a cursor to the target image on the screen and "marked" it. A position was computed for the target. The vehicle was sent GO and hover commands that should have put it 30 feet from the target. Due to timing discrepancies between the main computer, which provides the vehicle position-heading-altitude data and the sensor computer, which provides the ping number, the 30-foot standoff was not achieved. But a target was in the view of the FLS scan after the transit.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

1. **Side-Looking Sonar.** During the first attempt at a side-looking sonar search pattern, the main computer threatened to abort the mission and drop the ascent weights. Apparently the main computer lost the bubble on the interrupt structure used for intercomputer communications. SLS runs were determined to be too risky until dive termination was acceptable. Therefore, SLS was not again attempted until all other possible tests were completed. This problem will be investigated and improved upon for future dives.

2. **Side-Looking Sonar Target Marking.** The result of the SLS target marking (see #6 under accomplishments for target-marking description) was that the routine worked properly, but due to a timing discrepancy, the position for the target was not accurately found. Rich, Stan, and Howard will work on synchronizing the time better for the next test of this algorithm.

3. **CCD Camera.** During a photomosaic attempt, the CCD camera image was extremely noisy. Experiments were conducted to determine the source of the noise. Strobe failure was ruled out by proving that an illumination pattern existed in the image (this is done by adjusting the contrast). The vehicle was sent to a low altitude, all vehicle propulsion motors were secured, and a CCD image obtained. This image was of very good quality, which showed that the noise source was related to propulsion. Selectively operating propulsion motors while CCD images were taken led us to believe that operation of the vertical motors did cause the noise problem, and operation of the main motors did not cause the noise problem. The noise problem was proven to be intermittent when we attempted to isolate the source to the forward or after vertical motor. Due to its intermittent nature, isolation of the problem was not completed at sea. Further isolation and defeat of the noise source will be accomplished in the lab.

CONCLUSIONS

As a result of Dive 31, all vehicle control loops are stable. The vehicle can be safely commanded to perform transits at speeds up to 5 knots, holding depth to within ± 1 foot, or altitude within ± 5 feet. Hover altitude and hover depth control modes may be relied upon to hold the vehicle at ± 1 foot of the altitude/depth commanded due to implementation of type 1 hover altitude/depth loops.

The target-marking capability is a further enhancement of the operator's capability to supervise the AUSS vehicle contact evaluation. In combination, improved Doppler, hover at a radius, pause/continue, target marking, and in the future improved propulsion motor performance, improved vehicle model, and water speed sensor implementation will result in a greatly improved capability to perform contact evaluations.

Ser 941/30-92
13 Mar 92

MEMORANDUM

From: Jim Walton (Code 941)

To: AUSS Team

Subj: Advanced Unmanned Search System Dive 32 Report

Encl: (1) AUSS Dive 32 Report

1. Enclosure (1) is my report on the Advanced Unmanned Search System Dive 32. As you will see, we are really beginning to reap the rewards of our efforts.

JIM WALTON

Copy to:
532 (Hoffman)
781 (Nickerson)
94
941 (Cooke, Bell, Geurin, Held, Jones, Kono, Osborne, Pryor, Rutkowski, Someson, Tallerino, Uhrich, Walton, file, AUSS file)
942
942 (Collins)
943 (Bryan, Gillcrist, Mackelburg, McCracken, Rasmussen, Watson)
944 (Phillips)
946 (Grace)
9612 (Hays)

JMW
03–11–92

AUSS DIVE 32 REPORT
(Dive Dates, 12–20–91 and 12–21–91)

ACCOMPLISHMENTS

1. **Dive Duration.** This dive lasted 13.5 hours (bottom time). The dive was terminated by operator command, and there were no vehicle system failures during this time.

2. **Battery Endurance.** The battery provided 151 Ah to this dive.

3. **Acoustic Tracking.** We successfully used the brand new AUSS NS11 with the Thorn software to acoustically track both the ship and the vehicle throughout this dive.

4. **High Data Rate CCD Image.** While on the descent string, a 4800-bps CCD image was transmitted, received, and displayed. There were only two errors in the image, which means that the bit-error rate (BER) was 2/(256 x 256 pixels x 8 bits/pixel)=3.8 x 10**–6. It must be remembered that this is a single event, and is not yet indicative of typical performance. This is better than our test and evaluation master plan (TEMP) requirement (4800 bps with 10**–5 BER) and is closing in on our objective (4800 bps with 10**–6 BER). By the way, the only requirement in the operational requirement (O.R.) is that sensor data can be transmitted at 4800 bps. This does not mean we are out of the woods since the performance of the acoustic link is still directional (the vehicle acoustic link beam pattern is better in the port/starboard quadrants than it is in the fore/aft quadrants).

5. **High Altitude Doppler Performance.** While the vehicle is on the descent string, there is a perfect opportunity to look at the Doppler drift under various conditions. The vehicle settles out in a stationary condition where the heading, altitude, pitch, and roll are essentially static. The altitude is approximately 140 feet (due to lengths of the descent string lines) and the motors are not running.

During this dive, we collected data on the Doppler drift for three conditions: (1) acoustic link quiet except for status updates every 15 seconds, (2) flight recorder data nearly continuously transmitted up the acoustic link, and (3) CCD image data nearly continuously transmitted up the acoustic link.

Doppler northing and easting coordinate data collected in the vehicle flight recorder and transmitted to the surface through the acoustic link are plotted in figures G-1 and G-2. All of these data were collected while the vehicle was on the descent string. In figure G-1, the blue coordinates were plotted for a 26-minute period when only status updates were being transmitted. Also in figure G-1, the red coordinates were plotted for 10-minute period while flight recorder data were being transmitted. In figure G-2, coordinates were plotted for a 1-minute period when CCD data were being transmitted.

Figures G-1 and G-2 show the relationship between acoustic link transmissions and Doppler drift. The data are summarized in table G-1.

Table G-1. High-altitude Doppler drift versus acoustic link transmission.

ACOUSTIC LINK TRANSMISSIONS	FIGURE #	COLOR	PATTERN (feet)	TIME (min)	PATTERN GROWTH (ft/min)
15-Sec Status Updates	1	Blue	25	26	0.96
Flight Recorder	1	Red	35	10	3.5
CCD Image Data	2	Brown	7	1	7.0

So, it is seen that the Doppler drift is greater when the acoustic link is transmitting large amounts of data than when the acoustic link is transmitting small amounts of data. Various explanations for the high-altitude drift have been proposed. These theories are being explored in measurements and future experiments. The most popular theories are acoustic signal to noise (Doppler signal and acoustic link noise), electrical signal to noise, and vehicle-borne mechanical coupling of acoustic noise from the acoustic link into the Doppler sound head.

6. **Vehicle High-Speed Turn.** The AUSS O.R. requires that the vehicle be able to turn 180 degrees (reverse direction) within 2 minutes. I chose two cases to satisfy this requirement. The first case is a 180-degree turn while the vehicle is hovering (no advance speed). For this case, it was found on 10–18–90 that the vehicle is able to make a 180-degree turn in 42 seconds. The second case is when the vehicle begins the turn with an initial full forward velocity. Figure G-3 is the plot of the Doppler coordinates for the high-speed turn.

Figure G-4 is a zoom into the region of the turn with the addition of forward velocity direction vectors. The positions of the vehicle along the trajectory are represented by +s. Think of the +s as the tails (or feathers) of arrows, and the lines originating at the +s as the shanks of the arrows. The arrows are pointing in the direction that is the instantaneous vehicle heading. Interestingly, the vehicle does slip sideways while making this turn, but does not go into an uncontrolled "flat spin."

Figures G-5 and G-6 are plots of the turn with positions represented by dots, and the velocity (in the direction of the arrows of figure G-4) in ft/s are written next to the dots. The initial velocity going into the turn is 8.29 ft/s = 4.9 knots, and the vehicle decelerates to 3.17 ft/s = 1.9 knots at the bottom of the turn. The turn took 45 seconds to accomplish, and the separation between the vehicle tracks going into the turn and going out of the turn is 48 feet.

Figure G-7 is a vehicle performance plot for the turn. Note that the velocity scales are incorrect. The velocities are actually feet/sec, and the scales (at the left border of the plot) should be multiplied by 0.1 (i.e., VEL FWD–AFT (ft/s) DIV = 0.5), and scale would be –1.0 to 9.0. (The scaling problem was corrected soon after the dive). In this plot, the decrease/increase in fore–aft (F–A) velocity is clearly seen. Also, the starboard–port (S–P) velocity shows the side slip to the starboard during the turn. The maximum side slip is about 1.65 ft/s. Another interesting observation is the S–P velocity is about 0.2 ft/s to starboard going into the turn, and 0.15 ft/s to port going out of the turn. This probably occurred as a result of the component of current perpendicular to the tracks of the vehicle.

7. **Induced Experimental Obstacle-Avoidance Maneuver.** Figures G-8 and G-9 show the vehicle performance during the experimental obstacle-avoidance maneuver. This experimental maneuver was not initiated by an obstacle detection and is not the exact maneuver that will be

implemented eventually. It did tell us some important information about how the vehicle will perform when it is avoiding an obstacle.

To avoid an obstacle, the vehicle will command both main thrusters to thrust in full reverse until the vehicle's forward velocity is zero. In figure G-8, the experimental maneuver begins when both main motors (red and green traces) are commanded into full reverse (at about 14:24:15). The vehicle F–A velocity (purple trace) drops off from the maximum of 8.3 ft/s (4.9 knots) to 0 ft/s in 18 seconds. Assuming a straight line for the velocity during deceleration, integration of the velocity over the 18 seconds yields a distance traveled of 75 feet.

There was concern that during the obstacle-avoidance maneuver, the pitch of the vehicle would be excessive and would therefore affect the Doppler performance. In figure G-9 it is seen that the maximum pitch of the vehicle during the maneuver was 7.5 degrees. This 7.5 degrees is not a problem in the performance of the Doppler.

8. **Transit Depth and Altitude Control With Pitch Rate Feedback.** In previous dives, vehicle performance plots showed overshoot in the transit depth and altitude step responses. Jimmy Held simulated the transit control loops and added pitch rate feedback to the depth and altitude outer loops. It worked in simulation and it worked in the field as seen in figures G-10 and G-11. Figure G-10 is the depth step and figure G-11 is the altitude step. As always, the altitude step is noisy since the sensor (Doppler) is noisy.

9. **Doppler Accuracy During Waypoint Navigation.** Figure G-12 has both fish-cycle LBS tracking of the vehicle (+s), and Doppler coordinates retrieved from the vehicle flight recorder (triangles). The coordinates were collected for a time period when the vehicle was waypoint navigating around a box. The attempted legs of the box were 4000 feet long and parallel to the north/south, east/west axes.

The vehicle started at the north/east corner of the box and went to successive waypoints at the corners of the box in a counterclockwise direction until it returned to the north/east corner of the box. Upon reaching the north/east corner, the vehicle turned around and traveled from waypoint to waypoint around the box in the clockwise direction until reaching the north/east corner again.

Many interesting observations can be made in a study of figure G-12:

The Doppler and the LBS systems both agree that the vehicle returned to the starting point after the counterclockwise (ccw) and the clockwise (cw) excursions around the box. This means the Doppler drift was minimal for a 32,000-foot (5 1/3 nmi) trip.

Both cw and ccw LBS tracks pass through waypoints at the corners, which very closely define the corners of a square with sides equal to 4,500 feet. This indicates that the vehicle did its waypoint navigation control job very well, and there is very little, if any, compass/Doppler alignment error. Also obviously there is a 500-foot (11%) difference between the Doppler and LBS squares. This 11 percent difference is purely a scaling problem, but the source of the scaling error is not yet understood. Theories include (1) sound velocity used in Doppler is incorrect and (2) polyethylene cover distorts the relative angles of the Doppler sonar beams such that an incorrect velocity is obtained.

The Doppler and LBS ccw track is bowed in toward the center of the square, and the cw track is bowed away from the center. This results from a vehicle on-board hydrodynamic or propulsion disturbance causing the vehicle to yaw to port. The vehicle makes it to the objective waypoints in spite of the disturbance. As the vehicle nears a waypoint, the error between the vehicle's bearing to the waypoint and the vehicle's heading increases, driving the heading of the vehicle more and more toward the waypoint. In future dives, this phenomenon will be explored further by adjusting the static rudder to compensate for vehicle imbalances.

10. **Side-Looking Sonar Target Detection.** During an SLS run, a small target was detected at nearly 500 feet. The vehicle was paused, the target was marked, and the FLS was used to close in on the target. A picture series with bias thrust was used to slowly "fly over" the target. After a few pictures were obtained of the target, the CCD image target-marking routine was used to determine the dimensions of the object in the plan view as seen by the CCD camera. Those dimensions were about 2 ft by 3.5 ft. This is a confirmation that the system may be used to detect and contact evaluate 1-meter targets at a range of 500 feet.

11. **AUSS Vehicle Descent and Ascent.** Being of great environmental conscience, energy conservation is practiced by the AUSS vehicle. During descent, the vehicle is pulled to the bottom by a line attached to a steel weight. When the mission is completed, two lead weights are released from the nose of the vehicle and the elevators on the tail are rotated up. The purpose of these two scenarios is to quickly take the vehicle to the bottom/surface without expending other than normal hotel-level energy, and to decrease the pattern of uncertainty associated with where the vehicle will be at the end of a descent or an ascent.

Figure G-13 is the Dive 32 descent. Depth is in black and pitch angle is in red. From the plot it is seen that the vehicle pitch was about 70 degrees, and the vehicle traveled approximately 2350 feet in depth in 490 seconds. This is roughly equivalent to 4.8 ft/s average. The O.R. is for 20,000 feet in 50 minutes, or 6.7 ft/s average. In the next dive, we will attempt to improve upon the descent rate by using the elevator to pitch the vehicle to more than 70 degrees. If the elevator does not solve the problem entirely, the size of the descent weight can be increased.

Figure G-14 is the Dive 32 ascent. Depth is in black, pitch is in red, and elevator angle is in blue. The pitch angle went past 90 degrees, and the vehicle rolled over several times during the ascent. This explains the "clipped" or "limited" waveform of the pitch angle during the ascent. In future dives, the elevator angle will be decreased (decreasing pitch angle) to eliminate this effect.

The 2300-foot ascent took 305 seconds. This is roughly equivalent to 7.5 ft/s average. This is much better than the 6.7 ft/s average rate required to ascend 20,000 ft in 1 hour as required by the O.R.

PROBLEM AREAS, TROUBLESHOOTING, AND SOLUTIONS TO PROBLEM AREAS

1. **Acoustic Tracking.** We were not able to turn on the transponder net with our new NS 11 using its amplifier. We did, however, hook the NS11 system to a Mackintosh power amp and were able to turn on the net and track the rest of the dive.

2. **Target Marking and Contact Evaluation.** During SLS runs with target marking and immediate contact evaluation, position errors were experienced. Two targets were successfully prosecuted, but the SLS target marking placed the vehicle 50 to 60 feet shy of the target in both cases. Clock-timing discrepancies and other sources of error in the target marking routine will be investigated further to improve performance in the future.

CONCLUSIONS

Another banner dive! By careful attention to issues of reliability, we have brought the system to a point where I can write a detailed test plan and expect to follow it step by step until we are unable to keep on stepping. Dives are terminated when the energy in the vehicle or its operators is depleted. The operations tempo is now based upon making significant improvements in the subsystems, and not on maintenance and repair.

Target marking and target closing worked well during this dive. Based upon the results of this dive, I expect that contact evaluations taking less than 10 minutes will be common in the future. A side benefit of the CCD target marking was demonstrated. The CCD target marking was used to measure the dimensions of an unknown target in the CCD field of view.

We conducted several demonstrations showing more O.R. and TEMP requirements that can be satisfied. During this dive, the ascent rate and the high-speed turn time both qualified under the O.R. A single uncompressed 4800-bps CCD image transmission qualified for the 10**–5 ber TEMP requirement. The descent rate shows promise of qualifying with adjustment of the pitch angle and perhaps the descent weight size. Target marking and target closure efficiency is improving, which will improve the overall search rate mentioned in the O.R. The capability to meet most of the operational requirements has been demonstrated at some time during the 32 dives we have conducted.

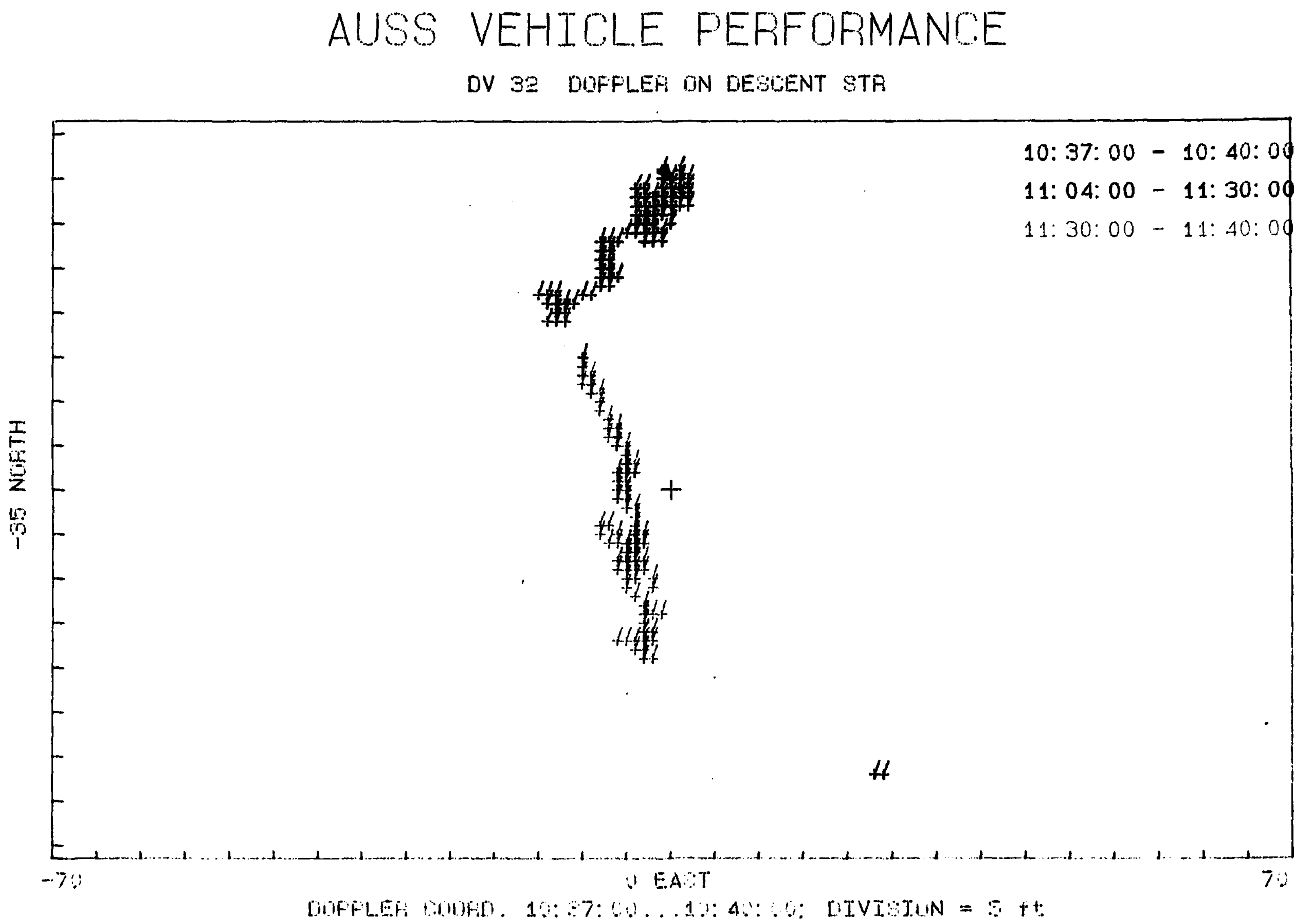


Figure G-1. Doppler position plot with vehicle on descent string.

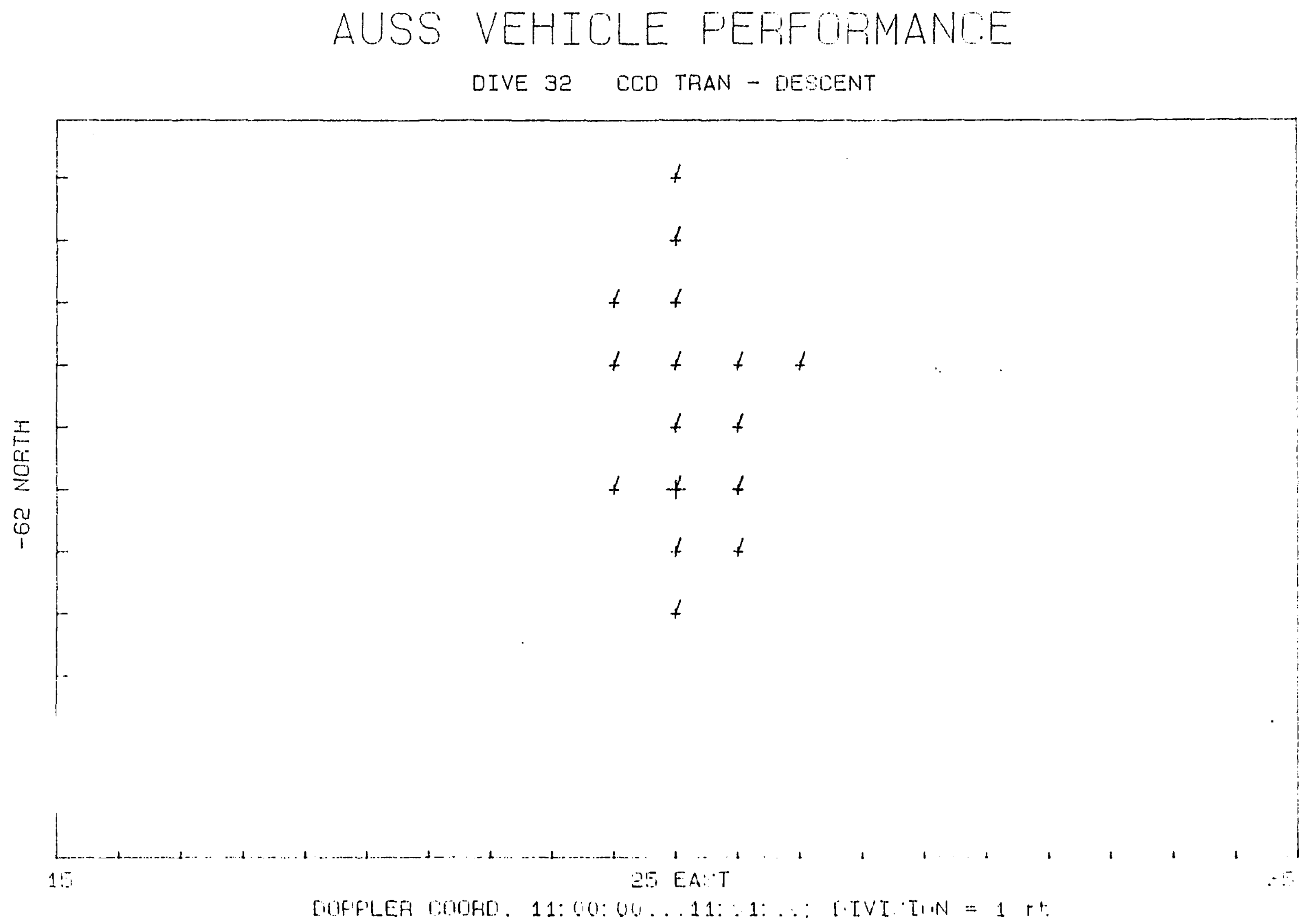


Figure G-2. Doppler position plot with vehicle on descent string during CCD image transmission.

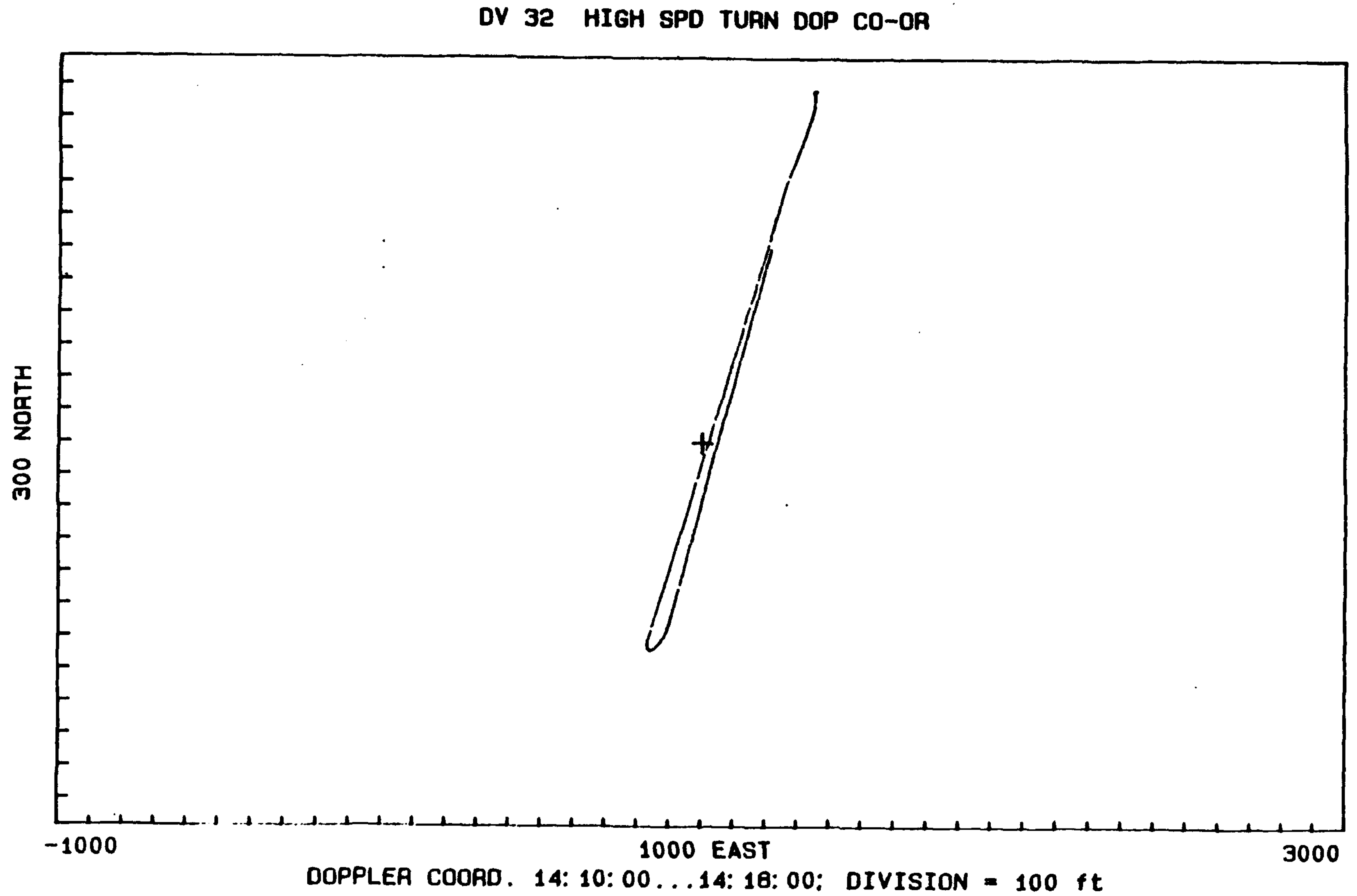


Figure G-3. Doppler coordinates for high-speed turn, division 100 feet.

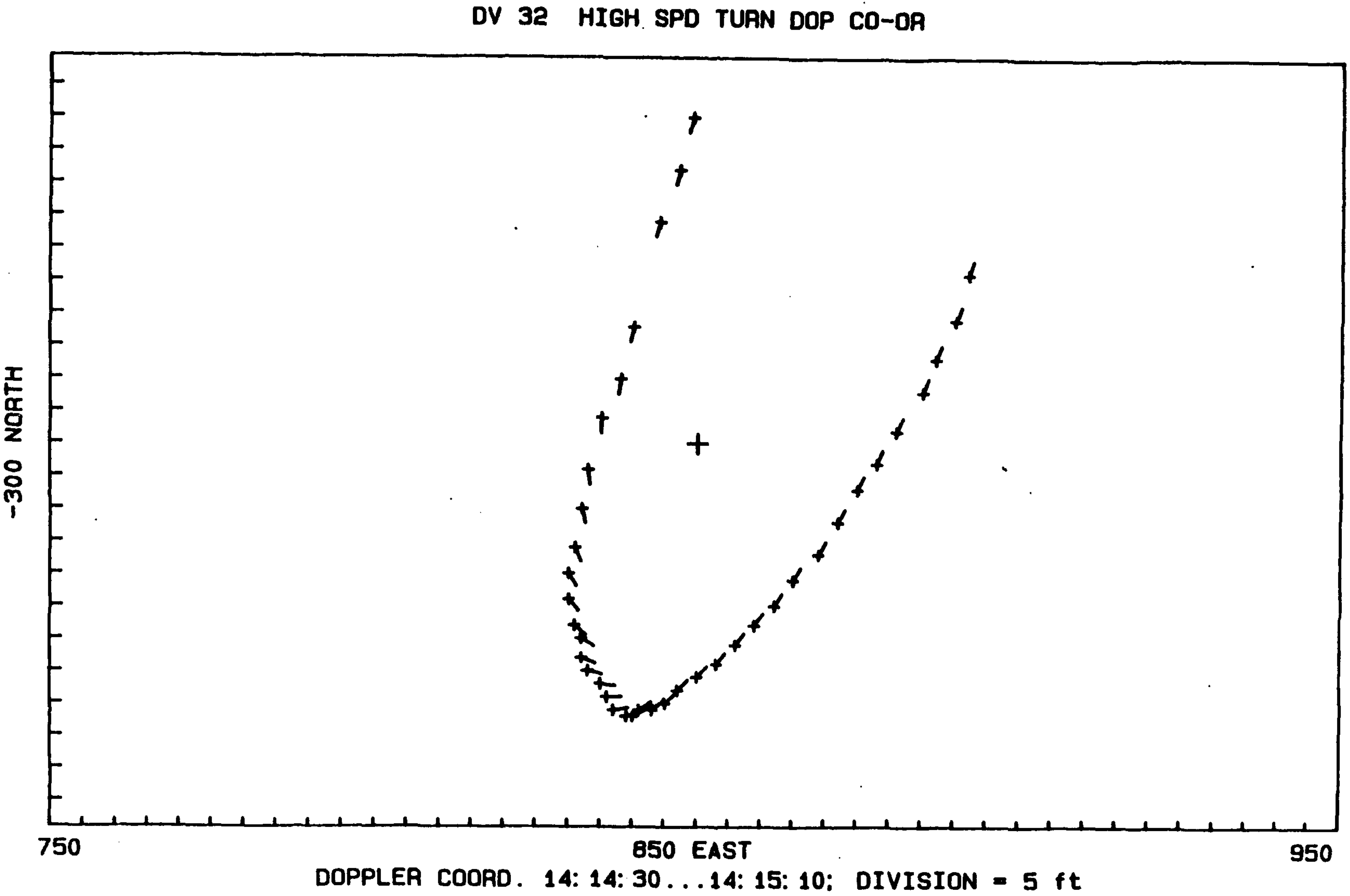


Figure G-4. Zoom into high-speed turn with forward velocity direction vectors, division 5 feet.

