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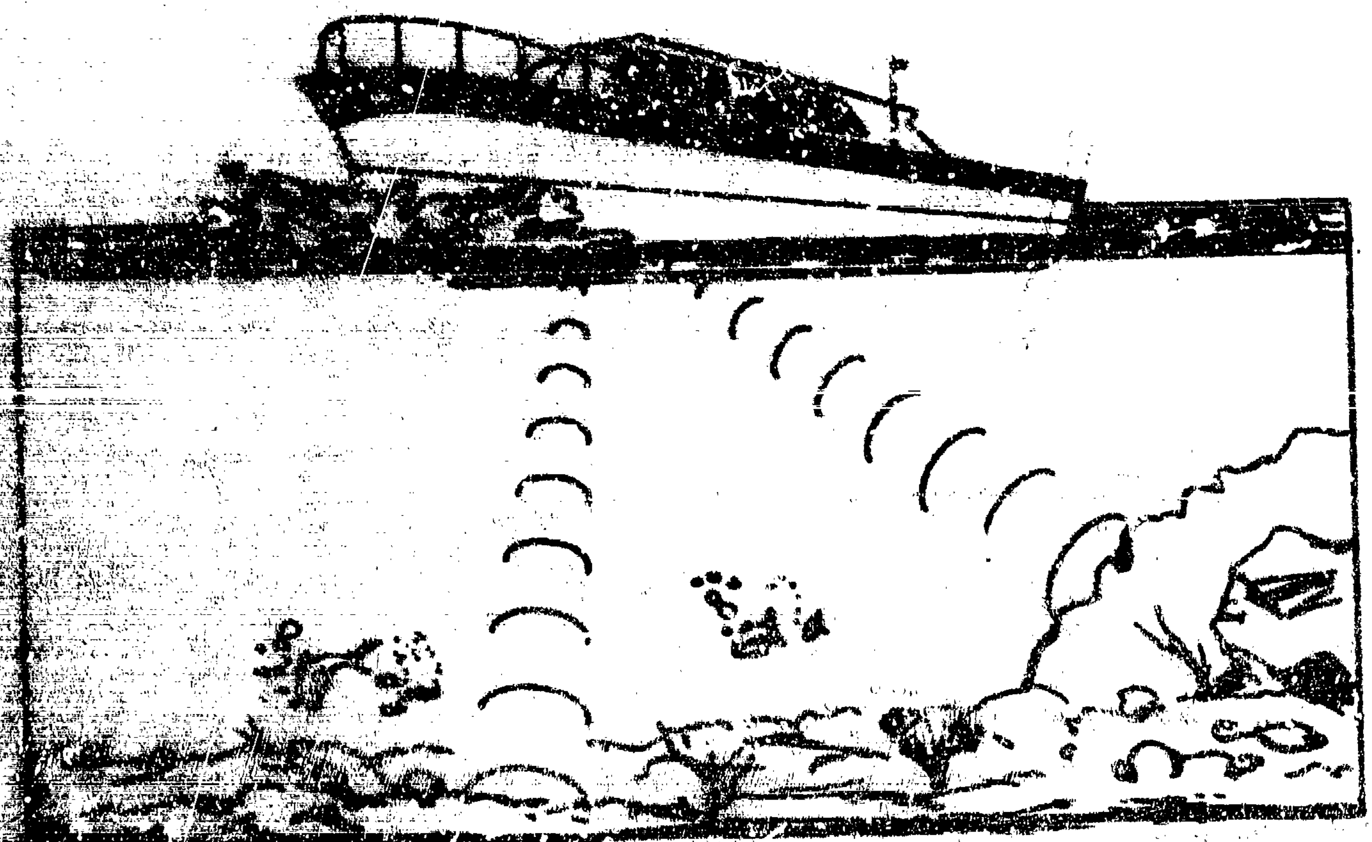
Coastal Hydrographic Sonar/ Advanced Acoustic Techniques Technology Assessment Report



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ABSTRACT

Technological options for increasing the productivity of hydrographic survey launches are reviewed, based on observations of the Naval Oceanographic Office survey operations in the Golfe de la Gonave, Haiti, during May 1982.

It was found that multi-beam sonars have the potential to increase productivity by 50% in terms of area surveyed per day per launch for water depths between 75 and 200 meters, or possibly by 100% over the very limited depth range of 145 to 200 meters. By contrast, under the operating conditions observed during the May 1982 operation in Golfe de la Gonave, major improvements in reliability and maintainability combined with use of the new LCP(L) MK-12 launches can potentially increase productivity by up to 310%.