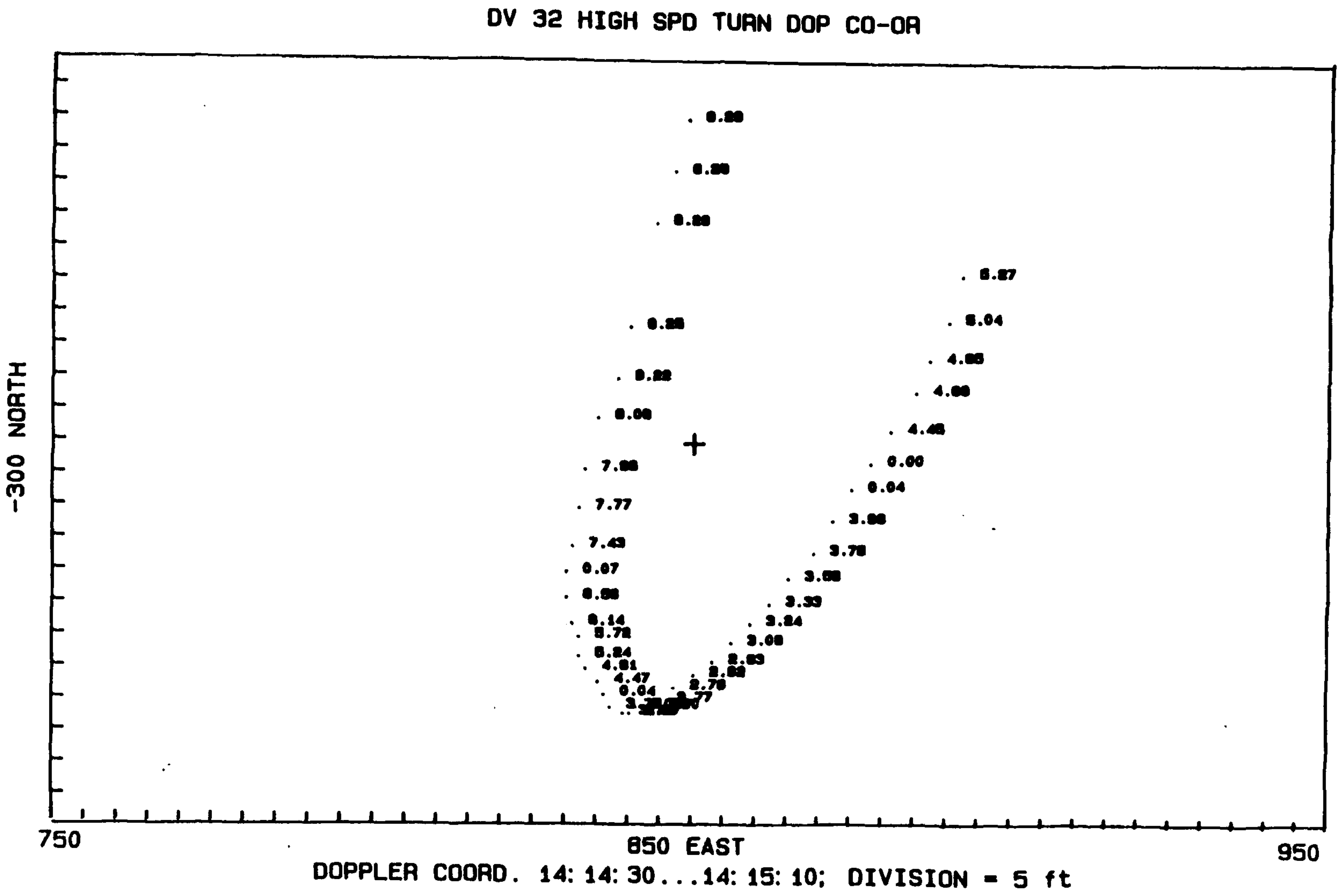


Figure G-5. High-speed turn, division 5 feet.

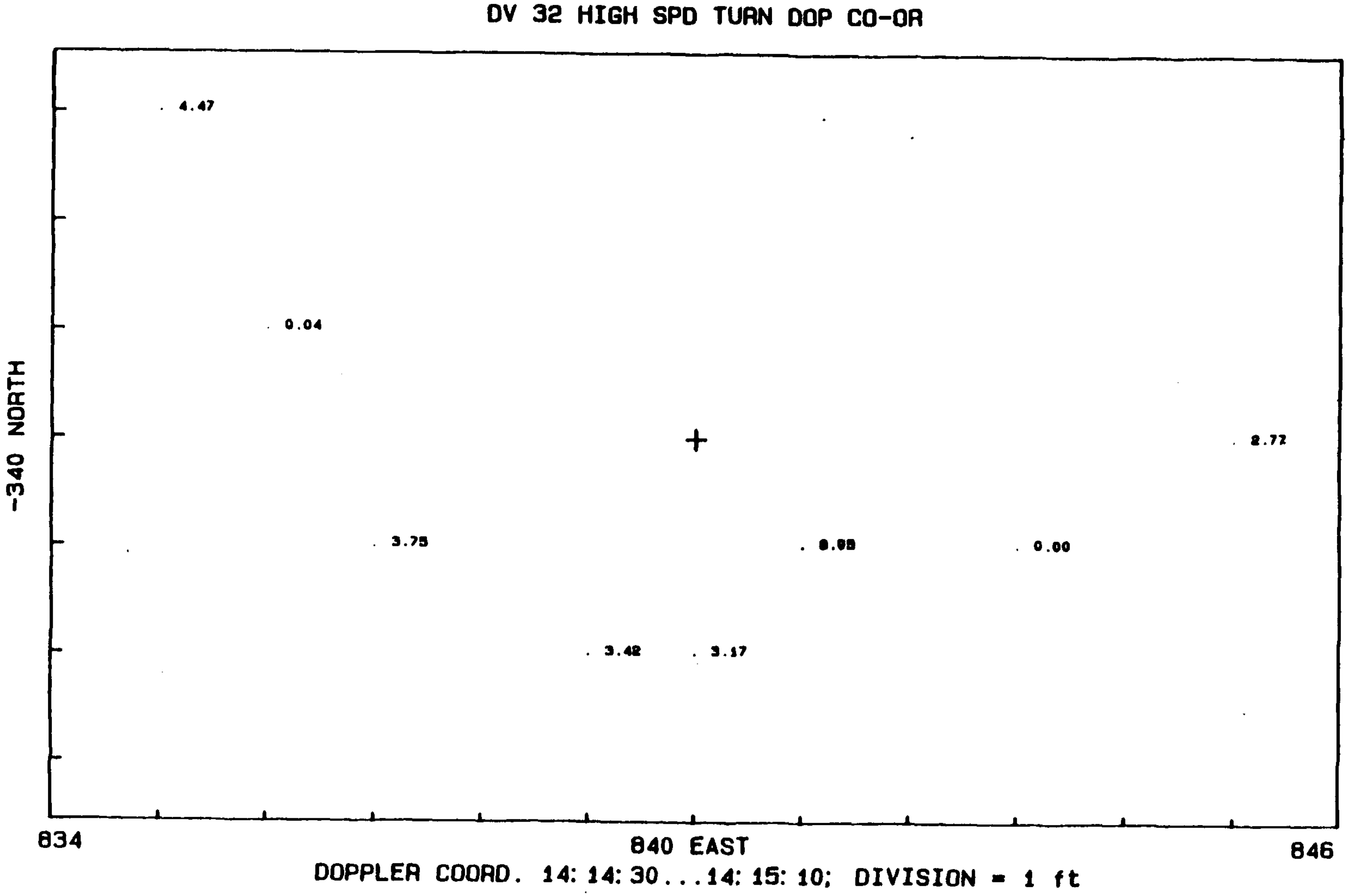


Figure G-6. High-speed turn, division 1 foot.

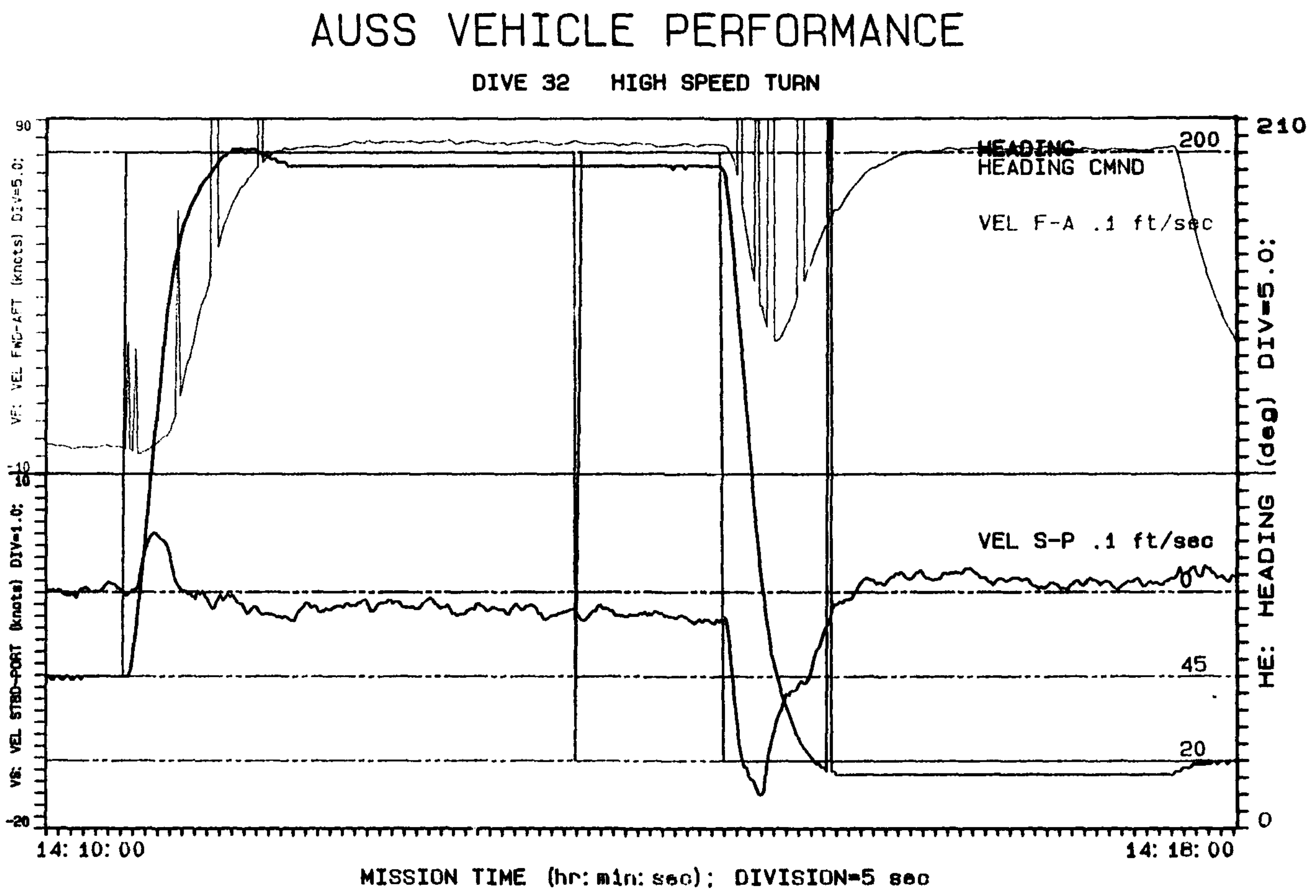


Figure G-7. High-speed turn, heading and velocity.

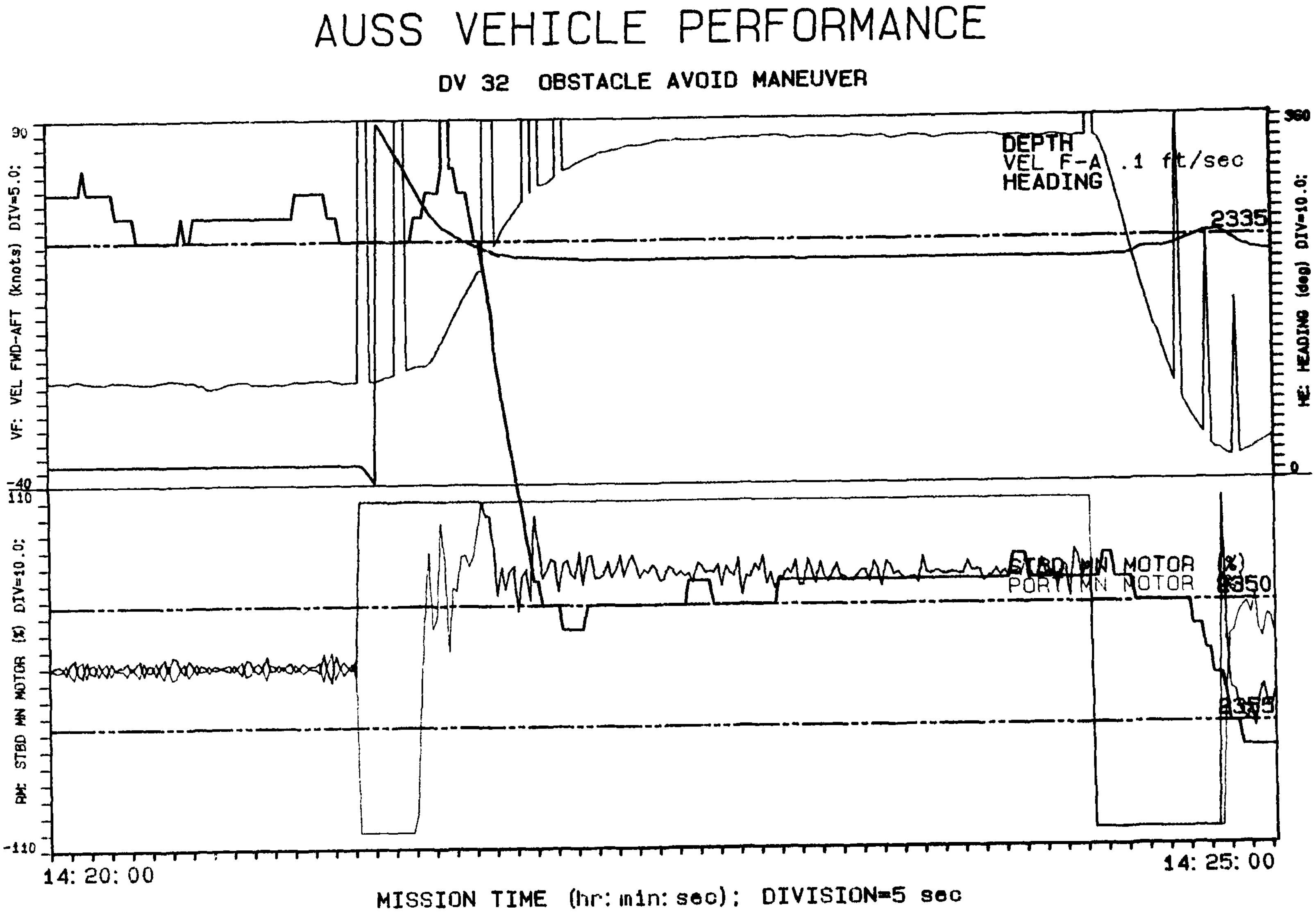


Figure G-8. Begin obstacle-avoidance maneuver at 14:24:25.

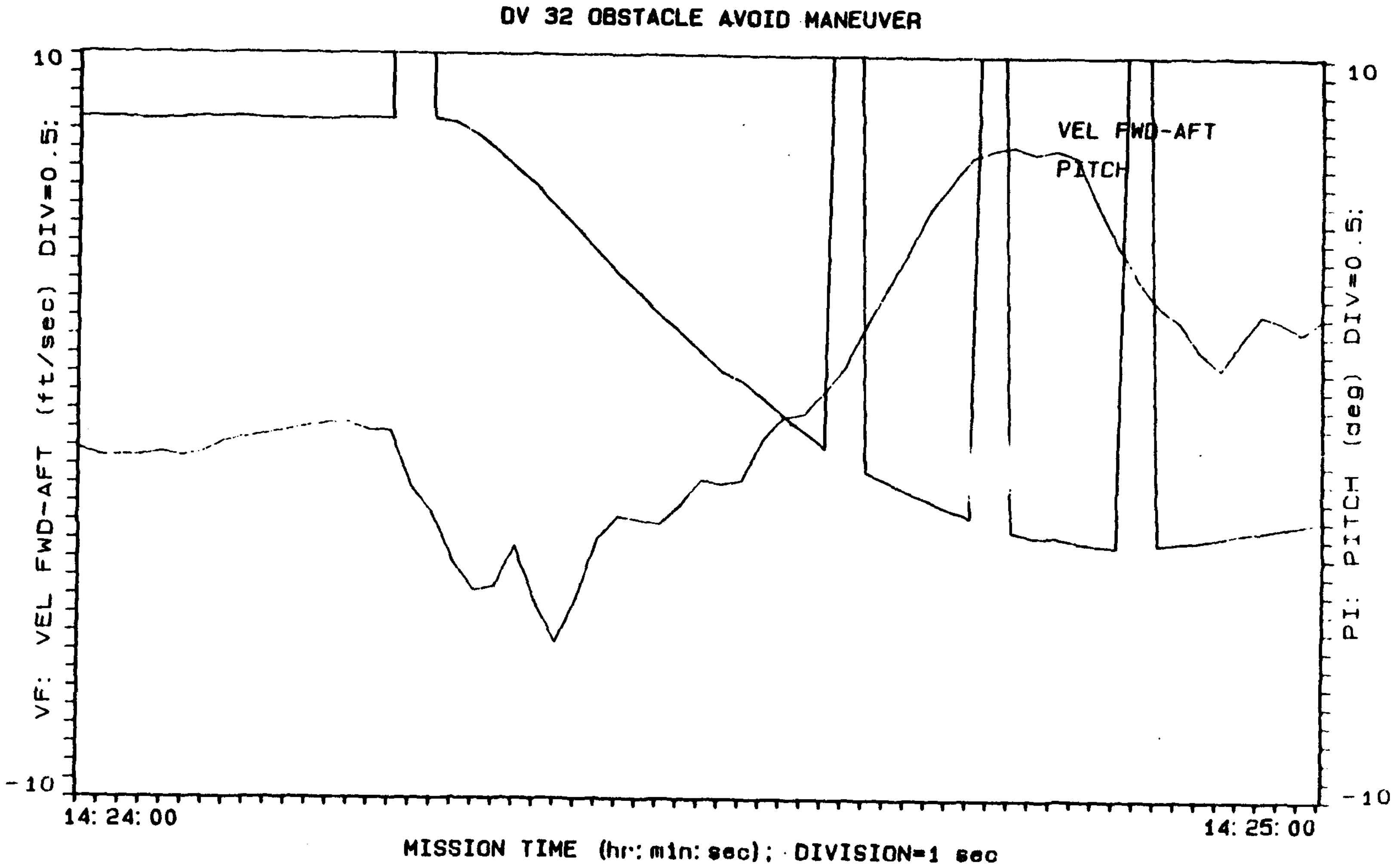


Figure G-9. End obstacle-avoidance maneuver, maximum pitch 7.5 degrees.

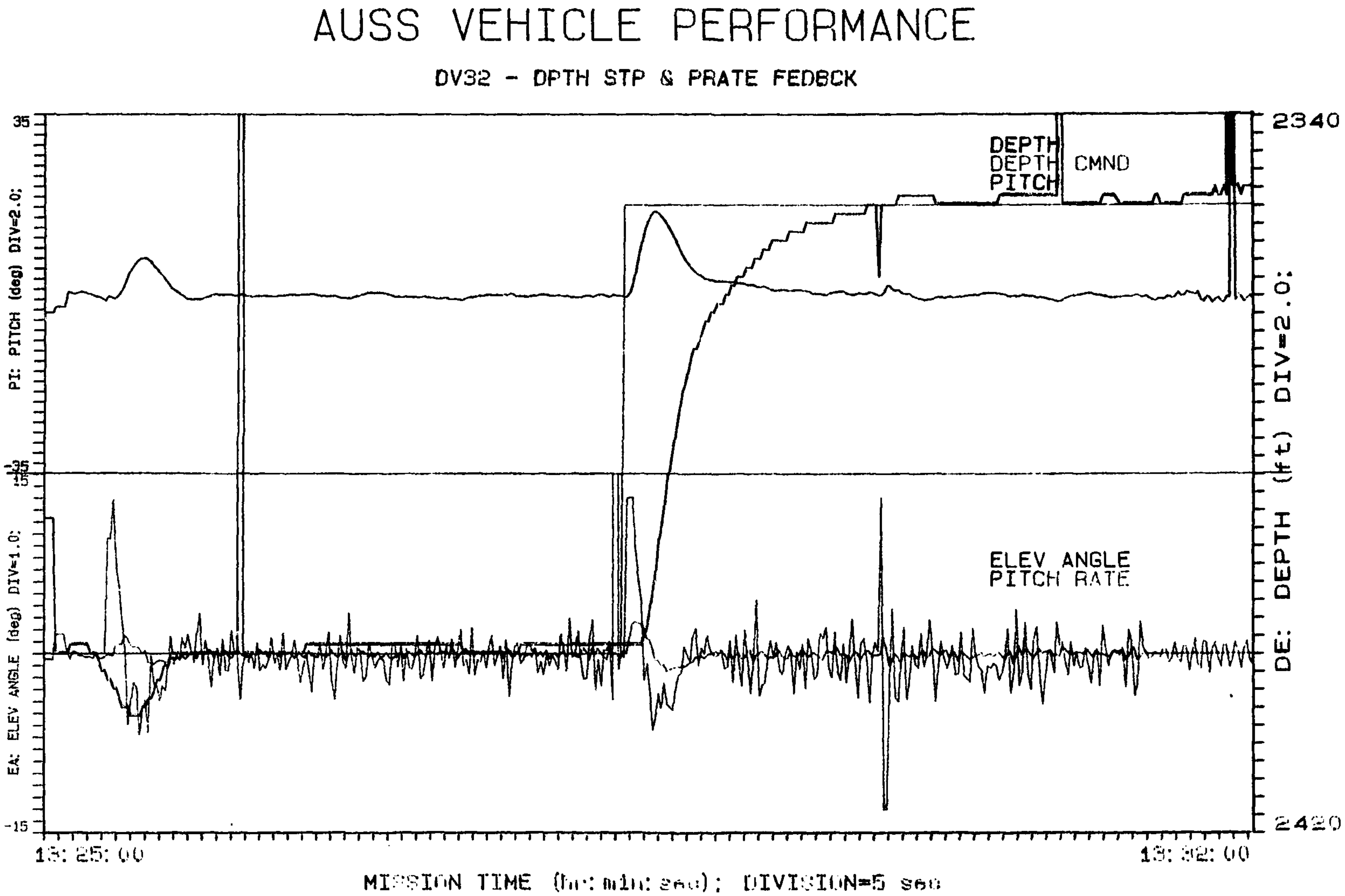


Figure G-10. Depth step, division 5 sec.

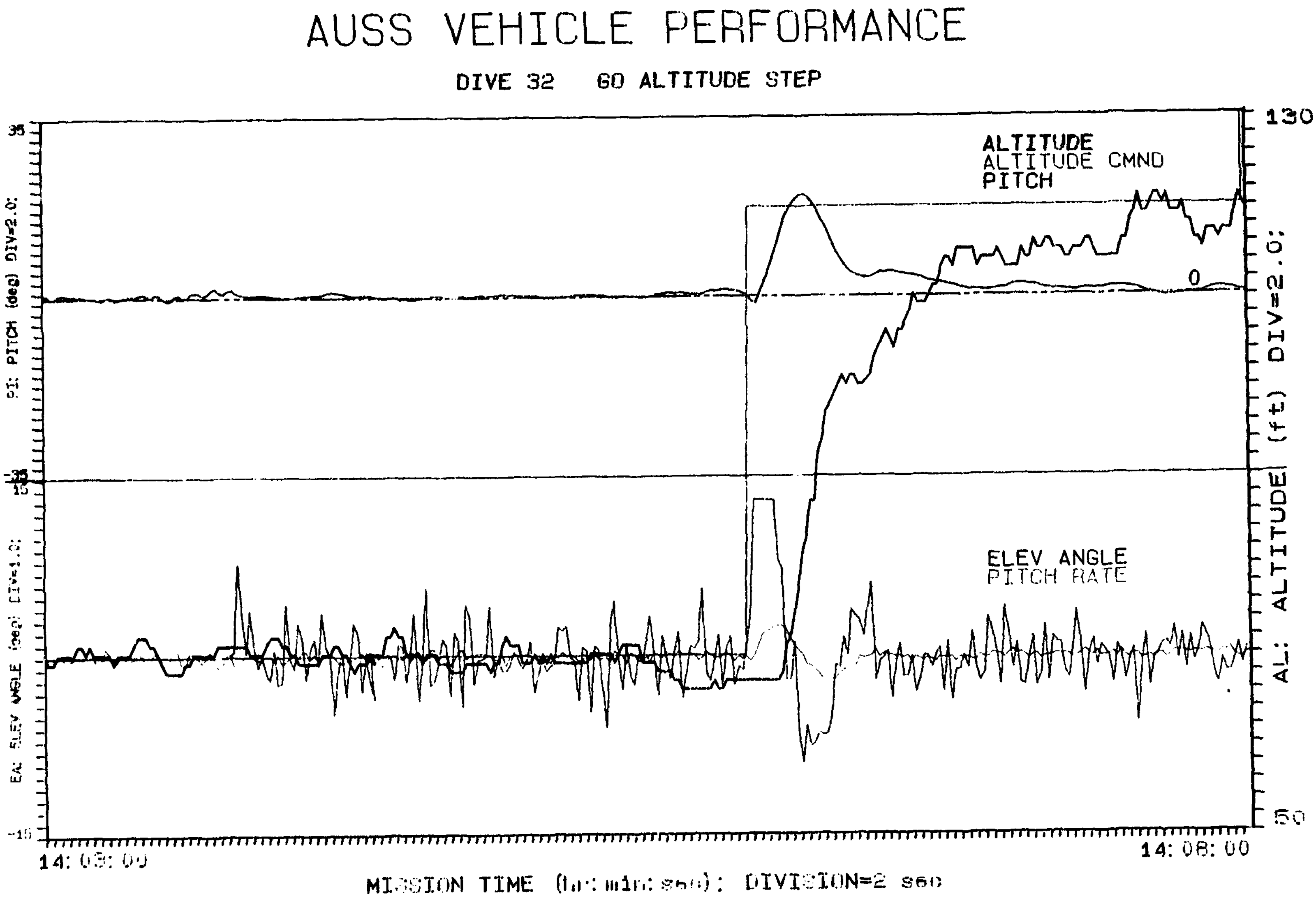


Figure G-11. GO altitude step, division 2 sec.

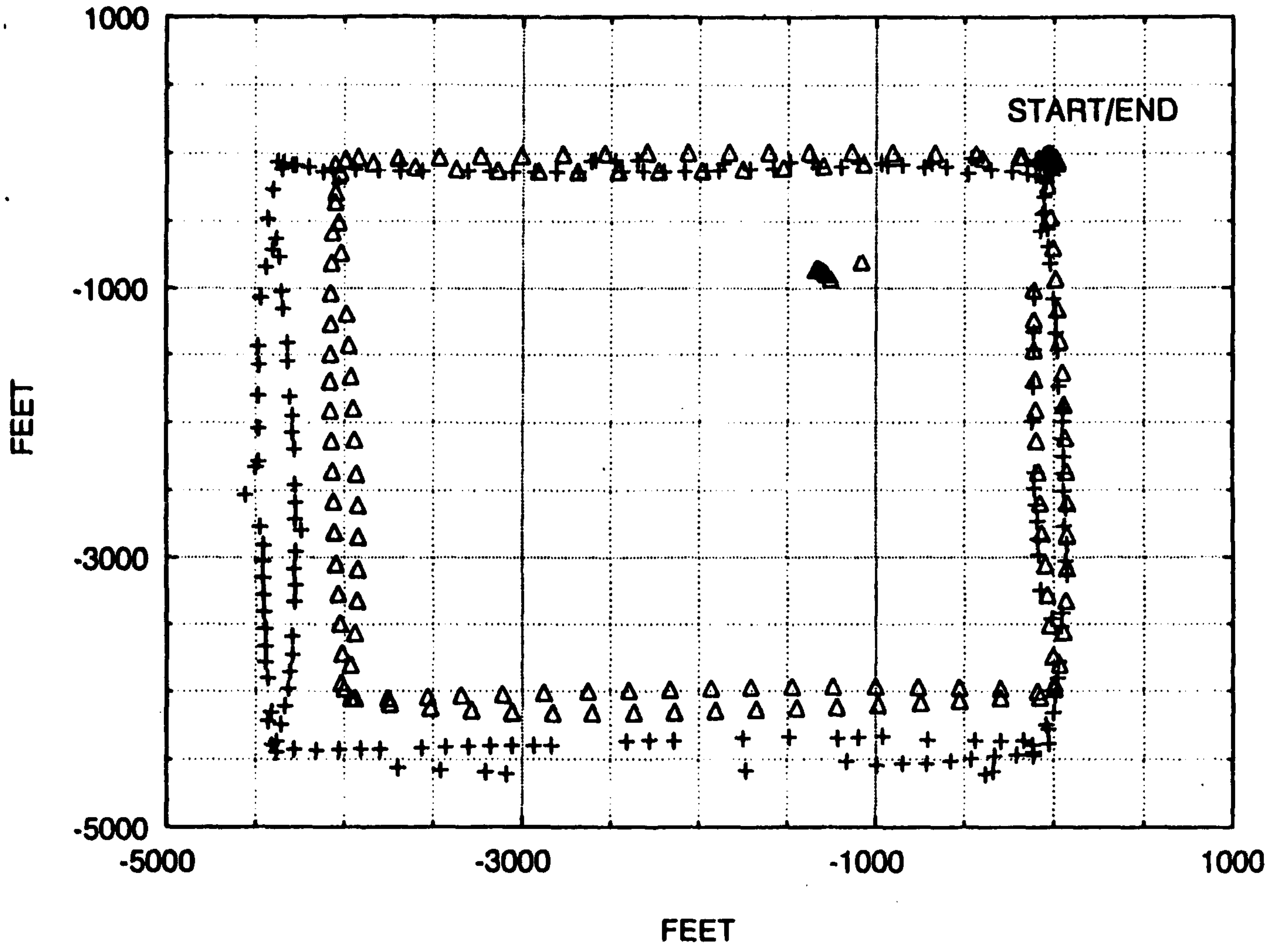


Figure G-12. Box run LBS tracking.

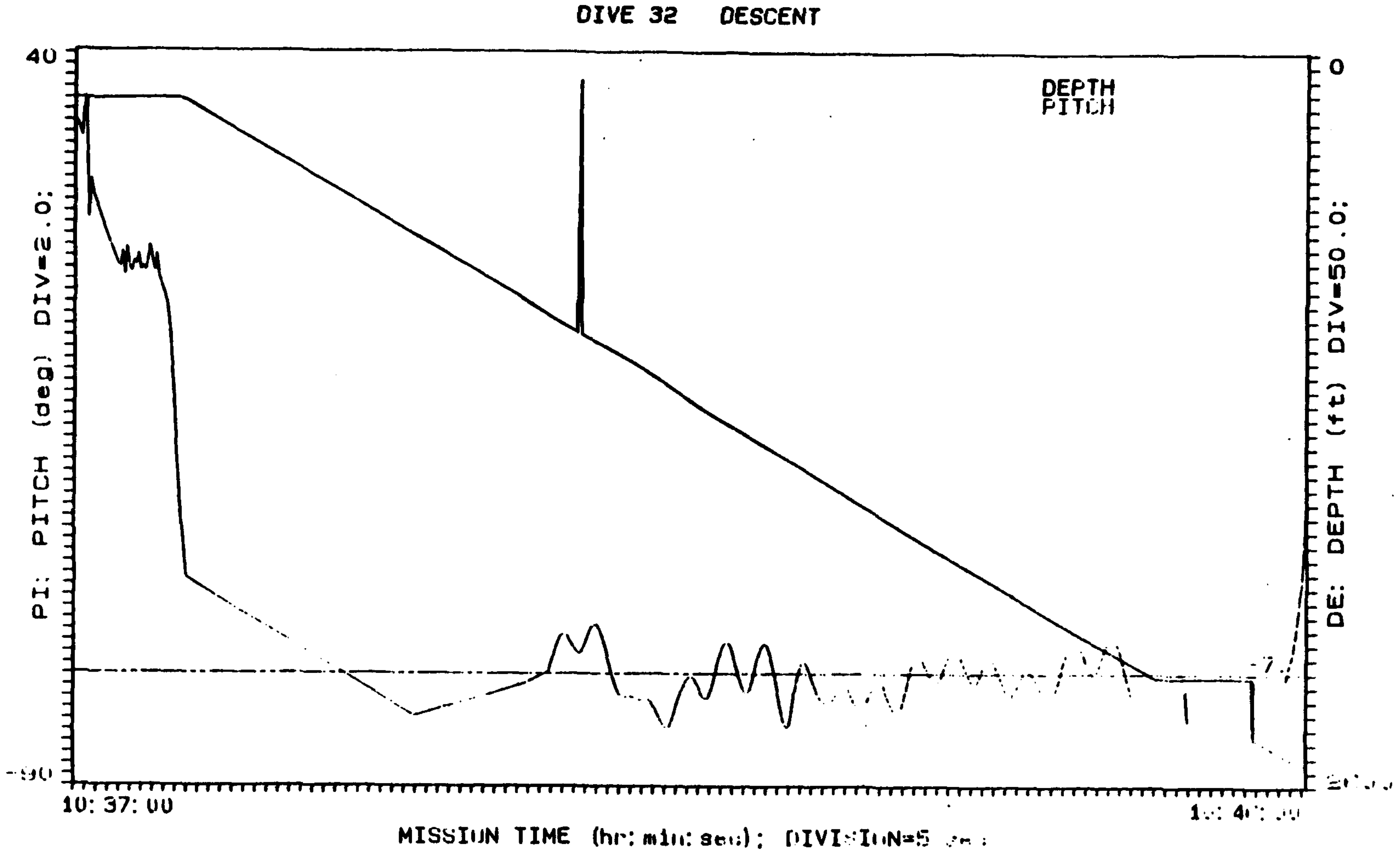


Figure G-13. Dive 32 descent showing depth and pitch angle.

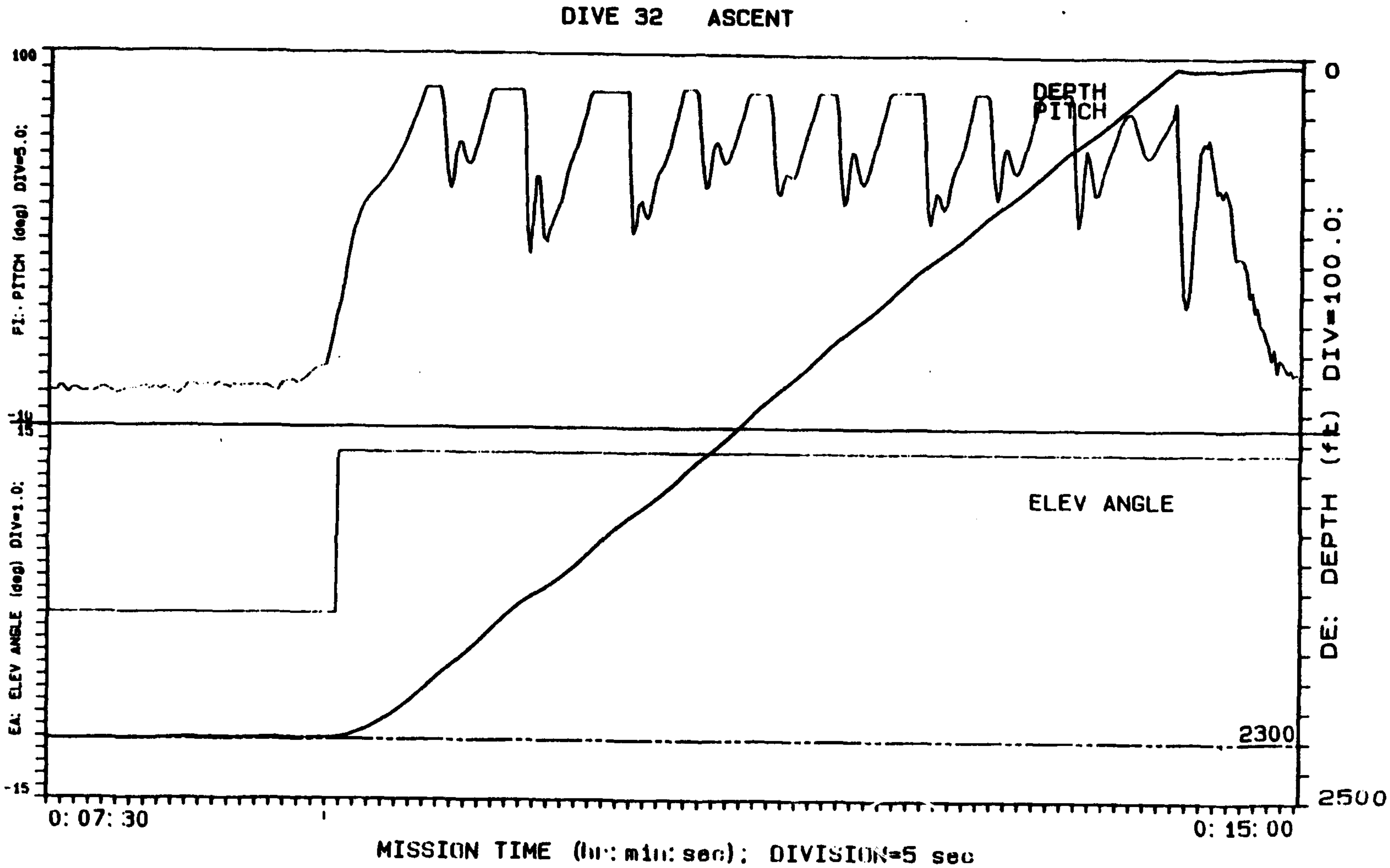


Figure G-14. Dive 32 ascent showing depth, pitch, and elevator angles

Ser 941/35–92
15 Apr 92

MEMORANDUM

From: Jim Walton (Code 941)

To: AUSS Team

Subj: Advanced Unmanned Search System Dive 33 Report

Encl: (1) AUSS Dive 33 Report

1. Enclosure (1) is my report on the Advanced Unmanned Search System Dive 33.

JIM WALTON

Copy to:
532 (Hoffman)
781 (Nickerson)
94
941
941 (Cooke, Bell, Geurin, Held, Jones, Kono, Osborne, Pryor, Rutkowski, Someson, Tallerino, Uhrich, Walton, file, AUSS file)
942
942 (Collins)
943 (Bryan, Gillcrist, Mackelburg, McCracken, Rasmussen, Watson)
944 (Phillips)
946 (Grace)
9612 (Hays)

JMW
04–15–92

AUSS DIVE 33 REPORT
(Dive Date, 2–15–92)

ACCOMPLISHMENTS

1. **Dive Duration.** This dive lasted 11 hours and 20 minutes (bottom time). The dive was terminated by operator command, and there were no vehicle system failures during this time.

2. **Battery Endurance.** The battery provided 110 Ah to this dive.

3. **Differential GPS.** The Trimble GPS unit was upgraded to include differential GPS prior to this sea trip. We had good differential GPS during the transit out until we were off Pacific Beach. The problem appears to be the differential signal that originates on Point Loma is shadowed by obstructions between the source and the ship. Before the next sea trip, a relay will be installed on the NRaD (formerly NOSC) radio shack to relay the signal from the differential station to the OPAREA.

4. **Vehicle Roll.** During Dive 32, the static roll of the vehicle was measured at 6 degrees to starboard. Between Dives 32 and 33, a 6-pound weight was placed inside the front fairing against the port fairing skin. This resulted in a 3-degree correction such that the static roll was 3 degrees to starboard during Dive 33. With this information, we can calculate a more accurate cb–cg and the amount and placement of trim weights required to achieve 0-degree roll.

5. **High-Altitude Doppler Performance.** As was done during Dive 32, Doppler drift data were collected while the vehicle was on the descent string. The results were similar in that the drift pattern grew at a rate of 1 ft/min for minimal acoustic link transmissions (status updates only) and grew at a rate of around 10 ft/min for near-continuous transmission (CCD and flight recorder data acoustic link transmissions).

The Doppler polyethylene cover was removed prior to Dive 33. It may be concluded that the removal of the cover had no effect on the Doppler drift when operated at high altitude.

6. **Static Pitch Trim With Hovering Vehicle.** Howard McCracken added a new mode for handling the static pitch trim of the vehicle. When the vehicle is hovering (holding depth, heading, and holding 0-degree pitch angle), the trim weight is moved until the thrust of the forward and after vertical thrusters match. This routine was used successfully during this dive to adjust the static pitch trim of the vehicle.

7. **Hover Control Loops.** Recently, the hover depth and hover altitude control loops were upgraded from type 0 to type 1. Soon after this successful transition, it was noted there were some overshoot. This overshoot occurs because the limited integrator integrates for too long and doesn't "de-integrate" until after the objective depth or altitude is passed.

Recent Addition of "Type Switch." For this dive, Jimmy Held had Howard McCracken put a "type" switch in the hover depth and altitude loops. This switch is triggered by software that senses when the rate of change of depth decreases below a specified threshold. For rates above the threshold, the control loops are type 0, and for rates below the threshold, the control loops are type 1. This avoids the high values of integrated error fed back from the full time type 1 control loops.

Depth Loop. Figure G-15 is a plot of step changes in depth. Please note the depth scale is inverted compared to how we usually plot depth. In these 50-foot steps, the maximum overshoot as plotted is only 1 foot. With this, the hover depth control loop is complete.

Altitude Loop. Figure G-16 is a plot of step changes in altitude. As with the depth loop, the altitude control loop (although noisy because of the noisy sensor (Doppler sonar)) does not have appreciable overshoot and is now completed.

8. **Obstacle-Avoidance Maneuver.** In Dive 32, a pseudo-obstacle-avoidance maneuver was accomplished and reported. During this dive (#33), the next test of obstacle avoidance was accomplished. In this test, the vehicle was commanded to GO to a position (waypoint navigation), and a timer was started in the sensor computer by a special command sent from the surface. When the timer timed out, the sensor computer sent a command to the main computer to perform the obstacle-avoidance maneuver.

Time and Distance Traveled. The obstacle-avoidance maneuver data are plotted on figures G-17 and G-18. The initial velocity going into the maneuver was about 8.2 ft/s (4.85 knots), and the maneuver was terminated when the Doppler velocity measured was about 0.6 ft/s. The time for the vehicle to decelerate from 8.2 ft/s to 0.6 ft/s was 21 seconds (based upon the time between full port main thruster command and zero thrust command to both motors). An approximate value for the distance traveled during this period can be obtained by assuming a straight line relation between the velocity and the time and then integrating. The value obtained by this method is 80 ft.

Sources of Error. Besides being approximations, the determinations of the time to complete the obstacle-avoidance system maneuver and the distance traveled during the maneuver are in error because the Doppler does not exactly track the velocity of the vehicle during deceleration. The performance of the Doppler during deceleration is shown in figure G-19. This performance curve is for the Doppler in the slow track mode (which we were in during Dives 32 and 33).

For the data in figure G-19, the Doppler was on a carriage, which is accelerated to a constant velocity of 5 ft/s, and then decelerated to 0-ft/s velocity. The slope of the carriage velocity curve (deceleration) is different from the slope of the Doppler velocity curve (0.625 ft/s vs. 0.33 ft/s). Below 1.5 ft/s, the Doppler velocity curve is very nonlinear and trails off. Therefore, in our OAS maneuver sea tests, the vehicle reached 0-ft/s velocity before the curves in figures G-17 and G-18 indicate.

Future OAS Experiments. The Doppler may be switched into a fast-track mode. Although the fast-track mode tracks the velocity better during acceleration/deceleration, it suffers in resolution compared to the slow-track mode. In the future, OAS maneuver experiments with the Doppler in the fast-track mode may be conducted to determine the value of switching modes during deceleration and acceleration.

It would be better to rapidly decelerate the vehicle until there is no advance velocity. In the future, instead of using a positive velocity threshold, the threshold for turning off the OAS maneuver will be between –0.5 and –1.0 ft/s.

Pitch Angle During OAS Maneuver. The maximum vehicle pitch experienced (see figure G-17) during the obstacle-avoidance maneuver was –4.8 degrees. This is a very acceptable pitch angle and does not degrade the performance of anything on the vehicle.

Vehicle Heading Disturbances. In figure G-17, there is an obvious imbalance between the port and starboard thrust commands as the vehicle attempts to maintain a heading. In fact, during the GO command, the command to the port motor is 100% and the command to the starboard motor is 50%. For the next series of dives, we will adjust the vehicle rudder angle until the vehicle tends to run in a straight line between waypoints. At this point, it is hoped the commands to the main motors will be matched. If the commands are not matched, we will experiment to determine how the two propulsion units are not matched. Once the vehicle is flying straight and the propulsion is matched, we will be able to increase the speed such that the maximum vehicle speed will be well over 5 knots.

9. **Doppler Accuracy During Waypoint Navigation.** Figure G-19 has both fish-cycle LBS tracking of the vehicle (+s), and Doppler coordinates retrieved from the vehicle flight recorder (triangles). The coordinates were collected for a time period when the vehicle was waypoint navigating around a box. The attempted legs of the box were 4000 feet long and parallel to the north/south, east/west axes.

The vehicle started at the northeast corner of the box and went to successive waypoints at the corners of the box in a ccw direction until it returned to the northeast corner of the box. Unlike a similar experiment conducted during Dive 32, the vehicle did not make a U-turn and continue around the box in a cw direction.

Doppler Accuracy Experiment Observations. (Refer to figure G-20). The Doppler and the LBS systems both agree that the vehicle returned to the starting point after the ccw excursion around the box. This means the Doppler drift was minimal for a 16,000-foot (2 2/3 nmi) trip.

The LBS tracks pass through corners of a square with sides approximately equal to 4,120 feet. This indicates the vehicle did its waypoint navigation control job very well, and there is very little if any compass/Doppler alignment error. Obviously there is a 120-foot (3%) difference between the Doppler and LBS squares. This 3% difference is better than the 11% error experienced in Dive 32. The difference in this dive is (per Jerry Mackelburg's insistence) the polyethylene cover over the Doppler was removed. In the future, the Doppler will be lowered, the polyethylene cover will be reinstalled, and there will be holes in the cover to allow the Doppler sonar beams to pass unobstructed to and from the Doppler head without severely affecting the vehicle hydrodynamics.

10. **Side-Looking Sonar Search, Target Detection, Target Marking, and Contact Evaluation.** The basics of AUSS search all comes together (almost) in figures G-21 and G-22, and I'll

mimic Mike Rutkowski and state, I love this stuff! In figure G-21, the three-leg search pattern was started at letter A. When the vehicle was near B (see both figures G-21 and G-22), a target was seen on the port side-looking sonar (SLS). We scratched our heads and talked for awhile, and finally sent some Pause commands.

Pause and SLS Target Marking. The vehicle started its Pause at C. With the vehicle paused, we used the SLS target-marking routine to obtain the vehicle Doppler coordinates of the target. A command was sent to the vehicle to GO to a heading hold hover 100 feet from the target coordinates. The vehicle went to the region D, and held its heading while it drifted in a westerly direction.

AUSS Vehicle as a Current Meter. An FLS scan was taken at the beginning of the westerly drift, and another taken at the end of the drift. The scans, along with our old relative position target-marking routine, allowed us to use the vehicle as a current meter and collect data on direction of water current to use in our target-closing routine.

Old Target-Closing Routine. Our "good old target-closing routine" was used to tell us a vehicle position and heading to use to place the vehicle 30 feet down-current from the target. That position is near D1. The vehicle got to D1 via a GO command. From D1, the vehicle bias thrusted into the current. FLS images were obtained until CCD images could be obtained of the target below the vehicle, which they were.

New Target Routine. Our new target routine, hover at a radius, was exercised on the same target. After the bias thrust exercise was finished, the vehicle was commanded to hold a 30-foot radius hover with respect to the target coordinates. This hover occurred near E. After an FLS scan and confirmation of the target position, the vehicle was moved in for a 10-foot hover at radius. During this hover, the vehicle obtained CCD images.

Continue (SLS Broad Area Search) Command. After some LBS fixes of the vehicle hovering over the automobile were obtained, the Continue command was sent to the vehicle. The vehicle responds to the Continue command by going back to the business of searching with the SLS. As seen in figures G-21 and G-22, the vehicle left E and headed back to the first leg of the search pattern at point F, allowing the vehicle to get stable on the track and start searching before it reaches point C (the point at which the pause/continue sequence was initiated). Per the test plan, the SLS search pattern was completed without pursuing any other immediate contact evaluations. However, (and this is important later in this report) two targets were marked with the SLS target-marking routine.

11. **Quiet Photomosaic and Quiet Side-Looking Sonar.** The capability to do photomosaic patterns and SLS patterns with no sensor data acoustic link transmissions has been implemented. This was done so that we can compare the tracks the set of Doppler coordinates define and the tracks the LBS defines. A higher update with the LBS tracking is possible because the acoustic tracking does not have to compete with the acoustic link for the acoustic channel.

Quiet Photomosaic. Figure G-23 is the Doppler plot for a quiet photomosaic run. The test director lost the bubble on this one. The Doppler/LBS comparison does not make sense here. It is pointless to combine the LBS plot with the Doppler plot in figure G-23 because the LBS is only good to a few meters.

The data for the entire three-leg plot of figure G-23 were collected in 15 minutes. From experience we should not expect the Doppler drift during this time period to be greater than 15 feet. More likely, the drift was 10 feet or less. Tests will be designed for future dives to better measure these errors.

The vehicle and the vehicle control algorithms worked very well during the photomosaic. The turns were well-executed, and the tracks were relatively parallel.

The usable length (vehicle not turning) of the legs in figure G-23 is approximately 180 feet, and the maximum lane separation is approximately 38 feet. The commanded photomosaic was for 200-foot legs, 100% coverage (0% overlap), and 40-foot altitude. This should result in a 29-foot lane separation (2 x 40 ft x tan 19.7 deg, 19.7 degrees is the 1/2 angle of the CCD camera coverage). Overlap or adjustment in the algorithm will be used in the future to compensate for these errors.

Quiet Side-Looking Sonar. The LBS versus Doppler coordinate plot for the quiet SLS is shown in figure G-24. Both the Doppler and the LBS plots show good parallel tracks. If the LBS track is taken as truth, the scaling error in the Doppler is evident. For the north/south legs, it is seen that the error is accumulated going north, but the error between the N/S Doppler and LBS is zero after the vehicle has finished the southerly leg. This is expected of a pure scaling error.

The E/W Doppler scale error continues to accumulate as the vehicle moves farther to the east. This is expected, is consistent with the general results of the box experiment, but the E/W scaling error appears to be greater for the SLS parallel tracks than it was for the box experiment. This is not totally understood at this time. The scaling error will be looked at further and will be the subject of more experimentation during future tests.

12. **Postbroad-Area Search (plus post a lot of other things) Contact Evaluation.** The AUSS proved itself as a viable postsearch contact evaluation system during this dive. When referring to figure G-21 in the last sentence of the last paragraph of 10, above, I mentioned some targets that were marked during the SLS broad-area search. One of the targets, a 58-inch-diameter sphere, was pursued after ending the SLS search pattern, conducting the quiet photomosaic test, conducting the quiet SLS test, and conducting two lengthy flight recorder dumps.

Postsearch Contact Evaluation Process. From a random starting point (the point the vehicle happened to be at after the quiet SLS run), the vehicle was given a GO command to hover near the marked position of the sphere. After one operator error, where the vehicle was sent to the wrong coordinates, the vehicle was commanded to GO to the right position and take two FLS scans. The sphere was found quickly with the FLS, and a new FLS target mark was obtained from the FLS screen. The vehicle was moved to a hover at radius of 30 feet and yet another target mark was obtained from a FLS scan. Finally, the vehicle was sent to hover at a 10-foot radius with respect to the latest Doppler target coordinates. CCD images were obtained proving that we had in fact pursued the 58-inch sphere.

Target Size Verification With CCD Target Marking. Postdive utilization of the target-marking routine on the images of the sphere taken from a few different vehicle altitudes are consistent with each other and give a diameter for the sphere of 4.7 to 5.0 feet. (58 inches is about 4.8 feet).

A New Way to Determine Dynamic Vehicle Doppler Drift. The coordinates for the 58-inch sphere obtained by CCD target marking during contact evaluation were within 140 feet of the coordinat obtained by SLS during broad-area search. The CCD image was obtained 3.5 hours after the S image. Ignoring the inaccuracies that we are still ringing out in our target-marking process, the Doppler drift was 140/(3.5x60)= 2/3 ft/min (not bad!).

For the Advanced Student Only. An astute reader might ask why we were confident that it was the 58-inch sphere that we marked on the SLS screen and subsequently pursued in the postsearch contact evaluation. The answer is that we deployed two spheres years ago connected by a 50- to 100-foot piece of PVC pipe. Both spheres have a characteristic "ring" when seen on the SLS sonagram. The 58-inch sphere is a much stronger target than the other sphere, which is either 7 inches or 14 inches in diameter. Also, the spacing between the marks on the sonagram created by the ringing is proportional to the size of the spheres. There is a very low probability of seeing all these target characteristics together on the sonagram and it not be the spheres we deployed.

13. **AUSS Vehicle Ascent.** More progress was made in the vehicle ascent as seen in figure G-25. For the Dive 33 ascent, the elevator angle was reduced to 9 degrees from the 13 degrees used in Dive 32. For any of you who kept the Dive 32 report, you can see the improvement in a couple of ways:

> **Improved Ascent Performance.** The 9-degree elevator angle resulted in an average pitch angle of about 75 degrees, and only once did the vehicle pitch past 90 degrees and flip over. The 90-degree flip over occurred over and over again in Dive 32.
>
> **Improved Ascent Time and Rate.** The 2400-foot ascent in Dive 33 took 308 seconds, giving an average ascent rate of 7.8 ft/s. This is an improvement over the Dive 32 ascent rate of 7.5 ft/s, and I believe it is due to the fact that the vehicle is not frequently limiting at 90-degrees, flipping, and rolling as it ascends.

Prediction of 20,000-Foot Ascent Time. For a rough estimate of the time to ascend from 20,000 feet, an extrapolation of the test results reported here may be made. But I got curious about the decreasing displacement of the vehicle during ascent, and how it affects the time of ascent.

I got carried away and did attachment A. I hate doing these things and just throwing it away when I see the results, so I included it in this report. What I found is that the 20-kft vehicle ascent time prediction is 48.3 minutes when the decrease in buoyancy is taken into account. The rough estimate for the ascent time using the average ascent rate for this dive over a 20,000-foot ascent is 42.8 minutes.

I thought the change in buoyancy would put us over the O.R. requirement of 50 minutes. Fortunately, it doesn't. The one factor that I have not considered here is the change in pitch angle, which might occur as the vehicle ascends and loses buoyancy.

CONCLUSIONS

1. This dive should mark the final chapter in the hover controls development. The depth and altitude hover control loops have been upgraded to type 1, and "type switches" (switching from type 0 to type 1 near the objective depth/altitude) have been added to these loops. These type switches proved effective during this dive in avoiding previously experienced overshoot.

2. The obstacle-avoidance maneuver was tested during this dive. After the obstacle-avoidance command was initiated, the vehicle traveled 80 feet in 21 seconds before the obstacle-avoidance maneuver was complete.

3. There was a 9-percent improvement in the scaling of the Doppler. This scaling improvement appears to be a result of the removal of the polyethylene Doppler cover.

4. Both the traditional contact evaluation and the new hover at radius contact evaluation were successfully tested during this dive. The hover at a radius approach has shown a potential to significantly decrease the time for contact evaluations. The hover at a radius routine will also make contact evaluations much more feasible at greater depths due to its "automatic" nature.

5. The ability to do postsearch contact evaluations was demonstrated during this dive. A target was "prosecuted" and seen on the CCD screen 3.5 hours after it was initially seen and marked on the SLS screen. Comparison of the SLS target mark and the CCD mark rendered a 140-foot drift in Doppler coordinates. This gives us a drift rate of only 2/3 foot/minute.

6. The accuracy of the CCD target marking was demonstrated during this dive. Images of a 4.8-foot-diameter sphere were measured at a variety of altitudes. The measurements varied between 4.7 and 5.0 feet.

7. An evaluation of the vehicle ascent during this dive shows that the requirement in the O.R. for a 20,000-foot ascent in 50 minutes is possible.

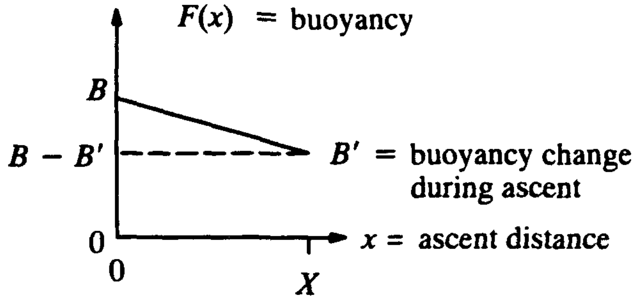
JMW
4–16–92

ATTACHMENT A
THE EFFECT OF DECREASING VEHICLE BUOYANCY ON ASCENT TIME

1. Buoyance Equation:

$$F(x) = mx + b$$
$$= \frac{-(B-(B-B'))x}{X} + B$$

$$F(x) = -(B'/X)x + B$$
$$= B - (B'/X)x$$



B = buoyancy @ beginning of ascent = in-water wt. of ascent wts.

X = distance traveled during ascent

2. Lead Weights:

$$W_{pb_{H_2O}} = W_{pb_{Air}} - D,$$

D = Displacement

$$W_{pb_{H_2O}} = 74^{\#} - \frac{74^{\#}}{710^{lb}/ft^3}\left(64\frac{lb}{ft^3}\right) = \underline{67.3^{\#}}$$
$$\therefore B = \underline{67.3^{\#}}$$

3. Ascent Time Equation:

$$F = C_D \rho A V^2/2$$

let $k_1 = C_D \rho A/2, k = \sqrt{k_1}$

or $k_1 = k^2$

$$F = k_1 \gamma^2$$
$$V = \sqrt{F/k_1} = F^{1/2}/k$$
$$dx/dt = F^{1/2}/k$$
$$dt = kF^{-1/2}dx$$

ENCLOSURE (1)

3. Ascent Time Equation (continued):

$$t = \int_0^X kF^{-1/2}dx$$

$$t = \int_0^X k(B - (B'/X)x)^{-1/2}dx$$

$$t = k\int_0^X \underbrace{\left(B - \frac{B'}{X}x\right)^{1/2}}_{U^{-1/2}} \underbrace{\left(-\frac{B'}{X}dx\right)}_{du} \left(-\frac{X}{B'}\right)$$

let $U = B - \frac{B'}{X}x$

$$du = \frac{B'}{X}dx$$

$$t = k(2)\left(B - \frac{B'}{X}x\right)^{1/2}\Big|_0^X \left(-\frac{X}{B'}\right)$$

$$\int u^{-1/2}du = 2U^{1/2}$$

$$t = -2k\frac{X}{B'}\left[(B - B')^{1/2} - B^{1/2}\right]$$

$$t = \frac{2kX}{B'}\left[B^{1/2} - (B - B')^{1/2}\right]$$

4. k and k_1:

$$k = \frac{tB'}{2X\ [B^{1/2} - (B - B')^{1/2}]}$$

$$k_1 = k^2 = \left(\frac{tB'}{2X\ [B^{1/2} - (B - B')^{1/2}]}\right)^2$$

Assume terminal velocity reached quickly compared to time t

from empirical data, dive 33.