Sector-scan sonars were found to have an attractive potential for detection of navigation hazards between sounding lines, mapping the perimeters of hazardous areas, and reconnaissance and survey planning. These capabilities will increase productivity provided the sonars are designed for operation at normal survey speeds.

ACKNOWLEDGMENTS

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COASTAL HYDROGRAPHIC SONAR/ADVANCED ACOUSTIC TECHNIQUES

TECHNOLOGY ASSESSMENT REPORT

1.0 INTRODUCTION

On 15 December 1981, the Defense Mapping Agency tasked NORDA to begin development of an improved hydrographic sonar to increase the productivity of the NAVOCEANO survey launches. This effort is responsive to DMA Guidance for Development of FY 84-88 Navy MC&G Program (U), as transmitted to the Secretary of the Navy on 16 February 1982. "Approximately 63% of the coastal charts and 60% of DMA Harbor and Approach Charts have been evaluated 'Limited Use.'" To solve this problem, a need exists to "Increase the productivity of the coastal survey program as a matter of primary importance. Continuing efforts should be made to increase data acquisition capabilities, whether by automated or manual methods. Particular emphasis should be placed on increasing effectiveness and efficiency of the sounding launches embarked." Simplicity, ruggedness, and efficiency of data processing must be stressed during the development of this sonar.

Discussions and meetings with NAVOCEANO resulted in the following clarification and amplification of the requirement:

Full compatibility with the NAVOCEANO/DMA operational scenario was identified as a priority requirement. Two major operational constraints which impact the design of a coastal hydrographic sonar are the platform and the operator. NAVOCEANO presently uses 36-foot hydrographic survey launches. It is probable that they will continue to use this size survey launch in the future. Factors which impact sonar design include the availability and configuration of space, availability of power, the hydro-acoustic environment which affects the performance of the sonar transducers, the physical environment which the electronic units must withstand, and the effect of boat motions on operator performance.

Subject to these constraints, the most important function of the Coastal Hydrographic Sonar is to enhance the efficiency and effectiveness of the routine acquisition of soundings. NAVOCEANO personnel identified the following additional capabilities as desirable, provided that they do not interfere with the priority requirement of full compatibility with the DMA/NAVOCEANO operational scenario.

- The ability to detect navigation hazards between survey tracks.
- A safer and more efficient approach to mapping the perimeters of hazardous areas.
- A more efficient approach to reconnaissance and survey planning.

2.0 SCOPE OF THE INVESTIGATION

In response to NAVOCEANO's emphasis on the importance of operability and maintainability within the context of their operations, the decision was made to devote the major portion of the FY 82 effort to the collection, assimilation, and analysis of information on the DMA/ NAVOCEANO operational scenario and on the performance of existing launch instrumentation. Additional effort was devoted to the collection of information on technology to add the previously identified desirable additional capabilities.

2.1 OPERATIONAL SCENARIO

With respect to the operational scenario, the fact finding methodology included consultations with NAVOCEANO personnel associated with hydrographic operations; review of launch drawings and specifications; inspections of launches; survey equipment and data processing equipment; participation in tests of the boat data logging system in Gulfport, Miss., visits to USNS HARKNESS dockside in Fort Lauderdale, Fla., and participation in the Haiti survey on board USNS HARKNESS during May 1982. Excellent cooperation was received from both NAVOCEANO and OCUNIT FIVE during this phase of the investigation. Personnel from both organizations were frank, forthright, and perceptive.

The scope of the investigation included the launches with their equipment and instrumentation, the maintenance scenario, operations, and the processing of data.

The instrumentation maintenance process was considered from the standpoint of equipment reliability, operating conditions affecting equipment reliability, equipment documentation, availability of spare parts, test equipment, training of the maintenance personnel, and working conditions under which maintenance is performed. Operations were considered from the standpoint of operating procedures and training of the operators.

Data was taken on the actual productivity of survey launches in terms of miles of track per day during the May 1982 SURVOPS. An attempt was made to correlate this data with operational constraints such as shoal water and with the status of the launches and their instrumentation.

The impact of the size of the launch on productivity was not considered because NAVOCEANO personnel advised the authors that definite plans had been made to acquire new 36-foot launches.

2.2 EXISTING LAUNCH INSTRUMENTATION

Data acquired on the launches included speed, limitation on speed imposed by the echo sounder, power supplies and problem areas related thereto, environmental conditions which affect the performance of both instrumentation and operators, and positioning of navigation antennas with respect to the sonar transducers.

The DSF-600 echo sounder was studied from the standpoint of operating characteristics at speeds from 6 to 12 knots in sea states 1 to 3 over varied terrain, and from the standpoint of reliability and maintainability.