$X = 2400$ ft

$t = 308$ sec

$B = 67.3^{\#}$

$$B' = \frac{2400}{20,000}(30^{\#})$$

$B' = 3.6^{\#}$

$B - B' = 67.3^{\#} - 3.6^{\#}$

$B - B' = 63.7^{\#}$

4. k and k_1 (continued):

ENCLOSURE (1)

$$k_1 = k^2 = \left[\frac{308\,\text{sec}(3.6^{\#})}{2(2400\text{ft})\ (67.3^{\#1/2} - 63.7^{\#1/2})}\right]^2$$

$$= 1.08\,\frac{\text{sec}^2 \cdot \text{lb}^2}{\text{ft}^2 \cdot \text{lb}} = \frac{\text{sec}^2 \cdot \text{lb}}{\text{ft}^2}$$

$$k_1 = 1.08\ \frac{\text{sec}^2 \cdot \text{lb}^2}{\text{ft}^2}\ ,\ K = 1.04\ \frac{\text{sec}}{\text{ft}}\ -\ \text{lb}^{1/2}$$

5. Coefficient of Drag:

$$k_1 = C_D \rho A/2$$

$$C_D = \frac{k_1}{A}\ \frac{2}{\rho} = \frac{1.08\,\frac{\text{sec}^2 \cdot \text{lb}}{\text{ft}^2}}{\pi\left(\frac{31}{12}\right)^2 \text{ft}^2/4}\ \frac{\frac{2}{64\text{lb}/\text{ft}^3}}{32\text{ft}/\text{sec}^2}$$

$$\underline{C_D} = 0.2$$

6. Time for 20,000-ft ascent.

$$X = 20,000\ \text{ft}$$

$$B = 67.3^{\#}$$

$$B' = 30^{\#}$$

$$B - B' = 37.3^{\#}$$

$$t = \frac{2kX}{B'}\left[B^{1/2} - (B - B')^{1/2}\right]$$

$$= \frac{2(1.04)\ 20,000}{30}\left[67.3^{1/2} - 37.3^{1/2}\right]$$

$$t = 2907\ \text{sec}$$

or 48.5 minutes

ENCLOSURE (1)

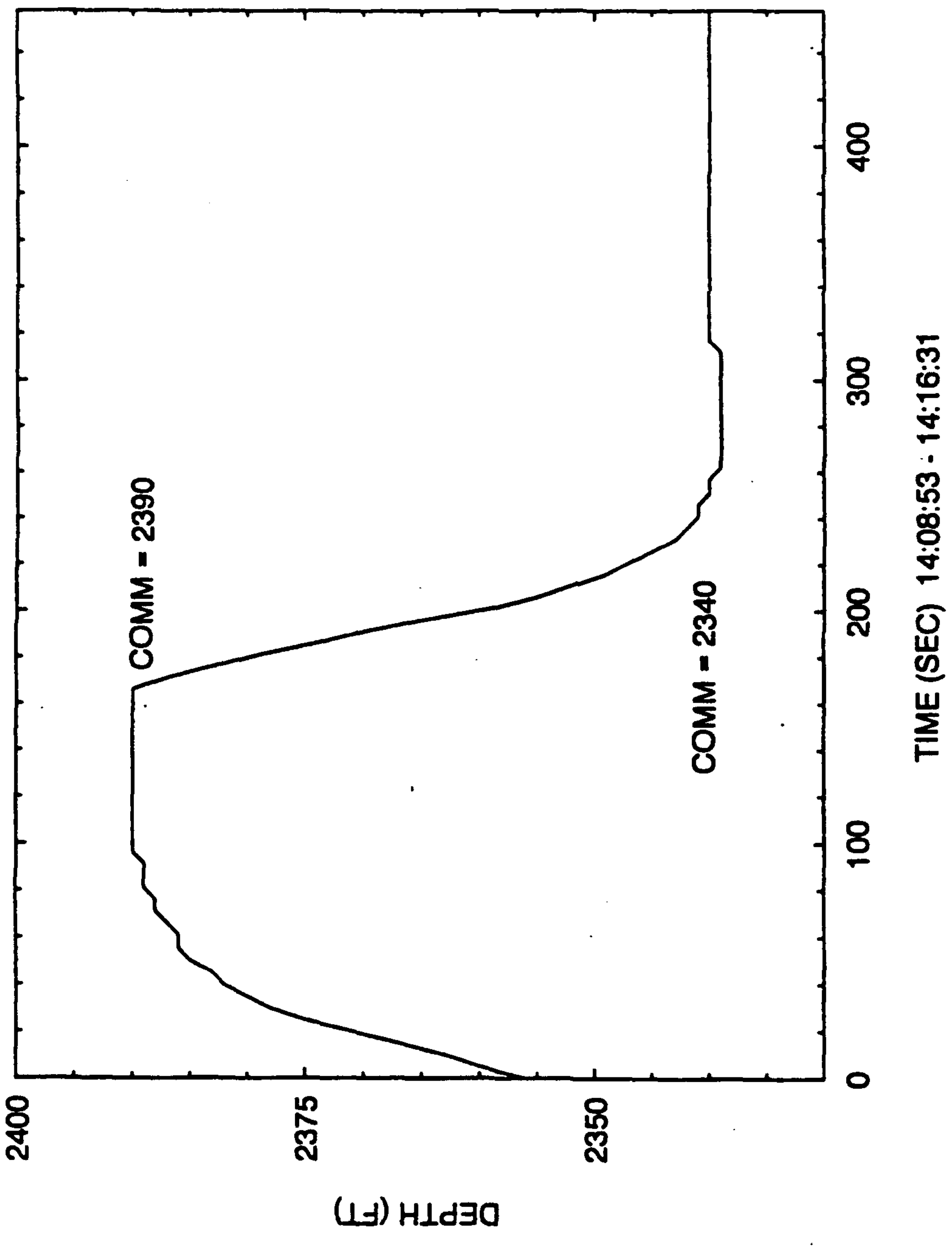


Figure G-15. Step changes in depth.

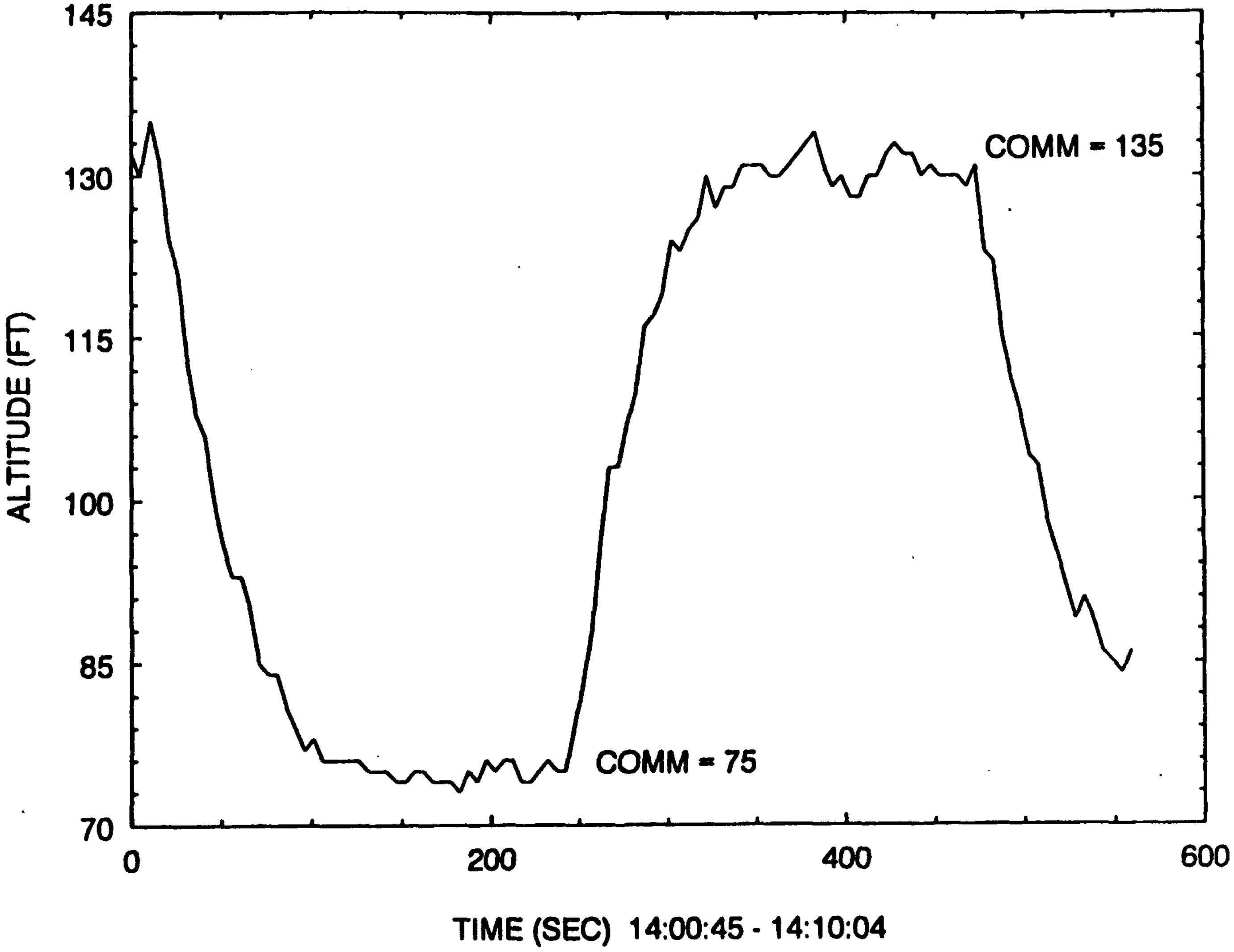


Figure G-16. Step changes in altitude.

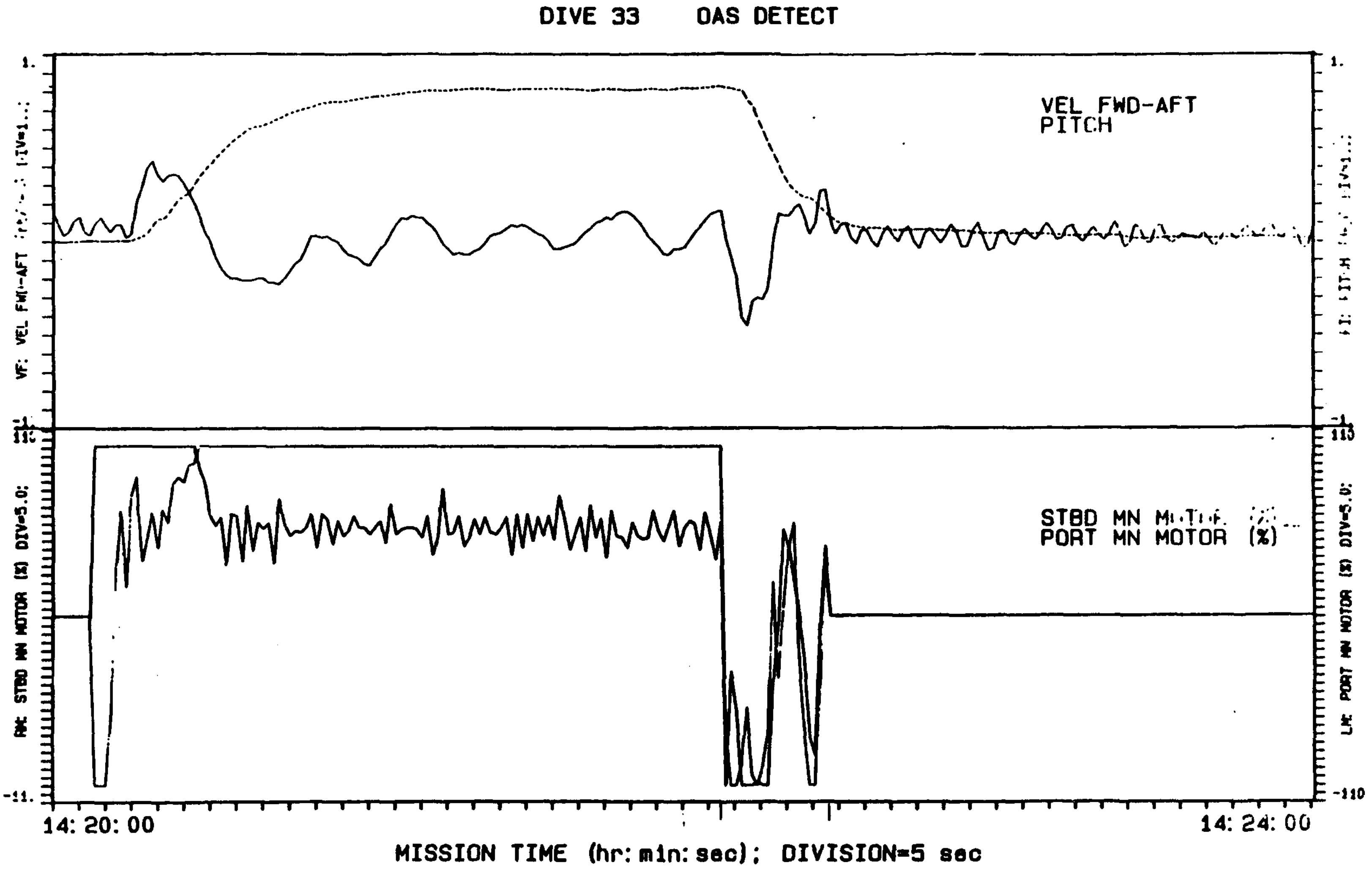


Figure G-17. Obstacle-avoidance plot, initial velocity about 8.2 ft/sec (4.85 knots).

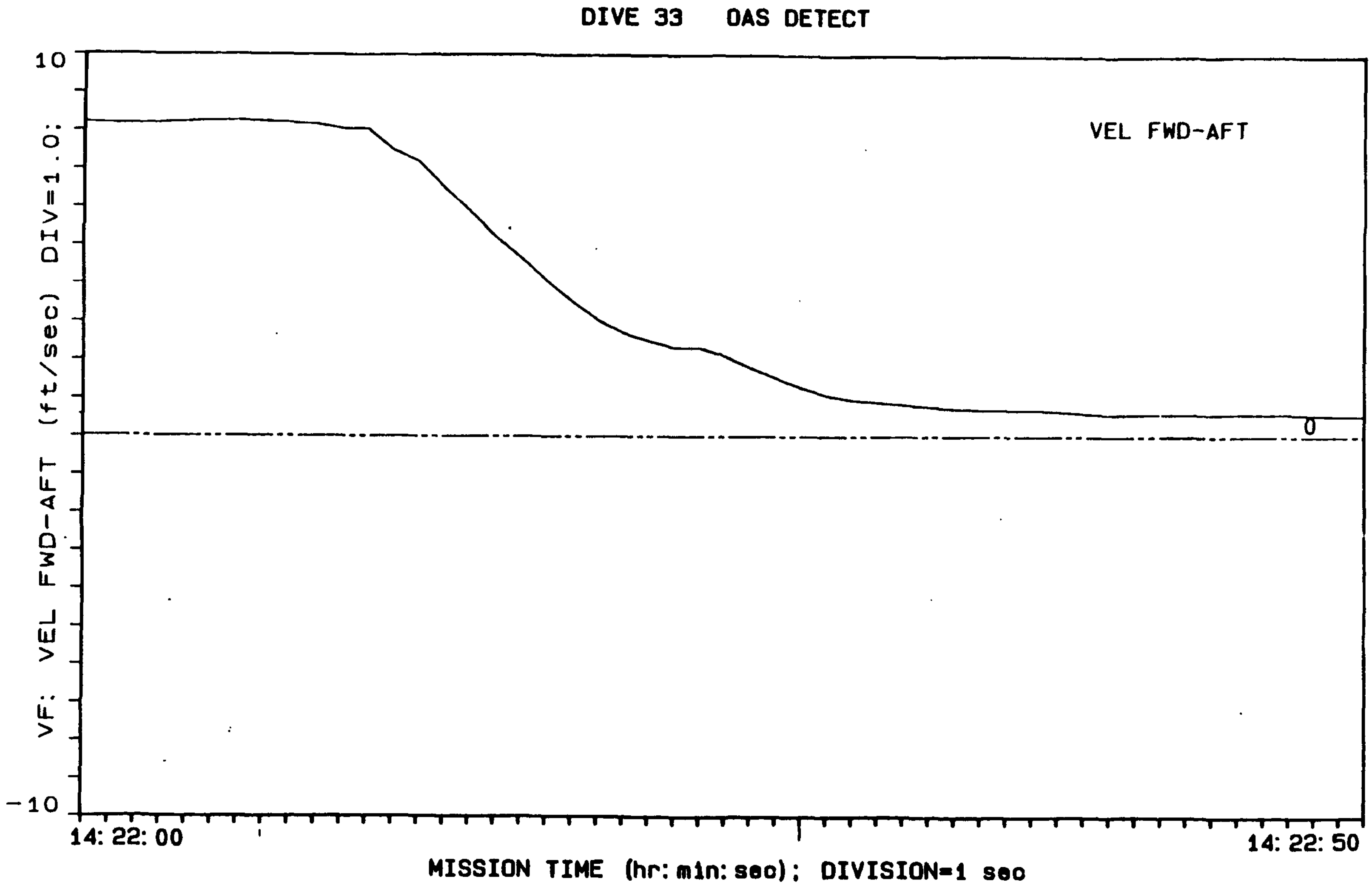


Figure G-18. Obstacle-avoidance plot, deceleration from 8.2 ft/sec to 0.6 ft/sec in 21 seconds.

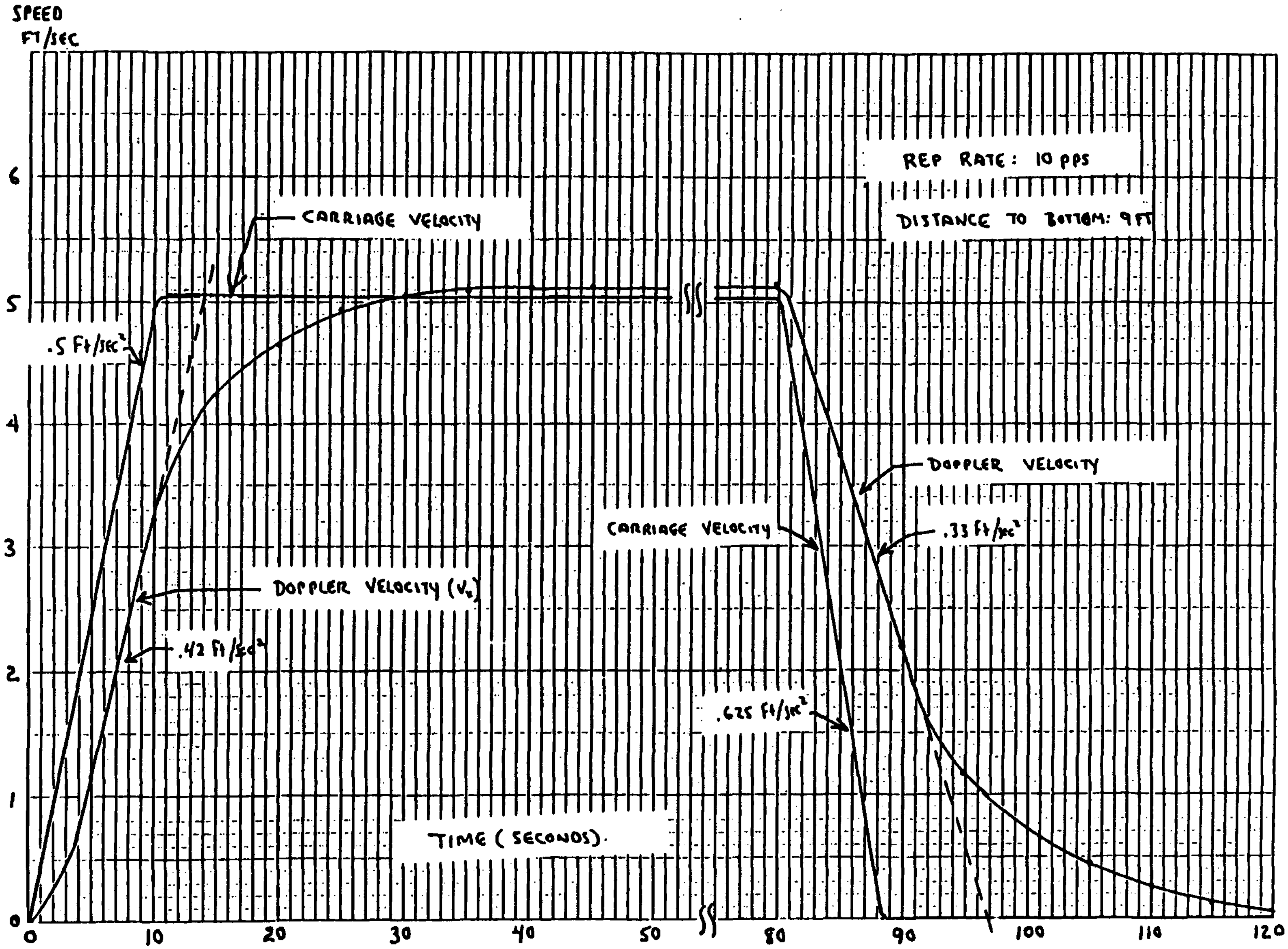


Figure G-19. Performance of the Doppler during deceleration.

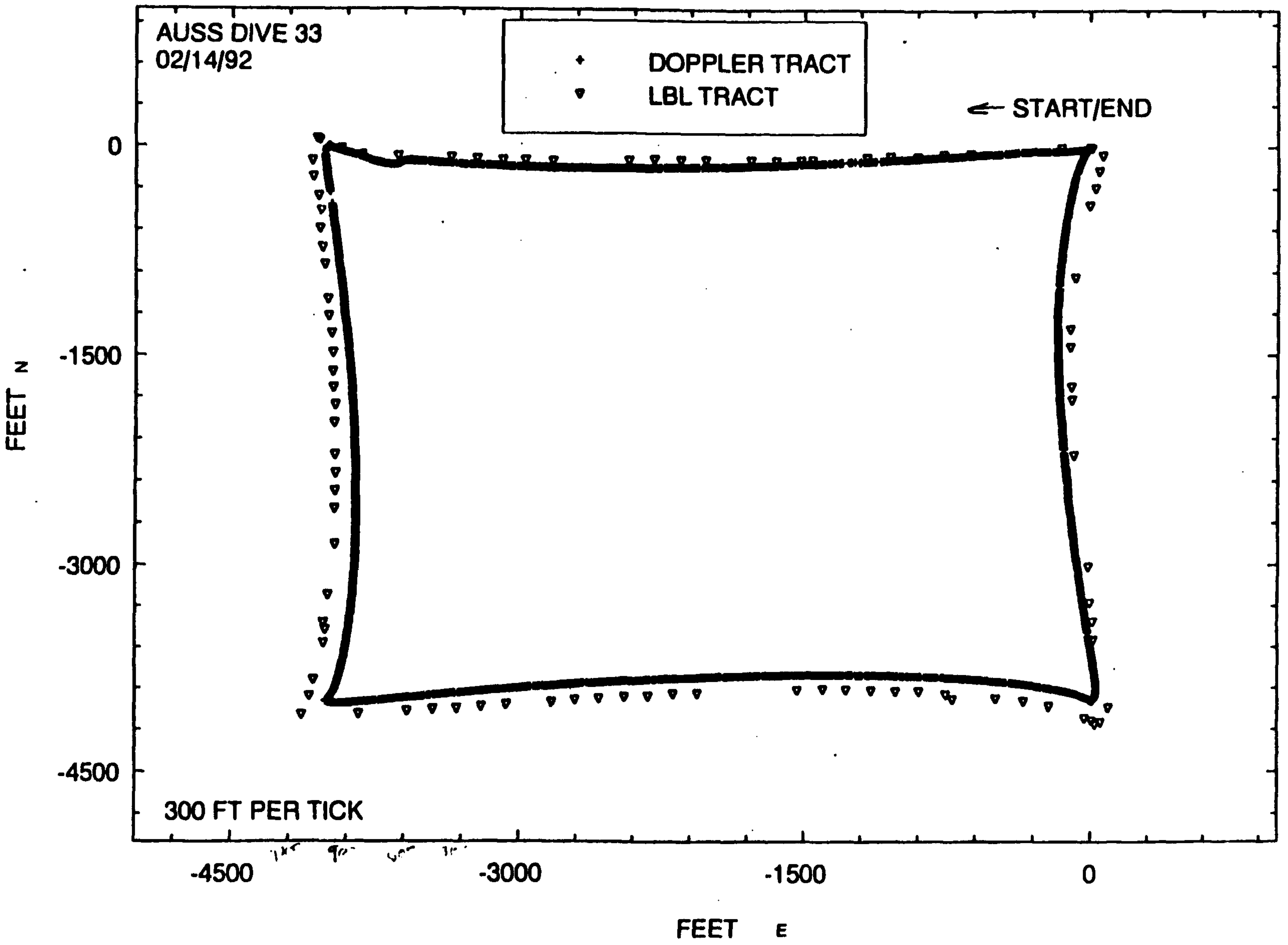


Figure G-20. Doppler and LBS tracking comparisons.

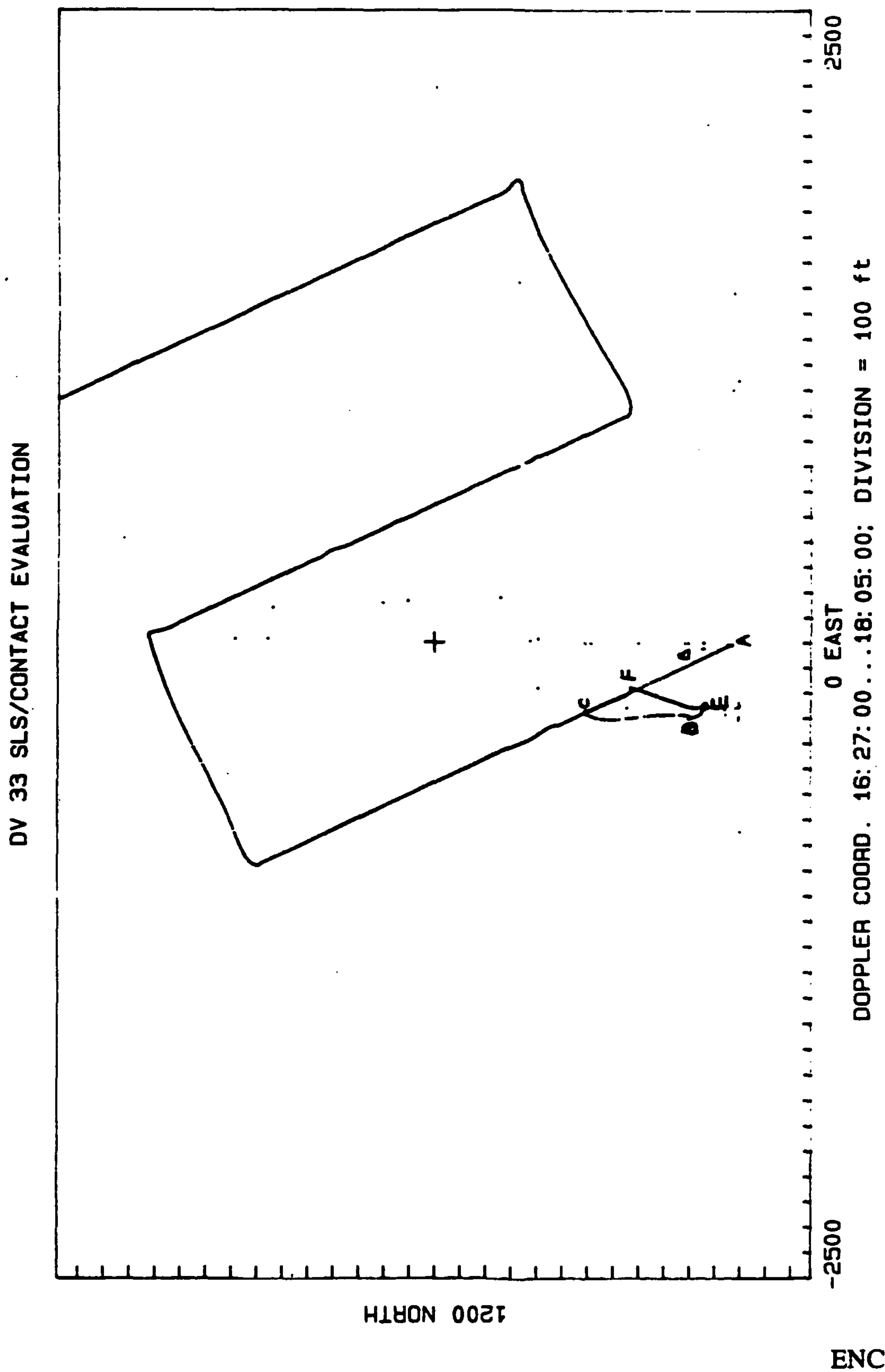


Figure G-21. SLS search, the three-leg search pattern starting at point A.

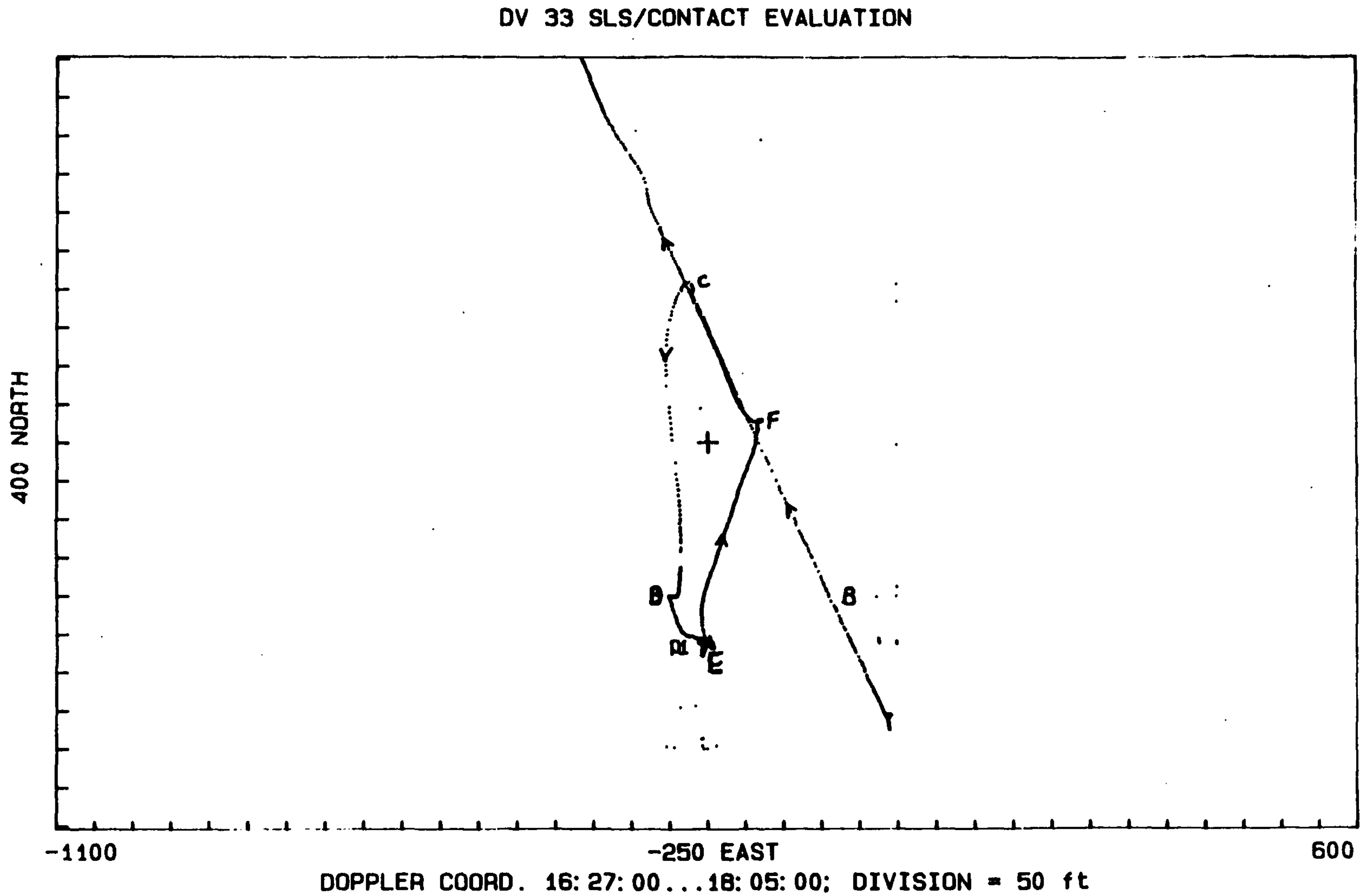


Figure G-22. SLS search, target detected on port side.

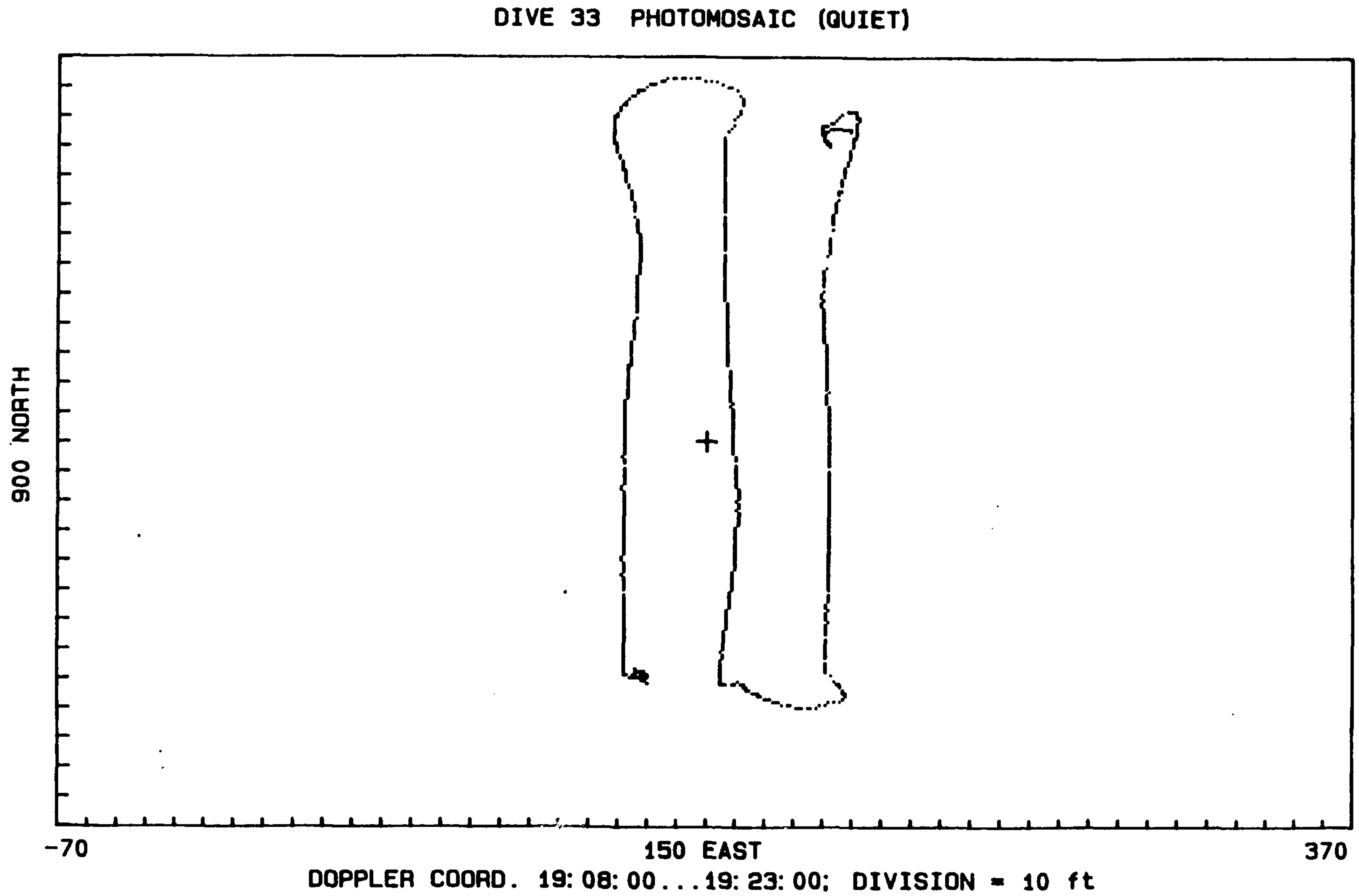


Figure G-23. SLS search, data for entire three-leg plot collected in 15 minutes.

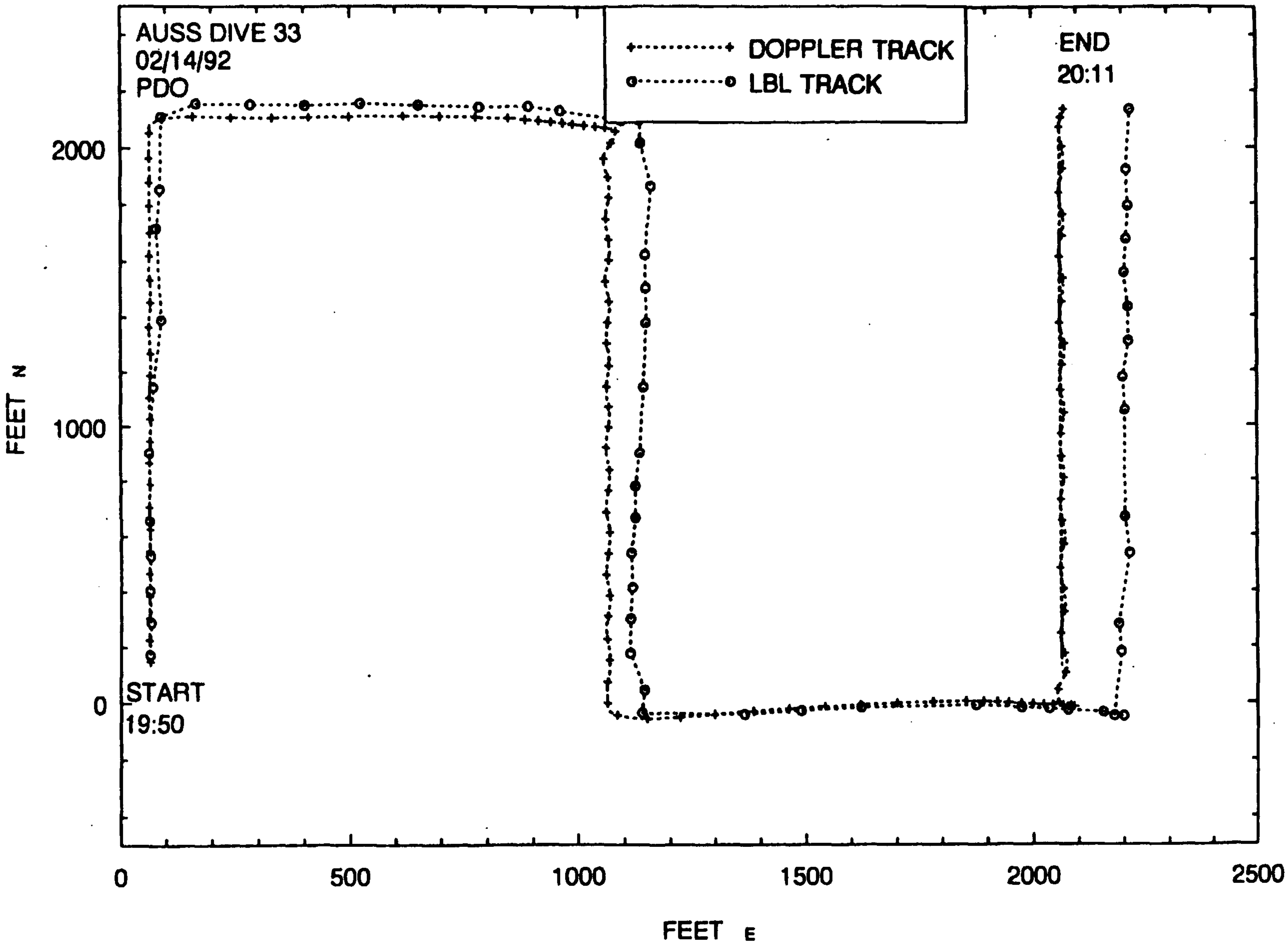


Figure G-24. LBS vs. Doppler coordinate plot for the quiet SLS.

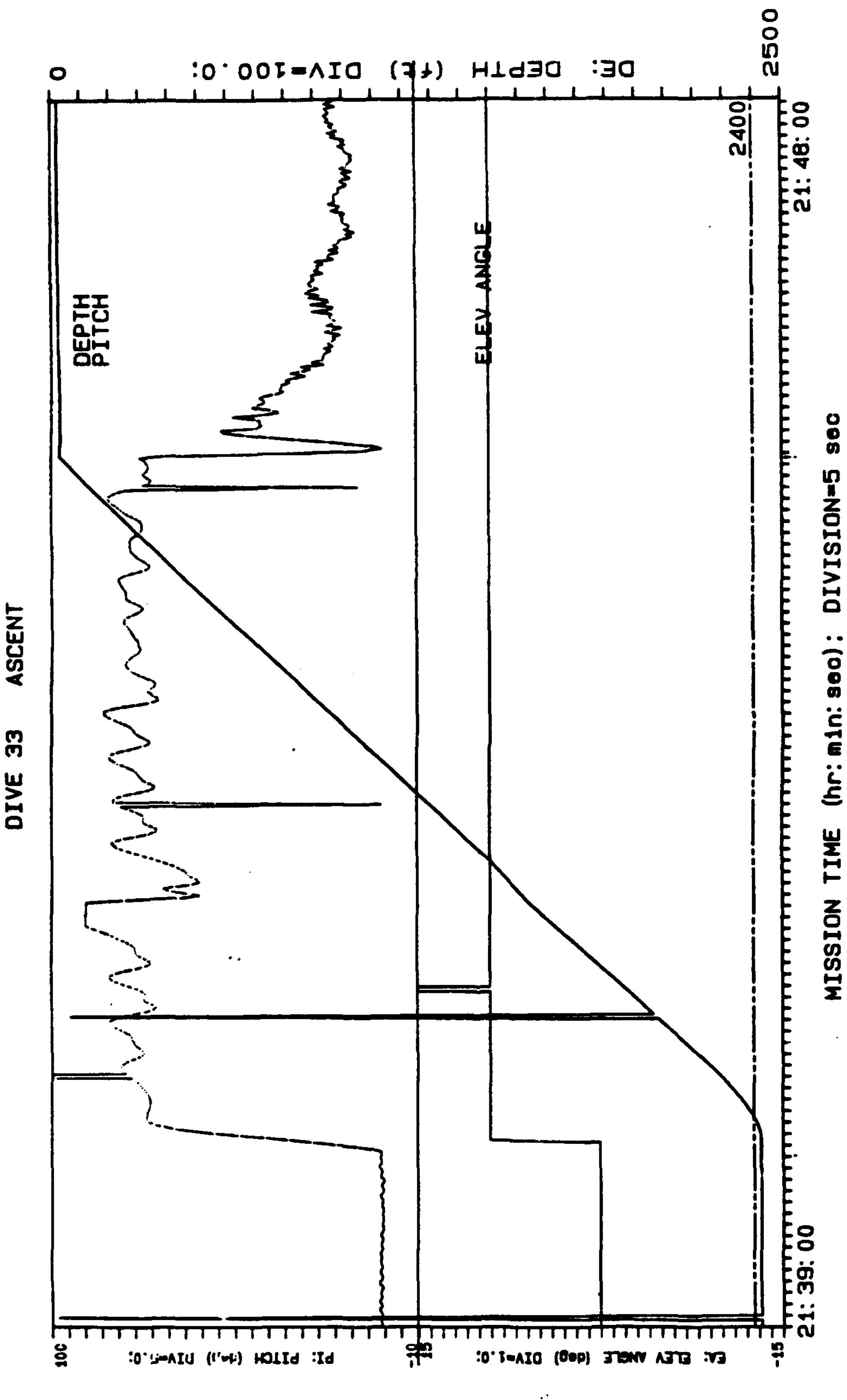


Figure G-25. Dive 32 ascent, elevator angle = 9 degrees.

AUSS DIVES 34 AND 35 REPORT
(Dive Dates 3–3–92 and 3–4–92)
OPAREA 3703

TEST PURPOSES

1. Confirm S/W solution to the sonar duty cycle problem
2. Conduct the first OAS tests using the OAS in transmit/receive mode
3. Conduct "box runs" to further evaluate Doppler accuracy.

ACCOMPLISHMENTS

1. **Dive Number/Duration.** 34/3.5 hr, 35/11 hr.
2. **Battery Endurance.** Dives 34/35; 45+105=150 Ah.
3. **Obstacle-Avoidance Sonar (OAS).** The test plan objectives were met but the postdive analysis is still in process. First-hand observations on board the *MARSEA FIFTEEN* during the tests were positive. The OAS did not work as well as was hoped. The OAS did transmit and receive an OAS signal from one of the targets on the bottom. The received signal appeared not to be of the "character" that was expected. Evaluation of these results is in process. The fact that the OAS worked on one of the close-to-the-bottom targets is encouraging.

AUSS DIVES 36 AND 37 REPORT
(Dive Dates 4–1–92 and 4–2–92)
OPAREA 3703

TEST PURPOSES

1. Test the 35-mm camera
2. Continue obstacle-avoidance sonar (OAS) tests
3. Test new electromagnetic interference (EMI) filters on motor power lines.
4. Evaluate the removable hard drive/flight recorder data.

ACCOMPLISHMENTS

1. **Dive Number/Duration.** 36/5.5 hr, 37/8.0 hr. The combined bottom time for Dives 36 and 37 was 13.5 hours. Dive 36 was 5.5 hours long, and dive 37 was 8 hours long. Dive 36 was terminated when the port main motor fiberglass shaft failed due to a failed roll pin. Dive 37 was terminated due to a low-battery-cell voltage.

2. **OAS.** Tests were conducted to use the OAS while on the descent string and hovering free. The vehicle was pitched at different angles to see the bottom and targets. Images were seen on the displays.

3. **EMI Filters.** Tests of the filters were successful.

4. **Target Surveys and Contact Evaluations.** Target surveys and contact evaluations were conducted. Attachment 1 to this report shows a 3-leg SLS search with contact evaluations. A significant result is that targets were picked up on both SLSs and pursued during the same contact evaluation sequence. After optically evaluating both targets, the vehicle returned to the original search track. The time for these contact evaluations, including the contact evaluation of both targets and transit between targets, was 23 minutes.

5. **On-board Removable Hard Disk.** The on-board removable hard disk has been implemented and performed satisfactorily during the dives. Flight recorder data are now stored onboard during the mission rather than sent up the acoustic link. The importance of this is the operation is not interrupted for the preservation of flight recorder data. Search sensor data are still routinely sent over the acoustic link as the operation occurs.

6. **Battery Endurance.** To accomplish both dives, 156 Ah were drained from the battery before a low-cell voltage occurred.

7. **Obstacle-Avoidance Sonar (OAS).** The software to control the OAS and display its image in the FLS format is in place and worked well during this dive. The signal level for the OAS was explored at length using a variety of targets, backgrounds, and standoff ranges including: descent string float with water background, bottom with various grazing angles, and targets on the bottom with various grazing angles. The results of these tests will not be reported here, but will be part of separate documentation.

8. **Doppler Accuracy/Rudder Angle Adjustment Effect During Waypoint Navigation.** Figures G-26 through G-29 show fish-cycle long baseline (LBS) tracking of the vehicle (Os), and

Doppler coordinates retrieved from the vehicle flight recorder (triangles). The coordinates were collected for a time period when the vehicle was waypoint navigating around a box. The attempted legs of the box were 4000-feet long and parallel to the north/south, east/west axes.

The vehicle started at the northeast corner of the box and went to successive waypoints at the corners of the box in a counterclockwise direction until it returned to the northeast corner of the box.

Flight Recorder Data Dropout. The flight-recorded Doppler data were good for half of the box experiment, i.e., the first two legs of the box (see figure G-26). After the first two legs, the flight-recorded Doppler data were unreliable. This was due to the flight recorder and not the Doppler itself. The Doppler continued to operate properly throughout the experiment as evidenced by the LBS track, which shows that the vehicle completed the box using the on-board Doppler–gyroscope navigation system.

Manipulation of the Doppler/LBS Box Data. In an effort to look at the remaining small scaling error in the Doppler, the data in figures G-26 through G-29 are translated such that the northwest corner of the Doppler box matches the northwest corner of the LBS box. No rotation was necessary. As seen in figure G-26, the Doppler and LBS western edge of the box are, on an average, quite parallel.

Doppler Head/Gyrocompass Alignment. Figures G-27, G-28, and G-29 show how the corners of the boxes were matched. The NW and the SW corners are both fairly well matched between the Doppler and the LBS. This further shows that the tracks were quite parallel, thus the angular alignment error between the Doppler head and the gyrocompass is minimal. These figures also show that the vehicle made a 270-degree turn to change from a heading of 270 to 180 degrees (this is a result of the waypoint and turn algorithms, is expected, and is not of any concern).

Doppler Scaling Error. If it is asssumed that the LBS track is truth, it is seen in figure G-29 that the vehicle traveled approximately 50 feet less than the desired 4000 feet while transiting from the NW corner to the SW corner of the box. The 50-foot error equates to a 1.25% along-track scaling error. This improved accuracy is a result of a software-scaling correction. In previous dives, the LBS track showed the vehicle traveled 3 percent farther than desired during a similar "box" experiment.

Rudder Angle Adjustment. We have been adjusting the rudder angle between dives in an attempt to balance the vehicle hydrodynamically in yaw. To help the reader through this somewhat involved paragraph, I have included table G-2. During Dive 33, the top and the bottom rudder were adjusted at 0 degrees with respect to the longitudinal axis of the vehicle. A 4000-foot "box" was run in a ccw direction. The box was "exploded" (the sides were convex), and the port main thrust was 50% of the starboard main thrust. During Dives 34 and 35, both rudders were adjusted to 2 degrees to port. The box run then was imploded (the sides were concave), and the starboard main thrust was about 50% of the port main thrust. For the dives reported here, Dives 36 and 37, the rudders were adjusted to 1 degree to port. The box, as seen in figure G-26, has fairly straight, slightly convex sides (exploded). The port main thrust is about 75% of the starboard main thrust as seen in figure G-30 (figure G-30 is for legs 1 and 2 of the box). For the next dive, the top rudder will be adjusted another 1/2 degree to port (making it 1 1/2 degree to port) with the bottom rudder remaining at 1 degree to port. This will, hopefully, yield straight waypoint runs (affected only by water current), yield straight dead-reckoning runs (affected only by water current), and allow both motors to run at nearly 100%. This will give the vehicle the maximum possible forward velocity in both waypoint and dead-reckoning runs.

Table G-2. Rudder angle adjustments.

DIVE NUMBER	RUDDER ANGLE (degrees, P/S)	BOX Dir, Shape	THRUST Stbd	THRUST Port
33	0	ccw, explode	100%	50%
34, 35	2, Port	ccw, implode	50%	100%
36, 37	1, Port	ccw, explode	100%	75%

9. Side-Looking sonar Search, Target Detection, Target Marking, and Contact Evaluation

Figure G-31 is the Dive 37 SLS search with contact evaluations. During this search, five contact evaluations were accomplished, two contacts were pursued in the wrong position due to a system error (and therefore not found), and one weak SLS contact was pursued, but not found on the FLS.

Five Contact Evaluations. The first two contact evaluations occurred soon after the search was started at position A. When the vehicle was paused at B, there was a target on the port SLS, and another on the starboard SLS. Both targets were marked and pursued in sequence at positions C, and then at D. The two target contact evaluation sequence took only 22 minutes from the time the port SLS imaged the target at C until the vehicle was searching again at E. Both of the contact evaluations involved FLS scans, CCD images, and LBS marking of the targets (both were automobiles). An operator error led to an interesting result. The FLS scan at C was taken with the vehicle accidentally at a 10-foot hover radius instead of a 50-foot radius, and the target was seen on the FLS!

The next two targets evaluated were at H and I. It took 47 minutes between the time the target at H was SLS-marked and the vehicle started searching again at J. All aspects of contact evaluation were accomplished for both targets during the 47 minutes including 50-foot-radius hovers for FLS scans, 10-foot-radius-hovers for CCD images, and LBS fish-cycle fixing of the target positions while the vehicle hovered over them. The long duration (47 minutes) was because several CCD retransmits were done on both targets. The target at H was an item never before visited by AUSS, and it is believed to be a fixture put in for ATV test purposes. The target at I was a set of engine blocks.

The final contact evaluation was of a set of engine blocks at L. This contact evaluation took 23 minutes. As usual, the time for contact evaluation I have given is the time starting with SLS target-imaging and ending with the vehicle resuming the search. During this contact evaluation, CCD images were collected while the vehicle hovered over the engine blocks at a variety of altitudes.

Contacts Pursued in the Wrong Positions. After contact evaluations were accomplished at C and D, the vehicle went back to the search track at E. Two mildly unfortunate incidents happened at E. First, the vehicle performed at 270-degree turn instead of a 90-degree turn to get back on the search track. Second, SLS data were being gathered and transmitted to the surface during this 270-degree turn. The sonars turned on as soon as the vehicle crossed the objective search path line. As the vehicle spun around, the sonars imaged the targets at C and D. Using the target-marking routine on these images, the operators obtained bogus positions for targets. When the vehicle was sent to find targets at these bogus positions, nothing was found on the FLS. The pursuit of targets at these positions was abandoned and the search was continued. Since this dive, the software has been improved such that the vehicle will obtain the search track without spinning around first.

A Contact Seen Once But Not Twice. Pure and simple, a weak image as seen on the poi [illegible] at position F, but could not be seen using the FLS after closing in on the position. After several attempts at seeing the target on the FLS, the position was abandoned. The FLS is known to be a lower performance sensor than the SLS. The lower performance of the FLS is believed to be the reason why the contact evaluation was not completed. Or, maybe it swam away!

CONCLUSIONS FOR DIVES 36 AND 37

Several data-collection techniques were tested and proven during this dive. These included obstacle-avoidance sonar signal performance data, Doppler accuracy data, rudder angle adjustment data, and Doppler head/gyrocompass alignment data. These techniques may be useful as a model for measurement of untethered Underwater Unmanned Vehicle (UUV) performance in the future. The status of these measurement and adjustment programs are: The obstacle-avoidance sonar signal to noise is disappointingly low; the rudder angle adjustment program is nearly completed; the Doppler accuracy problem has been reduced to mostly a scaling error, and the Doppler and gyrocompass alignment seems to be pretty good.

The performance of an SLS search with contact evaluations produced five good contact evaluations. The software supporting these contact evaluations and the tactics used by the operators are improving rapidly.

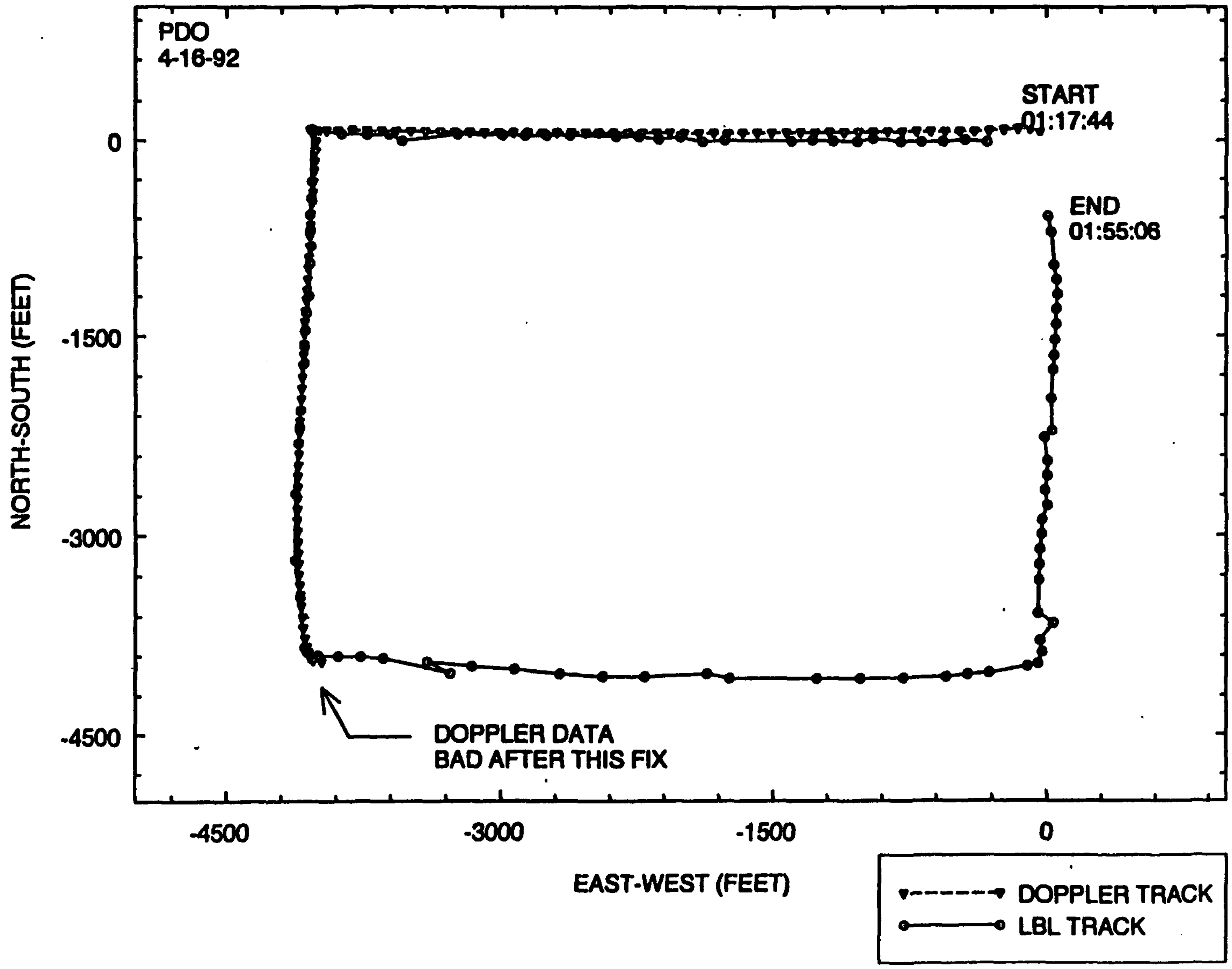
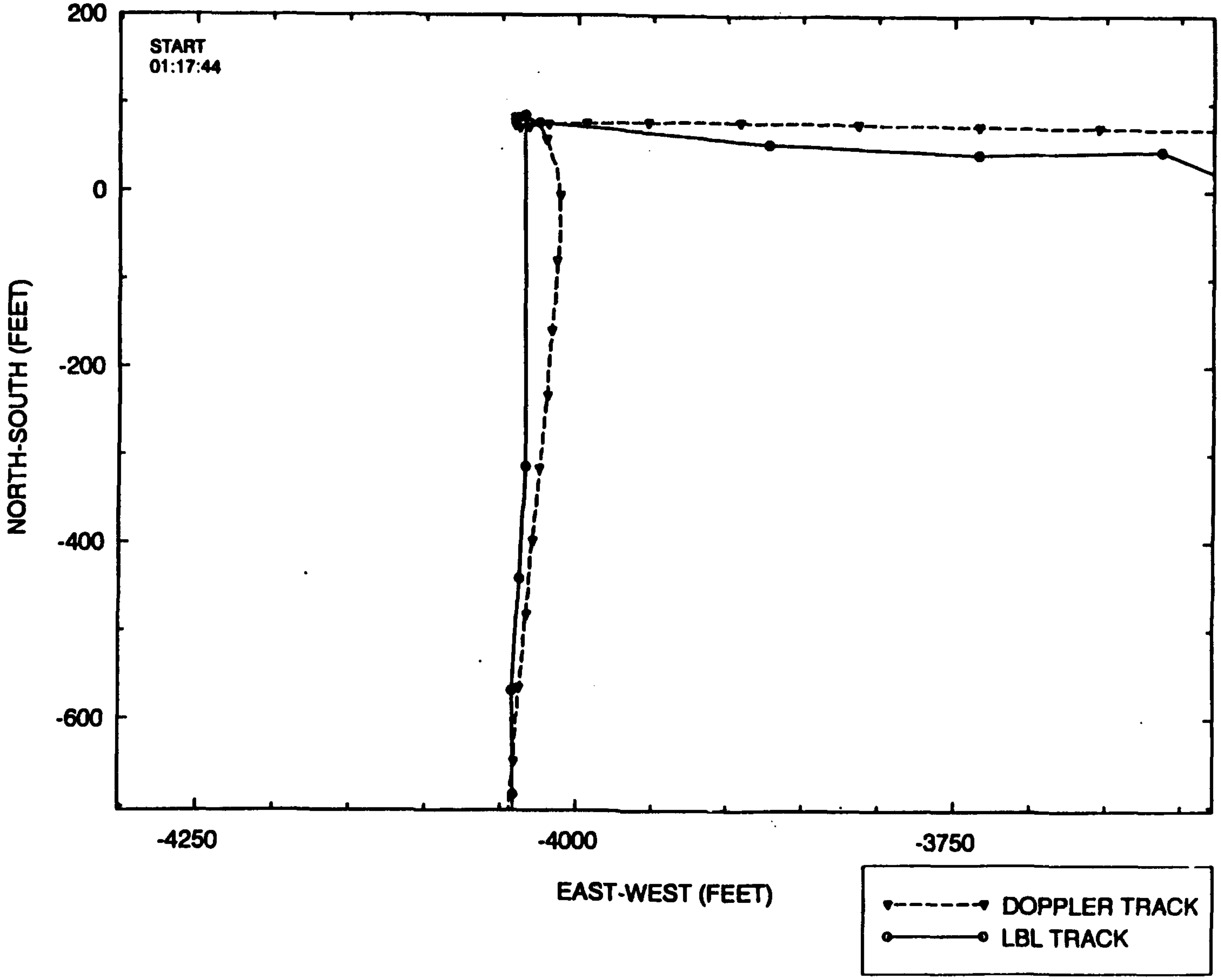


Figure G-26. Doppler/LBS vehicle tracking comparison.



: Figure G-27. Blow up of Doppler/LBS tracking NW corner.

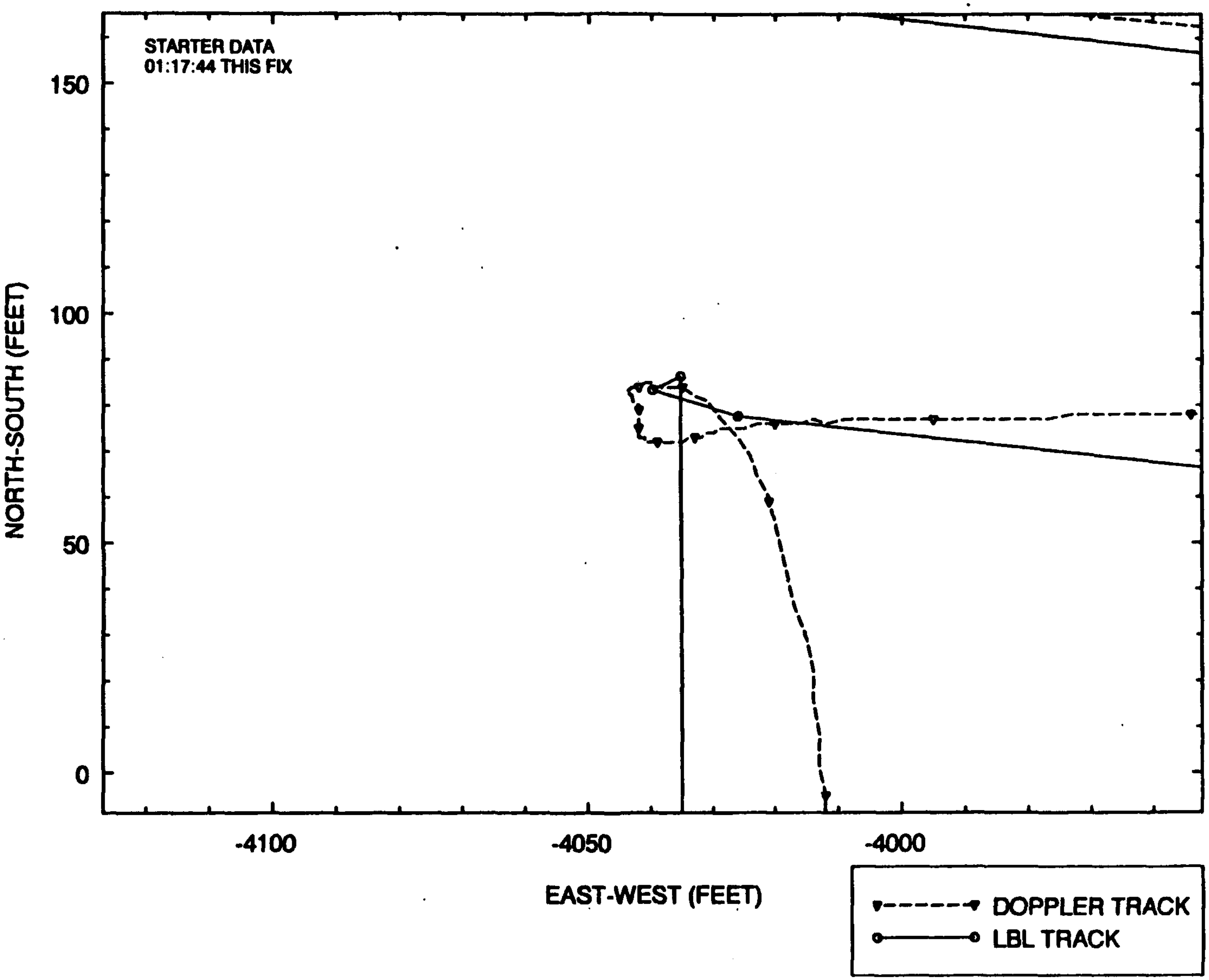


Figure G-28. Zoom of the NW corner.

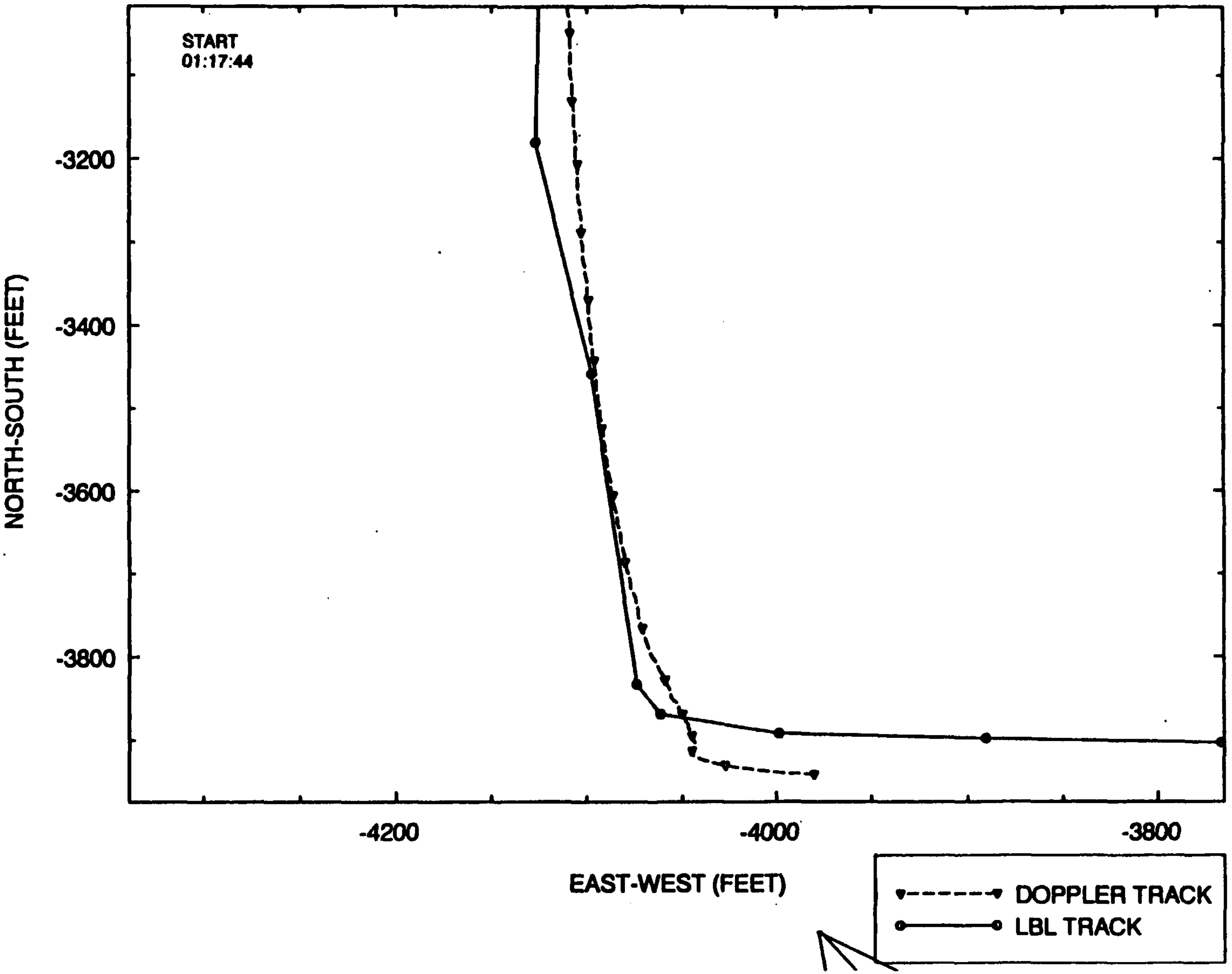


Figure G-29. Blow up of the SE corner of the vertical track, Doppler/LBS tracks.

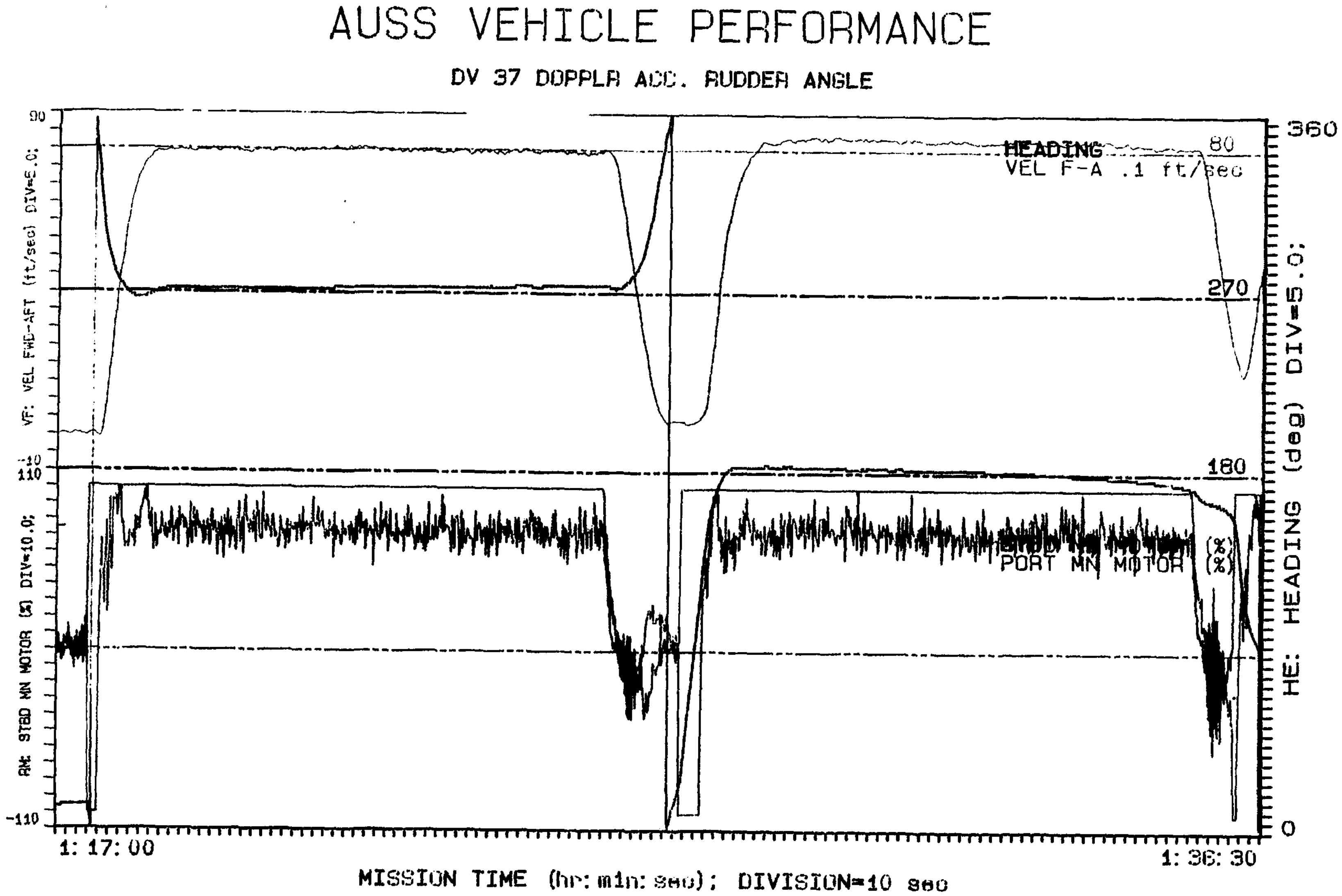


Figure G-30. Port and starboard thrusts during box run.

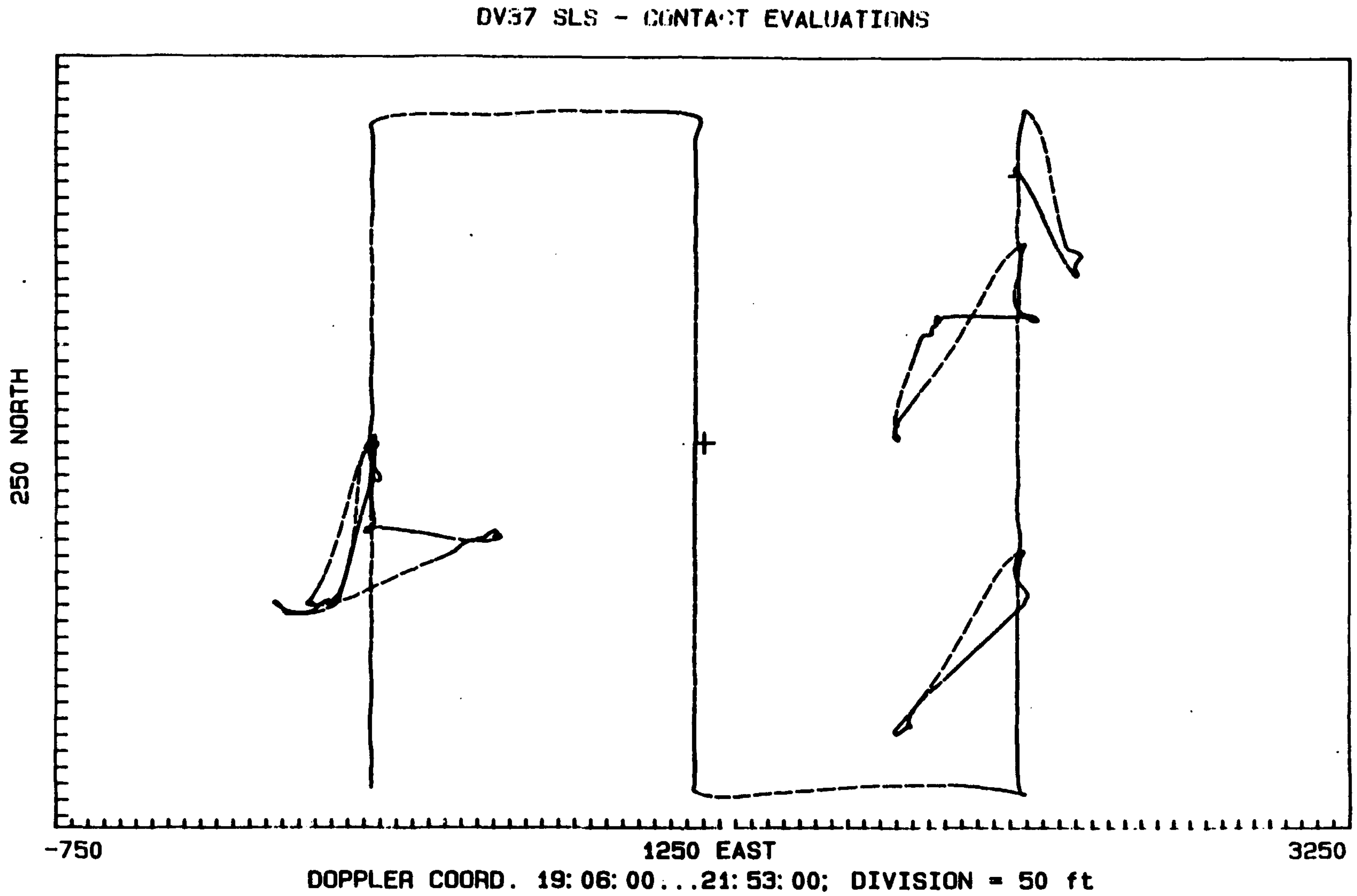


Figure G-31. Dive 37 SLS search with contact evaluations.

APPENDIX H

SAMPLE OF TOPICAL DEVELOPMENT TEST REPORTS

3900 Ser 941/ –91
04 January 1991

MEMORANDUM

From: Jim Walton (Code 941)

To: Head, Systems Engineering Branch (Code 941)

Subj: AUSS Descent String

Encl: (1) AUSS Descent String Diagram

1. INTRODUCTION

The AUSS descent string is a partially recoverable string of equipment which is used to pull AUSS to the bottom of the ocean. The primary purpose of the descent string is to take the AUSS vehicle to its operational depth.

Important advantages of the descent string approach are: Vehicle on-board energy is saved since vehicle propulsion energy is not used during descent; the position of the vehicle near the bottom of the ocean after descent is predictable within a reasonable error circle since the vehicle descends at a nearly vertical angle; the vehicle is held stationary by the descent string for a period of time at the beginning of a dive while the acoustic link can be tested, and vehicle tracking fixes can be taken; and when the vehicle is free of the descent string, the descent string transponder can be used as a fixed location transponder to aid in tracking.

2. OPERATIONS

The latest version of the AUSS descent string has been used successfully for AUSS descents on 5 occasions to date. These operations have been conducted in the usual AUSS transponder net in OPAREA 37–03. The nominal depth of the water for these dives is 2500 feet.

3. AUSS DESCENT STRING DESCRIPTION

Enclosure (1) is a diagram of the AUSS descent string. For descent, the entire string goes to the bottom as shown in the diagram. The vehicle releases from the string at its nose. Upon command, the transponder releases the line attached at its bottom, and the transponder and float come to the surface leaving the 2-pound and 100-pound weights and connecting line behind.

The AUSS vehicle is almost neutral with very little righting moment such that it is nearly vertical when pulled down with the descent string.

The arresting float is only 6 feet away from the vehicle such that the line between the vehicle and float cannot get tangled on the vehicle. The float has two purposes. When the descent weight hits the bottom, the descent string goes slack, but the vehicle has a high rate of descent and wants to override the descent string and potentially slam into the bottom. When the vehicle passes the arresting float and the 6-foot line becomes tight, the nose of the vehicle is tipped up and the vehicle decelerates. After the vehicle separates from the descent string, the arresting float is used to bring the descent string transponder to the surface. In enclosure (1), the blowup of the arresting float shows how the float is rigged such that it is pulled nose down during descent, and returns to the surface nose up. In the future, a double-nosed float will be implemented eliminating the requirement for the fancy float rigging.

The transponder is 40 feet below the float to accomodate the descent string launch sequence where the float is launched along with the vehicle from the launch ramp, and the transponder and weight are launched from a separate fixture at the center of the stern of the support boat. A small weight is located 20 feet below the transponder to avoid entanglement of the transponder in the line below it when it overshoots the line.

5. CONCLUSIONS

The latest version of the descent string and the launch equipment for the descent string have been proven. The system is effective for deployment of the vehicle to its operational depth without entanglement of either the vehicle or the transponder. Once the vehicle is released from the launcher, taking the arresting float with it, the rest of the descent string deploys without human intervention. These features make this a safe and easy to use system.

JIM WALTON

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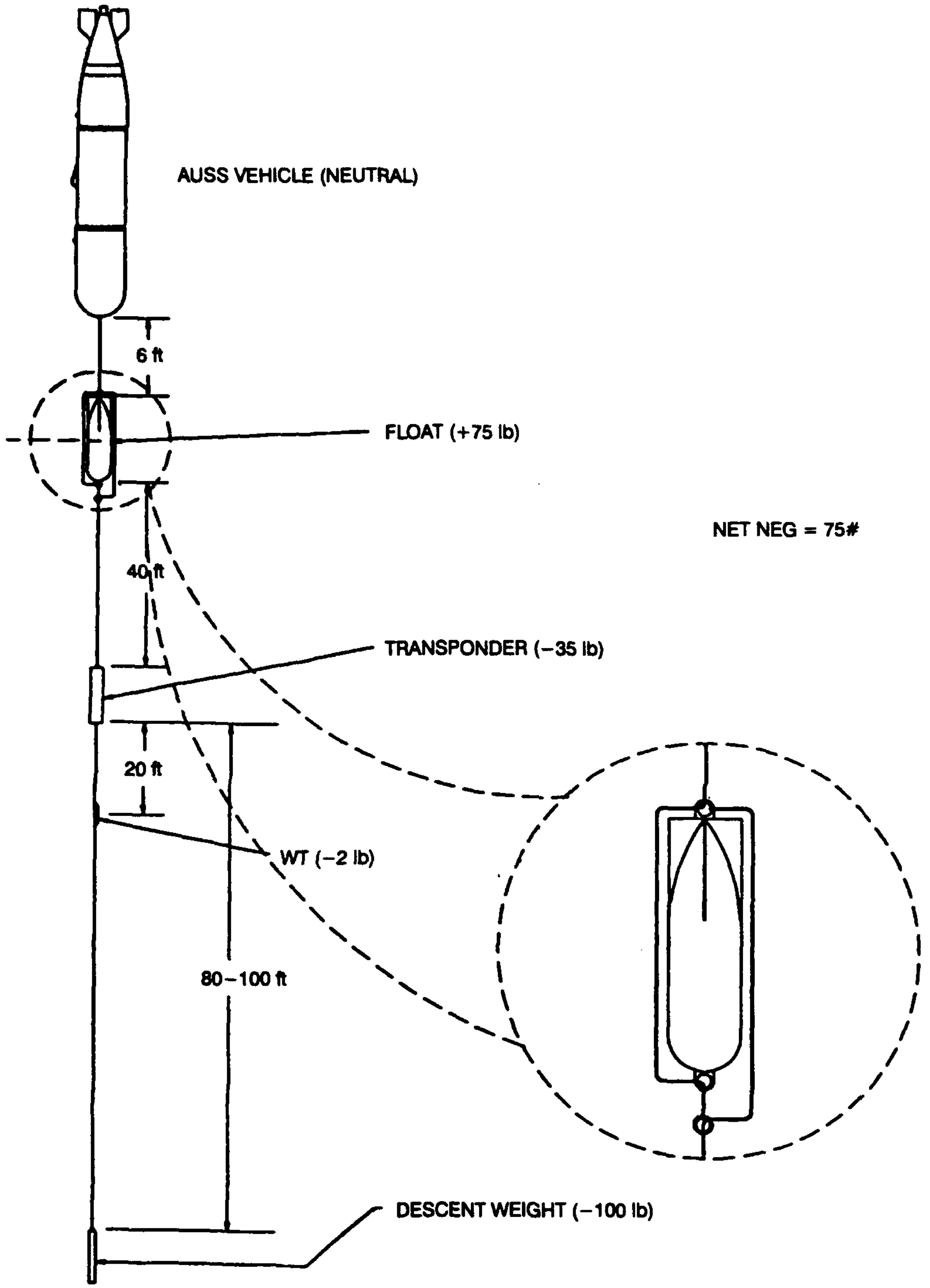

Figure H-1. AUSS descent string diagram.

3900 Ser 941/01–91
02 January 1991

MEMORANDUM

From: Jim Walton (Code 941)

To: Head, Systems Engineering Branch (Code 941)

Subj: AUSS Heading Control Tests for Hovering Vehicle (Hover Heading Control)

Ref: (a) "AUSS Acoustic Link, Tracking, and Hover Controls Tests,"
NOSC memo Ser 941/79–90 of 25 Sep 90

Encl: (1) Plot, AUSS Vehicle Performance, Heading Steps, 10–18–90

1. INTRODUCTION

The AUSS vehicle operator can invoke several vehicle control loops while the vehicle is hovering. Those loops are depth control or altitude control, pitch control, heading control, and hover with standoff from a vertical line. The subject of this memo is the heading control loop for zero headway or very little headway of the vehicle. This control loop is referred to as "hover heading control."

During AUSS operations on 10–18–90, the vehicle hover heading control was tested at sea for the first time. The results of these tests were very satisfactory, and the hover heading control can be considered completed with no changes required.

2. OPERATIONS

The hover heading control test plans are defined in reference (a). The tests were done within the usual AUSS transponder net in OPAREA 37–03. The water depth was nominally 2500 feet, and the vehicle was within 100 feet of the bottom throughout these tests.

3. HOVER HEADING CONTROL DESCRIPTION

Hover heading control can be in effect whenever the vehicle is not underway or is underway at a low rate of advance. The same control loop will by used for higher rates of speed, but the higher speed application has not yet been adequately tested. To hold heading, the hover heading control utilizes differential thrusting of the vehicle main propulsion motors (with built-in controllers). The controllers receive their control signal from the main computer group where the control loop software resides. The on-board compass provides vehicle heading to the control software, and rate feedback to the control software is provided by an on board yaw rate sensor.

4. FLIGHT RECORDED RESULTS OF HEADING STEPS

Enclosure (1) is a plot of data that was stored in the AUSS on board flight recorder. After the dive, the data from the flight recorder were extracted from the vehicle, and plotted. The horizontal axis of enclosure (1) is 24-hour clock time. The vertical axis is used for various different flight recorded values.

Referring to enclosure (1), commanded heading (in black) starts at 90 degrees, and steps to 180 degrees, 270 degrees, and 40 degrees follow. The step function heading changes produced no more than 2 degrees of overshoot in the heading of the vehicle (in blue). During the heading hold, the heading of the vehicle did not vary from the commanded value by more than 2 degrees. The step from 270 degrees to 40 degrees was commanded to assure that the vehicle turned through the fewest number of degrees to go between these two headings (130 degrees clockwise vs. 230 degrees counterclockwise.)

Still referring to enclosure (1), it is seen that the commands to the main thrusters (port=red, starboard=green) did not exceed ± 20% of full thrust to maintain heading control. It is also seen that the motors were driven to 100% differentially whenever a step in heading was commanded.

5. CONCLUSIONS

Jim Held's rigorous efforts in development of a vehicle dynamic model, and development and testing against the model of the hover heading control loop, along with Howard McCracken's software implementation of the control loop, has resulted in a completed hover heading control. It is expected that no changes will be made to the hover heading control.

JIM WALTON

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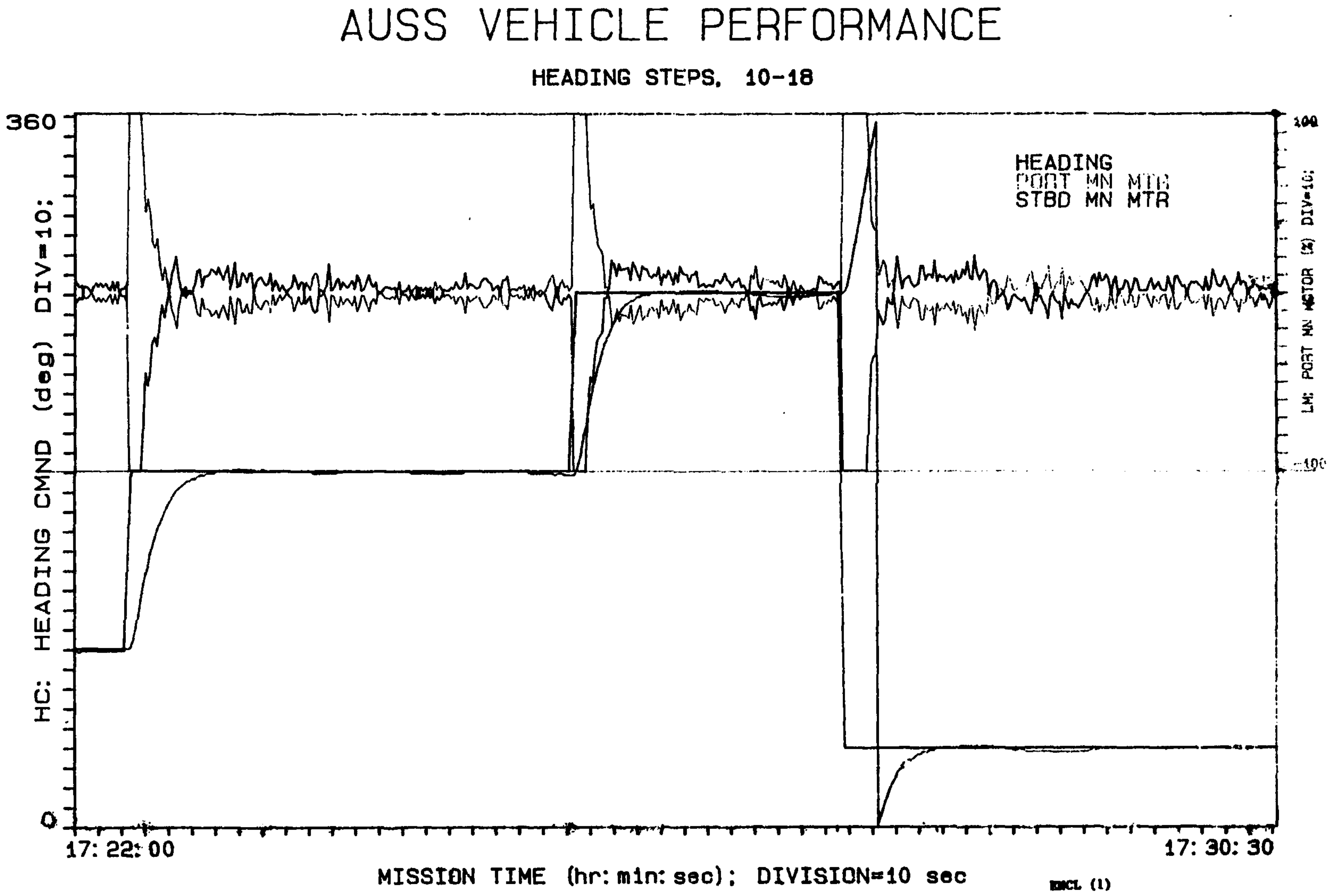

Figure H-2. Plot, AUSS vehicle performance, heading steps, 10–18–90.

3900 Ser 941/02–91
2 January 1991

MEMORANDUM

From: Jim Walton (Code 941)

To: Head, Systems Engineering Branch (Code 941)

Subj: AUSS Depth and Pitch Control While Hovering (Hover Depth and Pitch)

Ref: (a) "AUSS Acoustic Link, Tracking, and Hover Controls Tests,"
NOSC memo Ser 941/79–90 of 25 Sep 90

Encl: (1) Plot, AUSS Vehicle Performance, Depth Steps, 10–18–90

1. INTRODUCTION

The AUSS vehicle operator can invoke several vehicle control loops while the vehicle is hovering. Those loops are depth control or altitude control, pitch control, heading control, and hover with standoff from a vertical line. The subjects of this memo are the depth and pitch control loops for zero headway or very little headway of the vehicle. These control loops are referred to as "hover depth and pitch control."

During AUSS operations on 10–18–90, the vehicle hover depth and pitch control were tested at-sea for the first time. The results of these tests were satisfactory, and the hover depth and pitch control can be considered completed with no changes required. These two functions are discussed here together since the pitch control loop is stressed the most when the vehicle is changing depth.

2. OPERATIONS

The hover depth and pitch control test plans are defined in reference (a). The tests were done within the usual AUSS transponder net in OPAREA 37–03. The water depth was nominally 2500 feet, and the vehicle was within 100 feet of the bottom throughout these tests.

3. HOVER DEPTH AND PITCH CONTROL DESCRIPTION

Hover depth and pitch control can be in effect whenever the vehicle is not underway or is underway at a low rate of advance. The vertical thrusters are used to hold depth by thrusting together either up, or down. The vertical thrusters thrust differentially to control pitch. The vertical motors have built-in controllers. The controllers receive their control signal from the main computer group where the control loop software resides. A water pressure transducer provides vehicle depth values to the control software for depth control. A pitch pendulometer provides vehicle pitch to the pitch control software, and pitch rate feedback is provided by a pitch rate sensor.

4. FLIGHT RECORDED RESULTS OF DEPTH STEPS

Enclosure (1) is a plot of data which was stored in the AUSS on-board flight recorder. After the dive, the data from the flight recorder was extracted from the vehicle, and plotted. The horizontal axis of enclosure (1) is 24-hour clock time. The vertical axis is used for various different flight recorded values.

Referring to enclosure (1), commanded depth (in green) starts at 2295 feet. After holding for a short time at 2295 feet, the vehicle is commanded to make step changes in depth of –3 feet, –10 feet, –30 feet, and +13 feet.

The pressure transducer depth (referred to as "actual" depth) of the vehicle is in black in enclosure (1). Comparing the commanded (in green) and "actual" (in black) depths, it is seen that depth control steps produced no more than 6 feet of overshoot for the largest depth steps. Depth was held to ± 1 foot around depths which were about 8 feet less than the commanded depth. The error between the commanded (green) and "actual" (black) depths occur because this is a type 0 loop, and the depth error is not driven to zero by integration. A type 0 control loop was chosen over a type 1 loop for depth for a couple of reasons. First, the type 0 loop is less susceptable to noise. Second, what we are dealing with during the AUSS mission is relative depths of the vehicle. The type 0 control loop allows AUSS to change depths relative to each other accurately, even though the absolute depth of the vehicle is not well known. The absolute error of the depth transducer can easily be as great as or greater than the 8 foot error between the depth commanded and the depth read by the depth transducer.

To hold depth, vertical motor thrusts (in bottom half of plot, aft vertical motor is in blue, forward vertical motor is in red) were within ± 40% around an average thrust value of –15%. The average thrust value of –15% occurs because the vehicle is positively buoyant at this depth by an amount equal to the amount of thrust the vertical thrusters put out at 15% of full thrust.

When the vehicle changes depth, the pitch loop attempts to hold the vehicle level. Due to the added drag of the aft fins, the vehicle tends to pitch nose down when descending, and nose up when ascending. To hold the vehicle level when changing depth, the pitch control loop will cause the aft vertical motor and the forward vertical motor to thrust differentially to compensate. If the vertical motors saturate, a pitch angle will result. This is seen in enclosure (1) where in the bottom half of the plot, the aft vertical motor command is in blue, and the forward vertical motor command is in red. In the upper half of the plot, the pitch angle of the vehicle is in blue. It is easy to misinterpret the pitch angle plot, and improvements to the presentation of pitch have been made in later versions of the plot routine. Anyway, it is seen that pitch was held at 2 degrees nose up within ± 1 degree while the vehicle was holding depth. When the vehicle was changing depth and the vertical motors saturated in their attempt to maintain pitch, the maximum pitch angle was 7 degrees nose up or a maximum change of 5 degrees.

5. CONCLUSIONS

The results of the tests of depth and pitch control described here indicate the vehicle is adequately controlled in depth and pitch. Some adjustments to the depth loop to overcome overshoot may be made in the future, but these adjustments are not considered critical for general operation of the vehicle.

JIM WALTON

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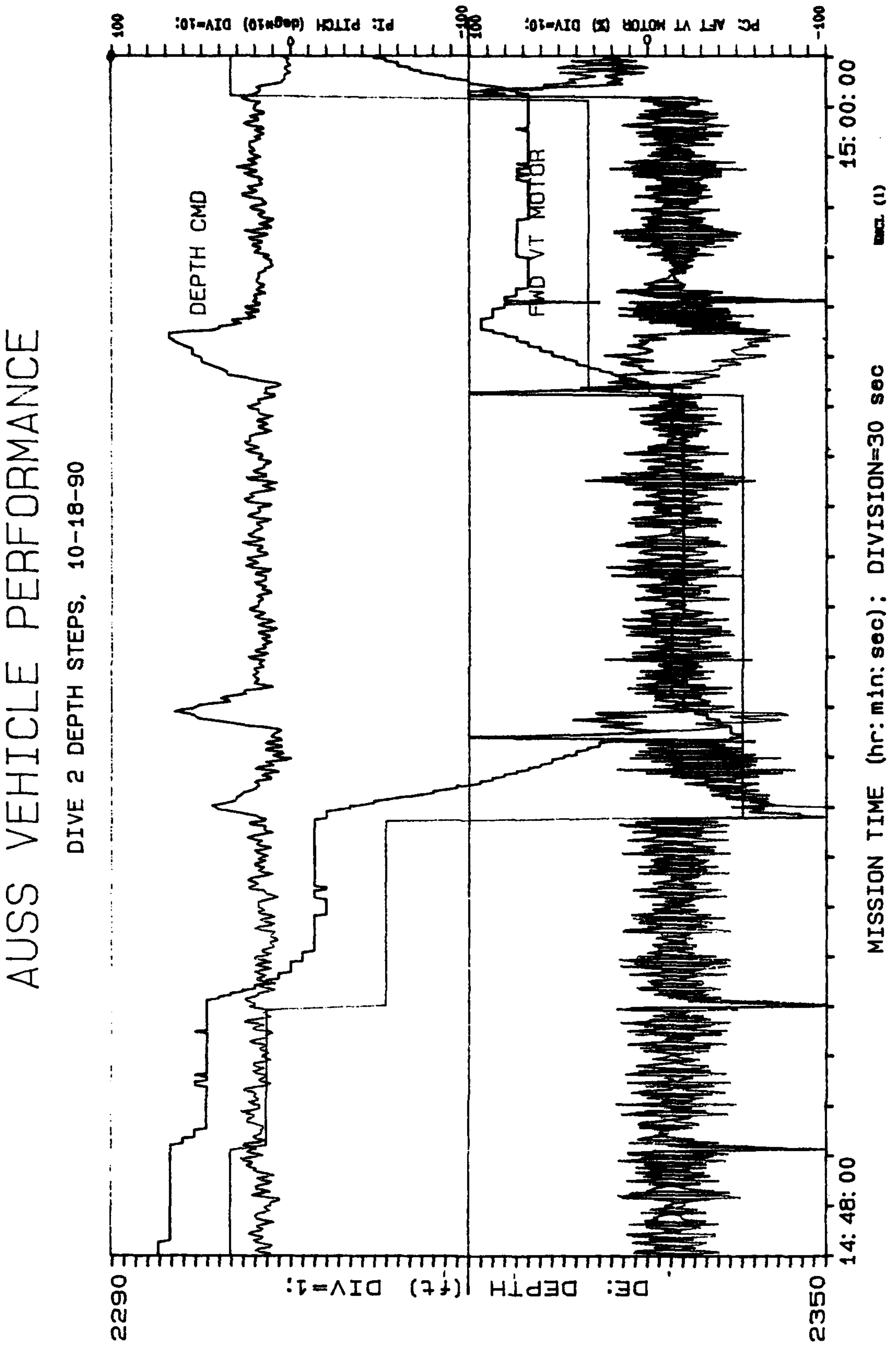

Figure H-3. Plot, AUSS vehicle performance, depth steps, 10–18–90.

ENCLOSURE (1)

3900 Ser 941/ –91
10 January 1991

MEMORANDUM

From: Jim Walton (Code 941)

To: Head, Systems Engineering Branch (Code 941)

Subj: AUSS EARS Batfish and Transducer Pole Operations

1. BACKGROUND

In the beginning, the AUSS vehicle was to be tracked primarily by short baseline. As time went by and we learned many lessons, it was found that long baseline and not short baseline tracking was necessary to obtain the position accuracy required of the AUSS mission, especially at great depths.

Due to the short baseline requirement, the original EARS fish was a tow body which was the same diameter as the AUSS vehicle, and had to be launched and recovered using the AUSS launcher. The EARS fish was launched before the vehicle and recovered after the vehicle. The EARS fish was configured in this fashion because it carried all of the necessary equipment to accomplish short baseline (SBS) tracking of the AUSS vehicle. The on board EARS short baseline equipment included a gyro compass, a vertical reference unit, and the short baseline tracking array.The fish also carried the acoustic link transducer which was used for both the long baseline (LBS) tracking of the vehicle, and acoustic link communications. All of this added up to a rather large EARS, and the two piece tow cable which was assembled during deployment of the fish was a lot of trouble.

2. PRESENT SYSTEM DESCRIPTION

For the present version of the AUSS, we have turned in the large EARS fish for a smaller "batfish" which is launched and recovered independent of the vehicle launch ramp, and carries only the acoustic link baffled transducer which is used for LBS tracking and for acoustic link communications. The batfish has a single electromechanical cable which is deployed and recovered easily with a cable winch.

Short baseline tracking has been retained as a backup to the LBS, but the transducer array is on a pole attached to the ship. The compass and vertical reference unit are in the control van which is attached to the ship's deck. This provides a less accurate but adequate backup system in case the LBS fails.

3. OPERATIONS

The batfish and transducer pole systems have been used together successfully for AUSS operations on 5 dives to date. These operations have been conducted in the usual AUSS transponder net in OPAREA 37–03. The nominal depth of the water for these dives is 2500 feet. The sequence of deployment has been the transducer pole (which is also used for acoustic link and LBS tracking), the AUSS vehicle, and then the batfish. This sequence has eliminated a previous problem that occurred when the AUSS vehicle and or the AUSS descent string would get entangled in the already-deployed EARS system during launch.

4. PERFORMANCE

At this time, the performance of the tracking and acoustic link systems utilizing the batfish and the transducer pole have not been fully explored. In part, the only water depth they have been used in is 2500 feet. Also, most emphasis has been placed upon bringing the various subsystems on line and because of this, very little time has been available to collect data for quantitative comparison of performance.

Some qualitative statements can be made:

It is possible to operate the acoustic link and tracking systems using either or both the batfish and the pole. The batfish is farther away from the ship noise, and the signal to noise at the batfish transducer improves when the batfish is lowered to deeper depths.

In 2500 feet of seawater, tracking and acoustic link communications can be accomplished at the transducer pole. Most all bets are off at the pole when acoustic noise and air bubbles are introduced by bow thruster operation or if the ship backs down for some reason.

The transducer pole has an advantage over the batfish when subsurface tracking is to be integrated with surface navigation in that the offsets between the surface navigation antennas and the transducer on the transducer pole can always be determined and taken into account.

5. CONCLUSIONS

Due to the realization that long baseline and not short baseline tracking is preferred for the AUSS mission, a simplified EARS concept has been adopted. The EARS batfish is much more convenient and safe to use than the previous EARS fish. The transducer pole is the best system when tight ship maneuvers are important, especially when backing down and going DIW are important. The transducer pole location is more susceptible to ship noise.

JIM WALTON

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3900
Ser 941/08–91
12 Feb 91

MEMORANDUM

From: R. Uhrich

To: Head, Code 941

Subj: AUSS Underwater CCD Images

Encl: (1) Diagram of AUSS Tether Configuration
(2) Image of AUSS Tether Line

1. During the fifth dive of the current series, on 5 December 1990, the newly configured AUSS obtained its first underwater CCD images. These test images were taken from an altitude of approximately 200 ft, with the vehicle still tethered to the descent weight, as illustrated in enclosure (1). The objectives were to determine whether the strobe lights were synchronized with the camera and to verify the linear contrast enhancement algorithm. Both objectives were met when the transmitted images displayed the expected backscatter pattern.

2. No bottom features were expected or found in any of the images, but a portion the descent line clearly appeared in one. In this image, reproduced as enclosure (2), the nylon line is the white jagged streak. (The jaggedness is an artifact of the pixel size.) The line extends downward, terminating at a bright object that is the top of the navigation transponder approximately 50 ft below the AUSS vehicle. The transponder float is not within the field of view. Backscatter from the strobes obscures the rest of the transponder and a darker line from it to the bottom.

3. Future tests will image bottom objects with high contrast from various altitudes to determine the potential range of the cooled CCD camera. Image compression will be introduced, which will permit use of higher resolution; and a backscatter subtraction technique will be evaluated. Images will also be optimized by retransmitting with varied contrast enhancement parameters.

4. A capability is being developed to store raw image data on board AUSS. These raw data will be extremely valuable in evaluating various image processing algorithms for potential incorporation in the system.

RICHARD UHRICH

Copy to:
941 (Cooke, Walton)
943 (Watson)

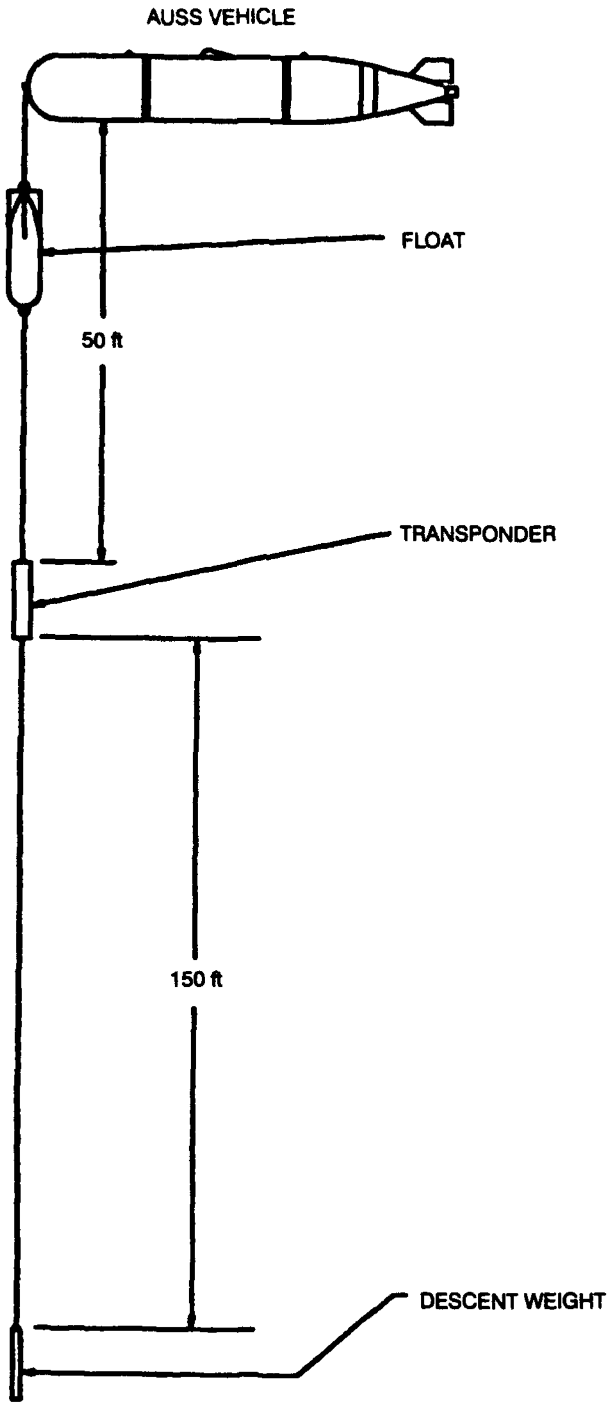

Figure H-4. Diagram of AUSS tether configuration.

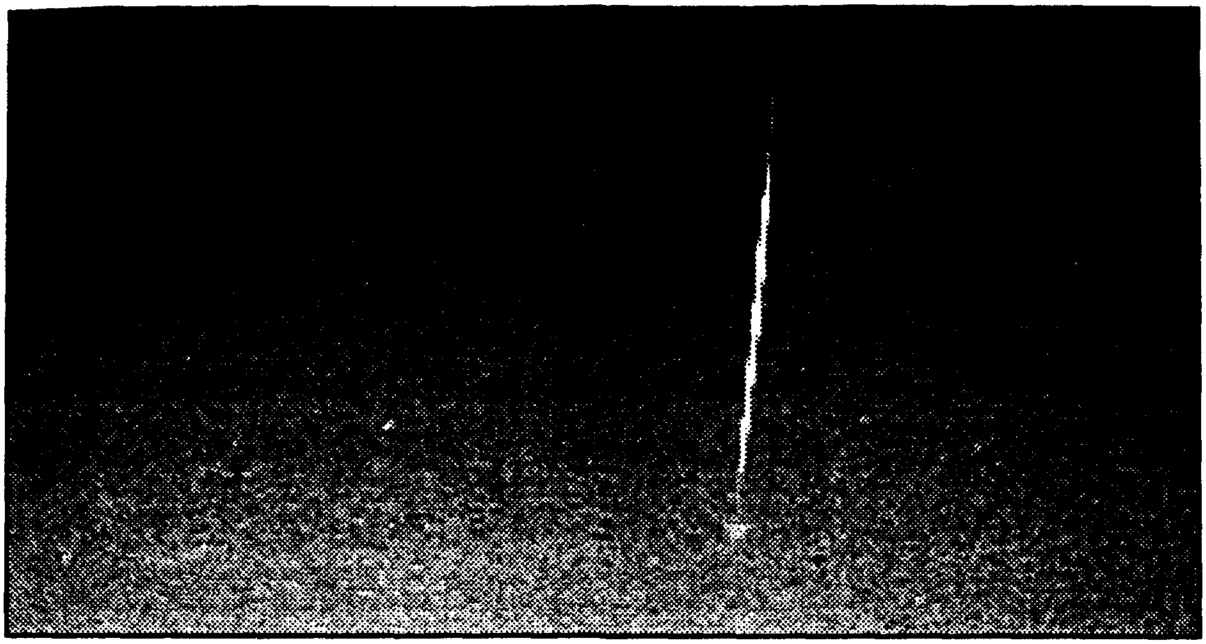

Figure H-5. Image of AUSS tether line.

ENCLOSURE (2)

Ser 941/48–91
1 Aug 91

MEMORANDUM

From: Jim Walton, Code 941

To: AUSS Team

Subj: Transmission of Compressed Data from the AUSS Vehicle

Encl: (1) Decompressed Image Of Descent Line Float
(2) Vehicle, CCD Camera, and Descent Line Float Geometry

1. During dive 20, 16 July 1991, the first compressed undersea images were transmitted from the vehicle to the surface ship through the acoustic link. Both compressed charge-coupled device (CCD) and compressed side-looking sonar (SLS) data were transmitted, received, decompressed, and displayed during this dive. All images were generated while the vehicle was still on the descent string. The vehicle was 140 feet above the bottom, and 2,345 feet from the surface. No propulsion motors were operating during the imaging and transmission of this data.

2. Enclosure (1) is a decompressed image of the descent line float. The geometry of the float, vehicle, and the CCD camera when this image was made is shown in enclosure (2). The float is in the upper right-hand corner of the image because it was ahead of the CCD camera, and the vehicle was rolled 6 to 7 degrees to starboard (clockwise roll when viewed from behind and down the axis of the vehicle).

3. An object of unknown identity appears at 0.75 inch from the left-hand border and 1.5 inches from the bottom border of enclosure (1). This object is real since it occurred in several retransmissions of the image (i.e., it is not noise in the transmission system). Since the vehicle was at 140 feet from the bottom, this object is believed to be something in the water column below the vehicle and not an object on the bottom.

4. Another characteristic seen in enclosure (1) is located at approximately 3.25 inches from the left border, and 1.5 inches from the top border. This artifact seems to appear randomly in both CCD and SLS decompressed images, and has been called a "worm." These worms may appear anywhere on a CCD or SLS image. Worms are a processing artifact, and appear in the lab as well as at sea. The source of the worms has been narrowed down to somewhere on-board the vehicle, and the worms are created at some time during compression and handling of the image. Investigation into worms is continuing.

5. Enclosure (1) is decompressed from a high resolution, low compression image. Before compression, the image was 512 by 384 pixels by 8 bits per pixel (the highest used by the Advanced Unmanned Search System), and the compression scheme utilized was the lowest of three possible levels of compression. Higher levels of compression involve higher levels of coefficient thresholding and quantization. The amount of compression is not deterministic, and is scene-dependent (depends upon the amount of entropy (randomness) within the image). Rich Uhrich has incorporated software in the surface image computer which keeps track of the number of bytes required to transmit an acoustic link image. This information will allow us to comment upon the level of compression obtained with each image during future dives.

6. The time required to collect an AUSS CCD image depends upon a number of factors. The image in enclosure (1) took 38 seconds to compress and transmit (C/T time) through the acoustic link. This C/T time is dependent upon the acoustic link data rate, which in this case was 2,400 Bits Per Second (bps) (1,200 bps per independent sideband). The transmission time may be improved by a factor of two by bumping the data rate up to 4,800 bps. The compression computation, not the acoustic link, was the pacing item in the transmission of enclosure (1). The acoustic link was quiet around 50% of the time while waiting for the 386 processor in the vehicle image manipulation computer to perform the compression computations. To relieve this bottleneck, the installation of a digital signal processor (DSP) is planned. The DSP will perform the two dimensional cosine transforms and coefficient compression eliminating these computations as the C/T time bottleneck.

7. It took 58 seconds from the time the picture command was sent from the surface to the time the image was completely presented on the screen. This 58 seconds roughly breaks down into:

a. 1 second round trip acoustic link time.

b. 8 seconds for the CCD to collect the image and pass it to the vehicle.

c. 38 seconds for compression-related processing, and transmission of the image (C/T time). This time is subject to imposed acoustic link quiet times (a variable time during which the vehicle looks for down transmissions).

d. 11 seconds overhead including vehicle image data handling time (a variable), and image pre-processing time (a variable).

The 1, 8, 38, and 11 second times are all variables which are dependent upon a number of factors. Some of these factors are slant range to the vehicle, content of the image, acoustic link data rate, message handling and interrupts, on-board processing, acoustic tracking quiet times, and other factors which are also beyond the intended scope of this memorandum.

8. In conclusion, we have demonstrated the transmission and decompression of images obtained and compressed at the submerged AUSS vehicle. The time to obtain the high quality image of enclosure (1) is a vast improvement over previous high resolution imaging (remember that lower resolution 256 x 256 x 6 bit images took over 2 minutes with the prototype vehicle). The transmission time will be improved upon further by the addition of the DSP, but will be slowed down by the addition of acoustic tracking quiet time and motor noise (which increases the image entropy).

JIM WALTON

Copy to:
532 (Hoffman)
661 (Nickerson)
94 (Info only)
941
941 (Cooke, Geurin, Held, Jones, Kono, Osborne, Pryor, Rutkowski, Someson, Tallerino, Uhrich, Walton, file)
943 (Mackelburg, McCracken, Rasmussen, Watson)

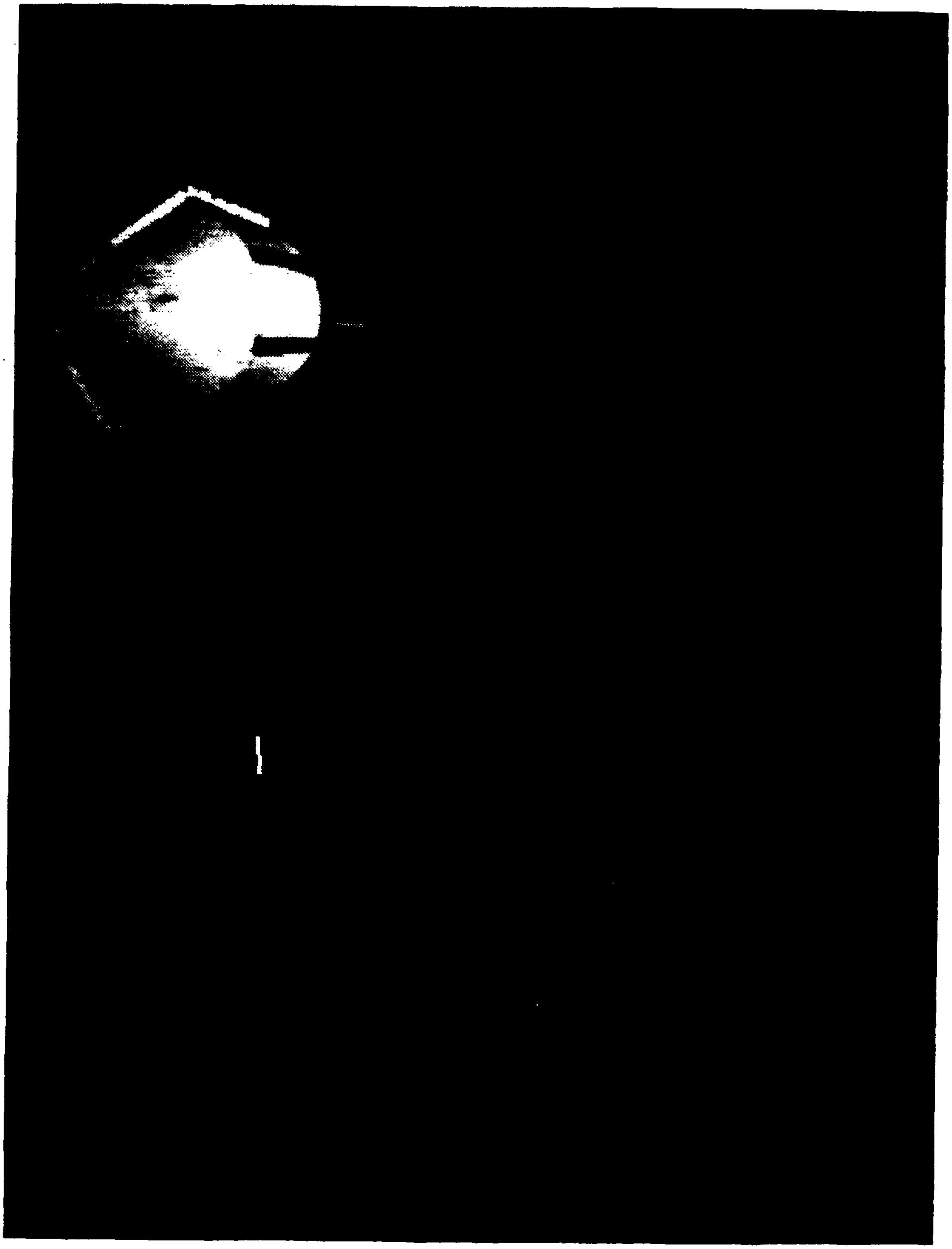

Figure H-6. Decompressed image of descent line float

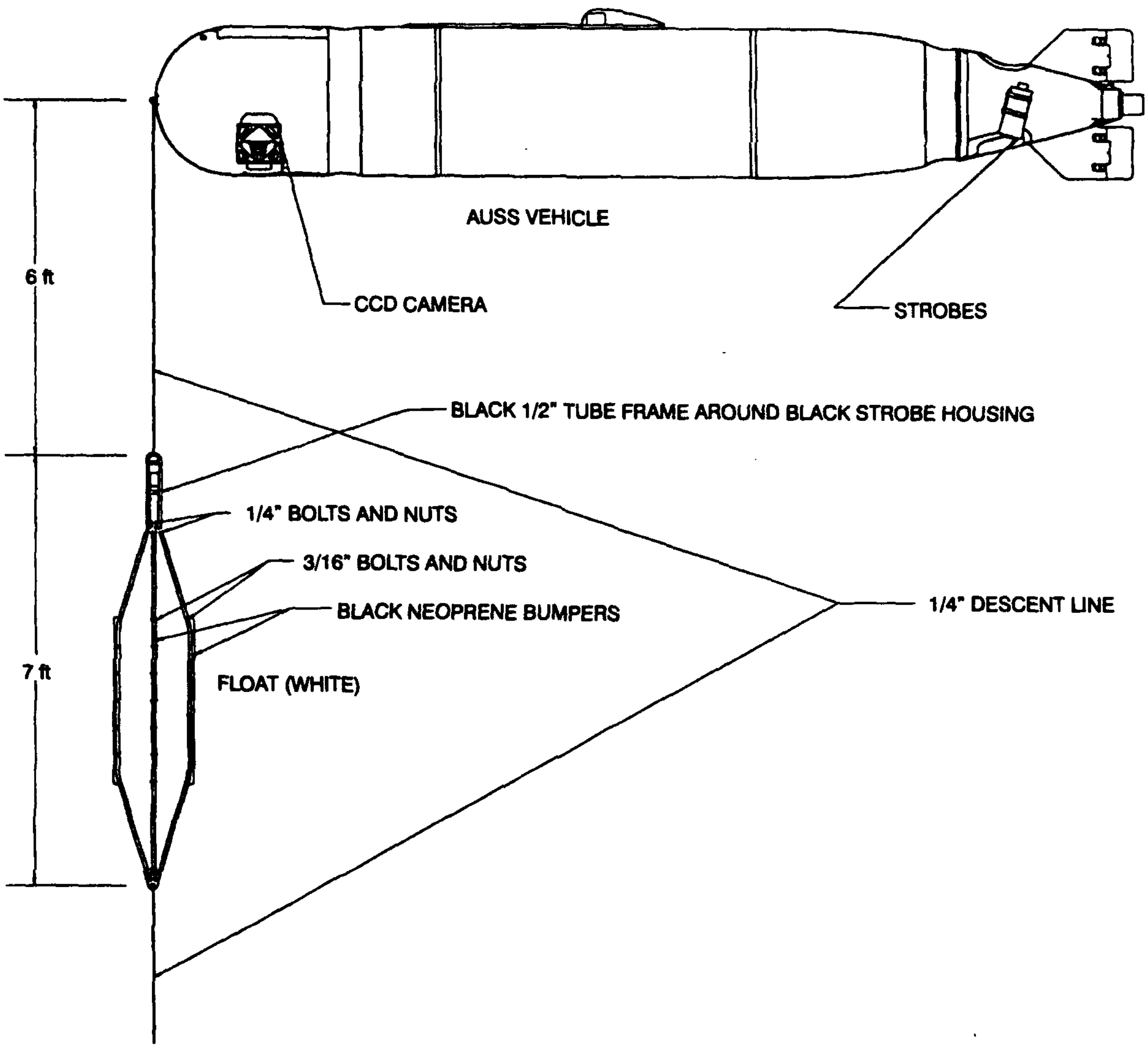

Figure H-7. Vehicle, CCD camera, and descent line float geometry.

Ser 941/50–91
14 Aug 91

MEMORANDUM

From: Jim Walton, Code 941

To: AUSS Team

Subj: Compression Ratio for the Charge-Coupled Device Float Image

Ref: (a) NAVOCEANSYSCEN memo Ser 941/48–91 of 1 Aug 91

Encl: (1) Image Geometry

1. Reference (a) discussed the first transmissions of compressed data from the Advanced Unmanned Search System vehicle. In particular, an image of the descent string float was explained, and the times involved in obtaining the image were broken down. The compression ratio was not discussed in reference (a). The purpose of this memo is to define the compression ratio for this image, and comment further on the geometry of the image.

2. Rich Uhrich has incorporated software into the surface image computer, which keeps track of the number of bytes required to transmit an acoustic link image. This will allow us to easily comment on the compression ratios of images in the future. This capability was not available during dive 20 (when the float image was obtained). Rich determined the byte count by hand for this image. Below are the results of Rich's effort:

For 8 bit bytes,

$$\frac{\text{Vehicle CCD image bytes (dry bytes)}}{\text{Transmitted bytes after compression (wet bytes)}}$$

$$= \frac{512\text{x}384 \text{ bytes}}{30 \text{ packets x } 256 \text{ bytes/packet}}$$

$$= 25.6/1 \text{ compression ratio}$$

3. Enclosure (1) is the geometry of the vehicle/float when the image was obtained. The dashed lines in enclosure (1) represent the 29.4 degree "vertical field of view" measured during the charge-coupled device (CCD) camera factory acceptance test. In enclosure (1), it was observed that the top half of the frame around the strobe should be out of the field of view. After reviewing enclosure (1) of reference (a), the float image, it was confirmed that this is in fact the case. The vehicle pitch angle was zero degrees when the image was obtained.

4. In conclusion, a respectable compression ratio was obtained with a high-resolution, low-compression image transmission, and the field of view measured by the factory acceptance test was consistent with the position of the float in the charge-coupled device (CCD) image.

JIM WALTON

Copy to:
532 (Hoffman)
661 (Nickerson)
94
941
941 (Cooke, Geurin, Held, Jones, Kono, Osborne, Pryor, Rutkowski, Someson, Tallerino, Uhrich, Walton, file)
943 (Bryan, Gillcrist, Mackelburg, McCracken, Rasmussen, Watson)

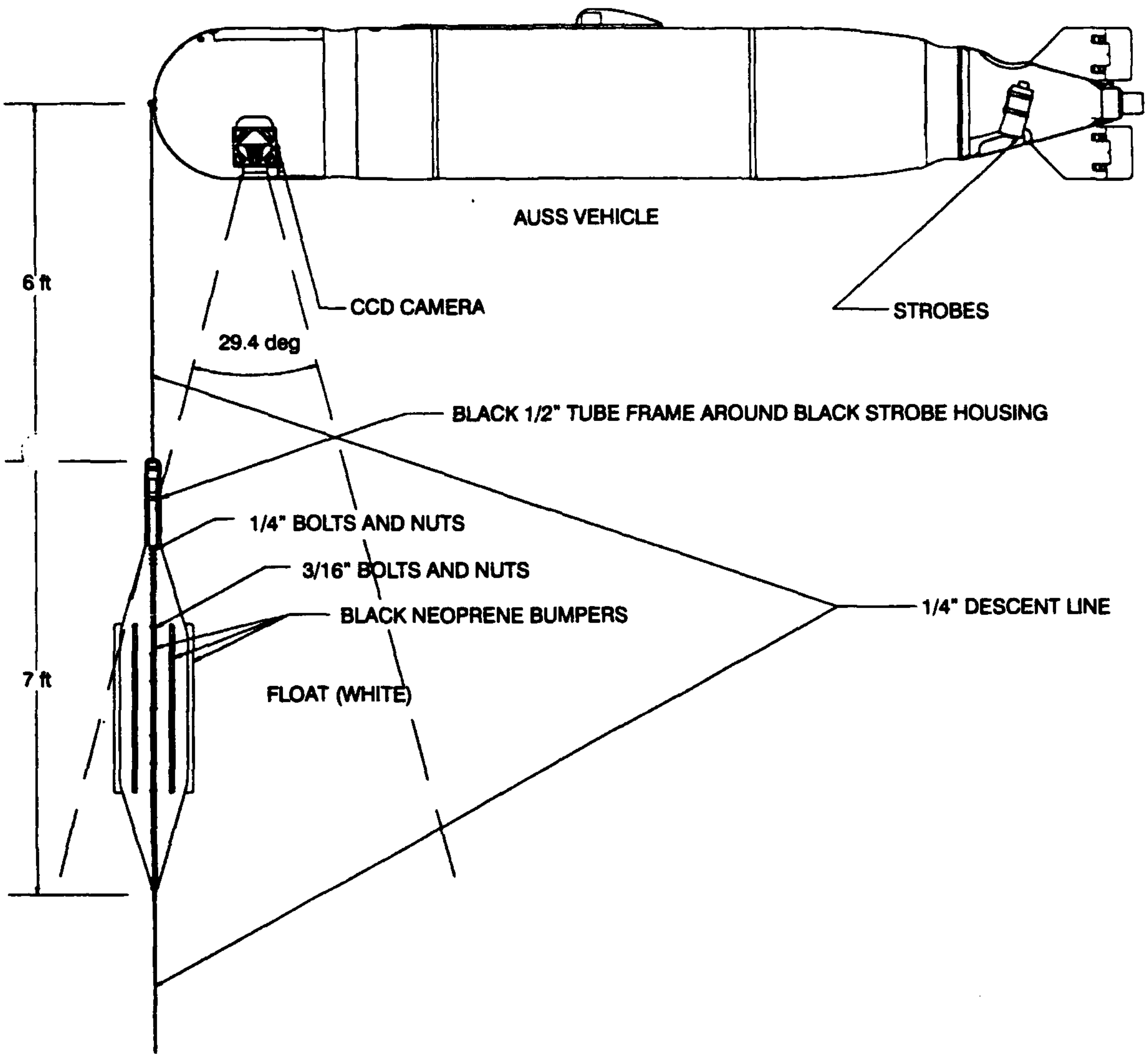

Figure H-8. Imagery geometry.

APPENDIX I

SAMPLE OF DEMONSTRATION DIVE REPORTS

AUSS DIVE 38 REPORT
(Dive Dates 05–05 and 05–06–92)
OPAREA 2743SX/2733NX

TEST PURPOSES

1. Conduct a search with the AUSS in a new area.
2. Evaluate the acoustic link at a deeper depth (4000 ft).
3. Evaluate the various search sensors.

ACCOMPLISHMENTS

1. **Dive Duration.** 14 hr 25 min

2. **Battery Consumption.** 169 Ah

3. **Search Performance:**

Search Cell Coordinates. The following search cell centers were established.

Cell one – lat 32° 35′ 36″, long 117° 31′ 4.2″
Source – 1978 SUBDEVGRUONE Sea Cliff Dive/Attempted Recovery
Cell two – lat 32° 36″ 56.40″, long 117° 30′ 25.80″
Source – 1983 Epilaurd Dive/Photo
Cell three – lat 32° 38″ 18″, long 117° 31′ 12″
Source – NRaD Code 942

Cell One Search Philosophy. Cell one was defined as an 8000-ft by 8000-ft area on a side square centered on the cell one coordinates. The search was divided into two areas: (1) a small area of 2000 ft by 3000 ft centered on the coordinates and (2) a larger area, which was the whole cell centered on the coordinates.

The search of the small area used the side-looking sonars (SLS) at a 500-foot-range scale yielding an approximately 1000-foot-search swath. This is typical of search patterns used during all development to date.

The smaller area was searched first. Although the dive bomber was not found, the area was rich with many types of targets. It should be noted that the SLS were working so well that we literally had to throw many of the targets out of consideration for contact evaluation purposes.

The entire cell was searched using the SLS operating at a 1000-foot-range scale. This SLS search was interrupted several times to do contact evaluations of the "larger" targets that were found. Again the dive bomber was not found, but many other items were found.

4. **4000-Foot Operation.** The system operated in 4000 feet of seawater, which is 60% deeper than previous operations.

5. **Acoustic Link Performance.** The acoustic link operated at 4800 bps for approximately 95% of this dive.

6. **Search Leg Length.** The search legs were 8 kft, which is 4 times any length used during development tests.

7. **Independent Vehicle On-Board Navigation.** The vehicle navigated using the on-board Doppler/gyrocompass system exclusively throughout the whole dive. The Doppler information was only checked (not updated) periodically with the long baseline navigation system network.

8. **Target Summary.** The targets that were obtained on the CCD camera were transmitted to the surface through the acoustic link at 4800 bps in 4000 feet of water. Below is a description of some of the targets found.

a. **Desk.** After location with SLS and FLS, a CCD image of a desk was sent through the acoustic link at 4800 bps. The image was taken at 19-ft altitude. The target was acquired on the SLS at approximately 760-ft range. Time 1941:40.

b. **Jumbled Debris.** After immediate contact closure of a debris field was achieved, a CCD image was obtained. In the image, there was a half circle in the lower portion of the field of view. This "wheel" was measured at 3.5-ft diameter and a 0.9-ft inside diameter using AUSS image measurement software. The "wheel" was among debris in a field of more than 20-ft diameter. This was at 4800 bps and an altitude of 31 ft. SLS acquisition range was 435 ft.

c. **Pancake Debris.** Several CCD images were taken in a debris field located with the SLS. The debris may be a wing of an old plane where the fabric has disappeared. This is speculation only. A series of photomosaic images were obtained in this area.

AUSS DIVES 39 and 40 REPORT
(Dive Dates 05–05 and 05–06–92)
OPAREA 2743SX/2733NX

TEST PURPOSES

1. Conduct a search with the AUSS near the new area searched on Dive 38.
2. Continue to evaluate the system performance in deeper water.

ACCOMPLISHMENTS

1. **Dive Number/Duration.** 39/7 hr 25, 40/40 min.
2. **Battery Consumption.** Dive 39/74 Ah; Dive 40/3 Ah.
3. **Search Performance.** The Douglas Dauntless WWII aircraft (SBD) was located during Dive 39. Figure I-1 shows the vehicle drop point and subsequent contact evaluations, B, C, D, which were not the target of interest and the contact evaluation that proved to be the SBD.

Search Cell Coordinates. The following search cell centers have been established.

Cell one – lat 32° 35′ 36″, long 117° 31′ 4.2″
Source – 1978 SUBDEVGRUONE Sea Cliff Dive/Attempted Recovery
Cell two – lat 32° 36′ 56.40″, long 117° 30′ 25.80″
Source – 1983 Epilaurd Dive/Photo
Cell three – lat 32° 38′ 18″, long 117° 31′ 12″
Source – NRaD Code 942

Note: Cell One was searched during Dive 38 without finding the SBD.

Cell Two Search Philosophy. Cell two was defined as an 8000-foot by 8000-ft square which was centered on the cell two coordinates. The search was not divided into two areas as was done on dive 38. A small central search area was not warranted due to the excellent performance of the system sonars on the 1000-foot-range scale during dive 38.

When the bomber was found, approximately one-half of cell two had been searched using the SLS operating at a 1000-foot-range scale. This SLS search was interrupted several times to do contact evaluations of the "larger" targets that were found. Figure I-1 shows the path of the SLS search. Point E is the location were the SBD was found.

In Dive 39, a real search was drawn to a successful conclusion. The navigation of the vehicle was accomplished with the on-board Doppler and gyrocompass. No tracking transponders were even deployed in this area.

Target Summary. The targets were first obtained with SLS, then with FLS, were imaged with the CCD camera, and transmitted to the surface through the acoustic link at 4800 bps from 4000 feet of water.

The dive 39 Doppler position chart shows the track of the AUSS vehicle during dive 39.

Point A is the launch point or descent string location.

Point B is the first contact where a contact evaluation was completed. The contact turned out to be a large (43 ft) open space frame.

Point C is the second contact evaluation location. The contact was a coil of cable composed of coil sections strewn around.

Point D is the third contact. We broke the SLS track and did not complete the contact evaluation because the FLS image was very small.

Point E is the last contact evaluation where the SBD was located.

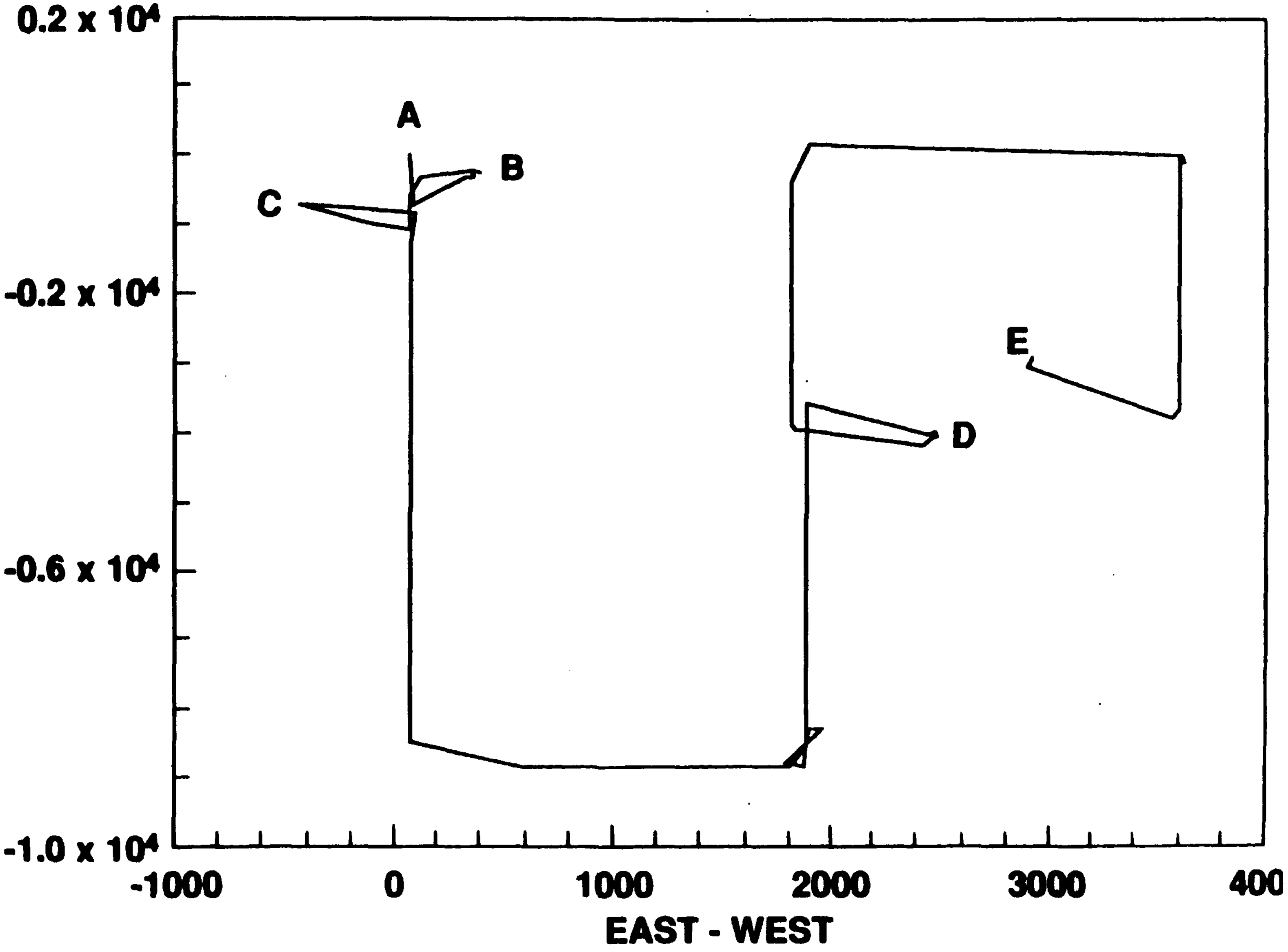

Figure I-1. Path of the SLS search with contact evaluations, dive 39.

AUSS DIVE 41 REPORT
(Dive dates 05–27 and 05–28–92)
OPAREA 2743SX/2733NX

TEST PURPOSES

1. Conduct a search using the photomosaic capability of the AUSS in the new area, which was used for the searches on Dives 38, 39, and 40. The known targets of the SBD and compact debris fields were to be used as the photomosaic targets to evaluate techniques.

2. Run the vehicle on an approximately 5-mile track under on-board control to the southern part of the OPAREA.

3. Evaluate the side-looking sonar (SLS) near the outer edge of the 1000-foot-range scale.

ACCOMPLISHMENTS

1. **Dive Duration.** 13 hr 53 min.

2. **Battery Consumption.** 154 Ah.

3. **Photomosaic.** The vehicle was able to run photomosaic tracks. The photos, being developed at this time, will allow the coverage of the photomosaic technique to be evaluated.

4. **Long Navigation Run.** The vehicle was able to run on its own in a controlled situation for a 5-mile run. The termination point of the 5-mile run was at a location for another reported target. At the completion of the run, a 8000-ft by 8000-ft search cell was defined. Approximately one-half of the cell was searched before the dive was terminated due to depletion of the battery charge. The USS *Sabalo* was the target supposedly in the area, but it was not located in the portion of the cell that was searched.

5. **Discoveries.** Many potential targets were imaged on the SLS, but only two were prosecuted using the contact-evaluation technique. The two targets turned out to be an unreported 55-foot yacht and an unreported aircraft that came to rest right side up. The boat and aircraft images taken by the CCD camera are very good. Hard-copy images are being printed at this time.

6. **SLS Performance.** The SLS were operated at a 1000-ft-range scale. The test was set up on the known position of the SBD in cell two. The track of the vehicle was programmed to have a closest point of approach (CPA) to the SBD of approximately 900 feet. The CPA was 878 ft on the port SLS.

7. **Doppler Plot.** Figure I-2 is a plot of the vehicle positions during the dive. The plot from top to bottom is approximately 6.5 nmi. At the top, there is a high density of plotted points, which I'll refer to as a "splotch" of points. This uppermost splotch is where the vehicle was launched, the 14-inch sphere was searched for, and the Doppler navigation system was initiated while hovering over a pipe structure that had been previously visited and position-surveyed.

The second splotch down is where the Dauntless bomber was reacquired. This splotch is where the bomber was used for a demonstration of both an immediate contact evaluation and a photomosaic.

The third splotch is where a debris field was reacquired, and a photomosaic was conducted over it. The fourth splotch (a small splotch) is where a 55-foot yacht was discovered and inspected.

The splotchy area in the middle of the square-wave search pattern at the bottom of the plot is where a Skyraider nightfighter aircraft was discovered and inspected.

The square-wave search pattern was conducted in an effort to find a submarine allegedly in the area of the search.

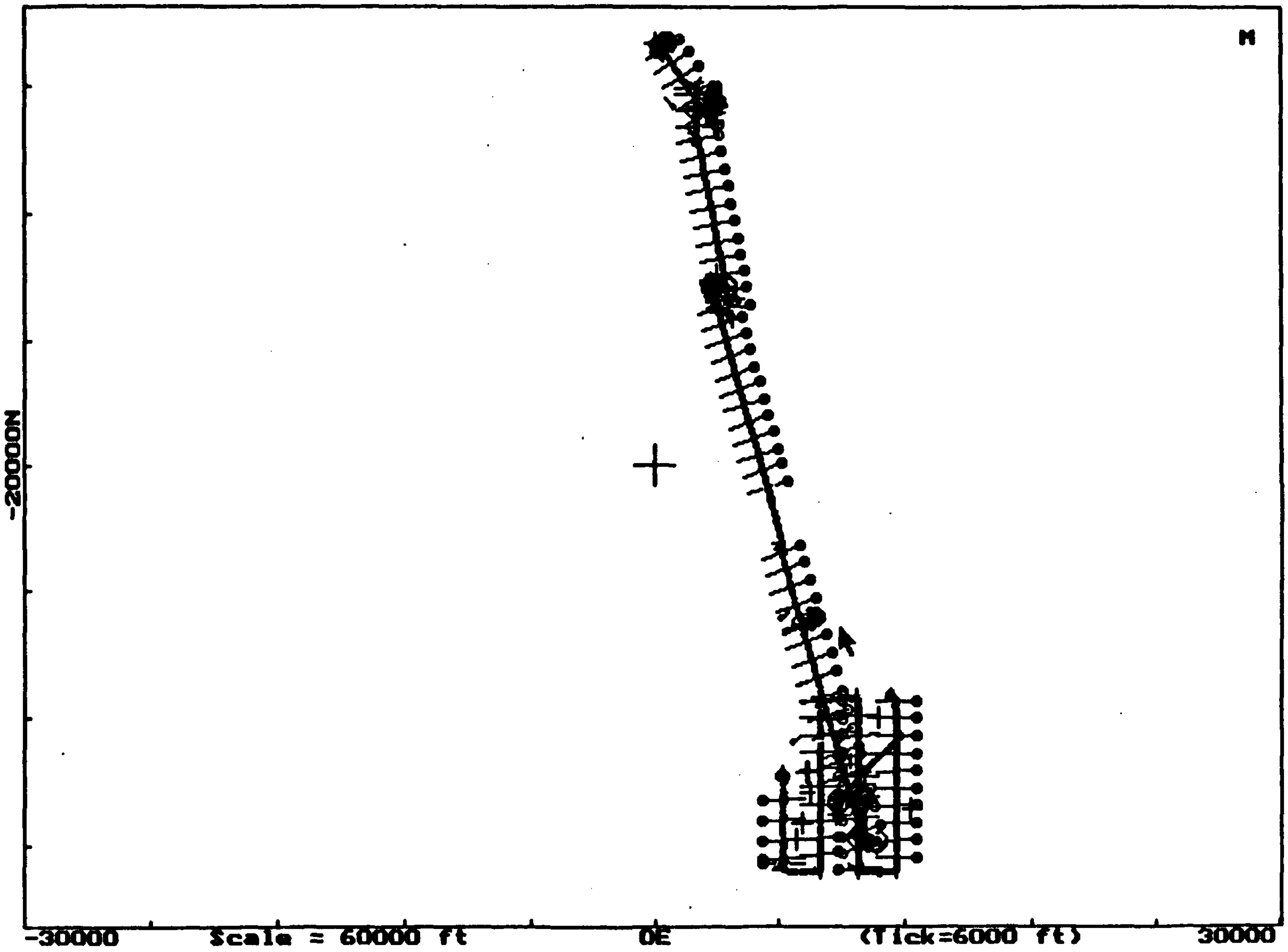

Figure I-2. Vehicle positions during dive 41 showing five "splotch" points.

AUSS DIVE 42 REPORT
(Dive Dates 06–03 and 06–04–92)
OPAREA 2743SX/2733NX

TEST PURPOSES

1. Conduct a broad-area search of an area that had not been previously visited.
2. Run the vehicle on an approximately 20-mile-search track under on-board control.

SITE SELECTION

This site was selected because of its broad flat floor at a depth of 4000 feet and also being the site of a recent crash of a Navy aircraft. Very little information was available on the crash other than a lat/long prediction. The search area was defined with the predicted position within it. The test was designed to be an SLS search with contact evaluations if a suitable target was found. The test was originally planned to include a known scattered debris field; however, the operational area with the scattered debris could not be scheduled because of submarine transits in the area of interest. As a result, the broad-area search did not include a known scattered debris field. The broad-area search would allow data to be gathered for an evaluation of various search parameters.

ACCOMPLISHMENTS

1. **Dive Duration.** 11 hr 58 min
2. **Battery Consumption.** 158 Ah
3. **Broad-Area Search.** The vehicle was able to run the SLS tracks and conduct a broad-area search. The SLS run started at 1025 and ended at 2030. A total of 7.8 legs were completed where each leg was 18000 feet (3 nmi) long. Figure I-3 is a plot of the Doppler track of Dive 42.

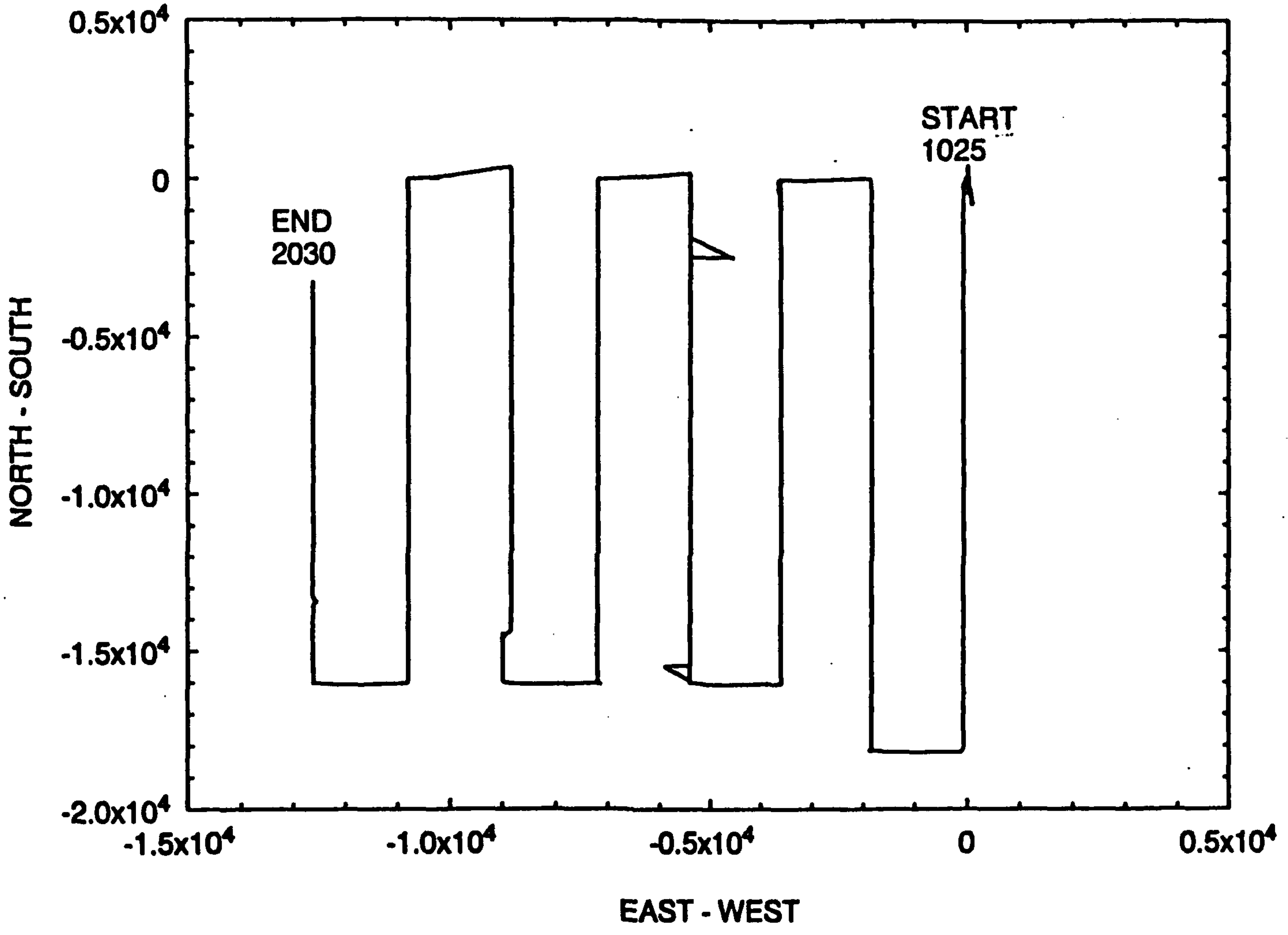

Figure I-3. Doppler track of dive 42.

AUSS DIVE 43 REPORT
(Dive Date 06–18–92)
OPAREA 2743SX/2733NX

TEST PURPOSES

1. In preparation for deeper dives, conduct tests for the first time using the adaptive equalization technique.

2. In preparation for deeper dives, conduct tests for the first time using the increased power level for the uplink transmission.

ACCOMPLISHMENTS

1. **Dive Duration.** 1 hr. Dive 43 was terminated by the vehicle operator after it was determined that the vehicle was not operating properly while still on the descent string.

2. **Battery Consumption.** 20 Ah.

What Happened??

Dive 43 was the first time the adaptive equalizer and the increased power level were actually tested at sea. The adaptive equalizer could not be adequately evaluated during this dive because of a combination of two problems: the uplink transmission was unreliable, and the sensor computer would frequently lock up.

The increased power of the uplink had been implemented in such a manner that there was a switch point between the high and low power that was set for approximately 4000 feet. The switching may have induced a transient into the system that caused the sensor computer to lock up and require a reset. It has not been established at this time exactly what caused the problem. We decided not to continue the dive and to recover the vehicle and do troubleshooting. The vehicle was commanded to return to the surface and a recovery was accomplished. After the recovery, we decided to remove the switching feature and "strap" the power level to 30 watts. During check out, after the fixed power level was implemented, the power in the vans failed. We discovered that the uninterruptible power supply (UPS) had failed; so, we decided that further troubleshooting and subsequent operations on 6/18 were too risky. The descent string was subsequently recovered and the ship returned to port. The UPS was repaired over the weekend after determining that the battery-charging circuit had failed.

AUSS DIVE 44 REPORT
(Dive Date 06–22–92)
OPAREA 2722XX

TEST PURPOSES

1. In preparation for the 12-kft dive, conduct tests for the first time using the adaptive equalization technique.

2. In preparation for the 12-kft dive, conduct tests for the first time using the increased power level for the uplink transmission.

ACCOMPLISHMENTS

1. **Dive Duration.** 4 hr.

2. **Battery Consumption.** 43 Ah.

3. **Successful 12-kft Precurser.** The test objectives were met during dive 44 in that a final check prior to the 12,000-foot dive was accomplished. We did get data on the adaptive equalizer during the period that it operated. The data will be analyzed to determine the degree of performance that was obtained. The tests on dive 44 are the only testing that will be accomplished on the subject. A report will contain all the adaptive equalizer results.

AUSS DIVE 45 REPORT
(Dive Dates 06–23 and 06–24–92)
OPAREA 1900XX

TEST PURPOSES

1. Conduct broad-area search and contact evaluations in a 12,000-foot area.
2. Test the performance of the acoustic link in 12,000 feet of seawater.
3. Use the tracking system with vehicle in 12,000 feet of seawater.

SITE SELECTION

The 12-kft area that was chosen had been visited during a bathymetry survey and during November 1991 when a car body and a navigation net were deployed. The advanced tethered vehicle (ATV) also operated at this site in January 1992 while conducting trials in preparation for ATV turnover. The sites were selected because of their broad flat areas at depths of 4,000 and 12,000 feet. The 12,000-foot test was designed to be an SLS search with contact evaluations if suitable targets other than the car body were found. The broad-area search would allow data to be gathered for an evaluation of various search parameters and system performance parameters.

ACCOMPLISHMENTS

1. **Dive Duration.** 11 hr–8 min.
2. **Battery Consumption.** 130 Ah.
3. **Search And Contact Evaluation At 12 kft.** The test objectives were met during dive 45. AUSS conducted a successful search in 12,000 feet of water and was able to find a previously deployed target using the side-looking sonars (SLS), close the target on the forward-looking sonar (FLS), and take both CCD and 35-mm photographs of the target. The target was the rear portion of a car body.
4. **Photomosaic And Bottom Disturbance Imaging.** The ATV had dragged the car body. A set of five CCD images were taken sequentially during a photomosaic run over the car body in the direction of the track made as the ATV had previously dragged the car body approximately 50 feet. These sequential images show the car and the drag track. After development, there will be a 35-mm photomosaic of the same run.
5. **12-kft System Performance.** The AUSS team consensus is that the system performed at 12,000 feet as well as it had at 4,000 feet. One of the issues addressed at deeper depths is the vehicle trim and net buoyancy.

The data rate was evaluated and in general operated at 2400 bps throughout the mission. The data rate was found to be reliable at 2400 and would contain errors at 4800 bps. The down-link operated at 1200 bps throughout the complete dive without problems.

The Doppler did not perform as well as in previous dives, but we have not determined why the drift was higher than expected. The vehicle ran at 4 knots for much of the SLS runs. The broad-area coverage rate will be determined based on the speeds and swath widths. During this dive, the SLS used the maximum swath width of 4000 ft (2000 ft on a side), the maximum used to date. Actual performance is currently being evaluated.

6. Vehicle Trim and Buoyancy. The AUSS vehicle is "stiffer" than seawater (AUSS has a higher bulk modulus than seawater). This means that as the vehicle descends, it gains more buoyancy. Sixteen pounds of lead were added to the vehicle to render it neutral at depth. The weight was divided into two 8-pound weights and placed in the bow and stern areas as far to port as possible. The placement corrected for the depth effect and corrected the previous 7-degree starboard roll to a 1-degree port roll.

REPORT DOCUMENTATION PAGE

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6. AUTHOR(S)

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12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report describes and documents the Advanced Unmanned Search System (AUSS) test planning and test results. The test planning documentation for AUSS consisted of (1) broad overview plans with a high-level systems perspective, (2) more detailed plans covering focal technology and tactical test areas, and (3) detailed test plans written to assist in the direction of the activity during each individual dive. The three levels of planning allowed the AUSS effort to progress at a detailed technology and tactics problem-solving level without losing track of the big picture.

The test reporting consisted of three basic types. The first type were reports on the individual development test dives. The second type were reports on particularly important or interesting topics addressed during the development sea tests. The third type were reports on the sea tests that were dedicated almost entirely to the demonstration of the AUSS capability.

This body of test planning and test reporting documentation demonstrates the techniques and logic of the approach applied to the test program as well as the results.

The test program for the AUSS was highly successful due to many factors. Some predominant factors were system flexibility, the use of the acoustic link and flight recorder as test tools, a designed-for-test approach, safety considerations, system fail-safe properties, test philosophy, long-range test planning, and the short-term development interactive test planning. Without any one of or the synergy of these factors, the AUSS test program would not have enjoyed such success.

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