The Trisponder navigation system was considered from the standpoint of reliability, maintainability, and its impact on operations.

Meetings were held with NOAA personnel in Rockville, Md., and Washington, D.C., to acquire information on the instrumentation, staffing, and operation of the NOAA/NOS survey launches, the results of laboratory and field evaluation tests of the Raytheon DSF-600 echo sounder, the evolution of the DSF-6000 echo sounder in response to problem areas discovered during these tests, test plans for the DSF-6000, and supporting instrumentation/data acquisition development efforts.

2.3 TECHNOLOGY TO ADD DESIRABLE ADDITIONAL CAPABILITIES

As a parallel effort, preliminary information was collected on potentially applicable technologies such as multibeam sonars, side-scan and sector-scan sonars, image processing, and phase techniques for quantitative measurements with side-scan sonars. Industrial firms contacted included Raytheon, Wescon, the Harris Division of General Instruments, EG&G, Klein Associates, Edo Western, and Ametek Straza.

3.0 OPERATIONAL SCENARIO

3.1 LAUNCH OPERATIONS

3.1.1 Crew and Equipment

The typical launch crew consists of 5 people: the boat officer, the ET/fathometer operator, the plotter, the engineman, and the coxswain. Occasionally, a sixth crew member is present to keep the depth/navigation log and to relieve other crew members for occasional breaks. In shoal water, someone must stand bow watch (typically, the boat officer).

The electronic technician carries a reasonably good set of tools on board on the launch. This includes soldering equipment, but no test instruments. Maintenance performed on board the launches is normally limited to card substitution and to obvious items such as by-passing an obviously broken switch, etc.

The equipment on the Hydrographic Survey Launch (HSL), during the May 1982 SURVOPS in Haiti, consisted of a Del Norte Technology Trisponder Master Unit No. 210 with display Unit No. R03C, 24 vdc power supply No. 201 or 193 from Raydist Systems to power the R03C, 24 vdc power supply No. 201 or 193 from Raydist Systems to power the R03C, Raytheon Fathometer No. DSF-600, radio units VRC47 and PRC 77, and Marine Compass Model 95-B. Argo DM-45 or Raydist DRS are used instead of Trisponder whenever the required ranges to shore stations exceed approximately 20 nautical miles.

The HSL electronic/electrical system is powered by a 115 vac ONAN generator, model MDJ-1R, which is started from battery power, and two 12 vdc batteries connected in series to produce 24 vdc. The

MDJ generator has a rating of 3 kw of power, and the batteries are rated 100 amp-hours on some HSL's and 200 amp-hours on others (depending on availability).

3.1.2 Procedures

The OCUNIT FIVE launch crew has an 0500 wakeup for breakfast. The crew members are ready for launch at 0630. Transmit time to the operating area is typically 0.5 hours to 2 hours, depending on the relative positions of the ship and the lines to be surveyed. One half hour of this transit time is normally required to raise the mast, connect navigation antennas, and to check out the depth scale of the fathometer. If Raydist is used, an additional procedure is required to resolve lane ambiguities; this involves maneuvers of both the ship and the launches. NORDA has not observed a Raydist calibration, but OCUNIT FIVE personnel report that Raydist calibration requires 1 to 1.5 hours when everything goes smoothly. The launches are recovered at 1630. The time available on track for actual surveying may vary from 3.5 to 8 hours, depending on transit time, navigation technique used, and time required for launch and recovery.

The boat officer is given a designated area and a procedure, which the crew follows to acquire data. This procedure includes steering survey lines along circular lines of position; the navigation system is therefore positioned so that it can be seen by the coxswain as well as the plotter. After arriving at the designated area, the boat officer will guide the coxswain to a specific position, which is displayed on the RO3C in meters from remote shore stations. The crew is then responsible for the operation of the equipment, plotting, documentation of position, depth recording, event, and local time recording. Positions are recorded in the survey journal and plotted on a boat sheet; at the same instant the electronic technician engages a marker switch which marks the DSF-600 chart paper. For the May 1982 SURVOPS in Haiti, navigation fixes were taken every 60 seconds. The frequency of depth readings recorded in the sounding log varies from 15 to 60 seconds. Depth sounders are always set to zero tide correction and zero draft correction, as correcting data for tide and draft are mother ship data processing functions.

The start of each line, fix number, time of day, and depth are annotated on the fathometer chart. This process is repeated until the end of the line. At the end of the day, the boat officer takes the data to the NAVOCEANO data processing center on board the mother ship where the data is logged and processed by NAVOCEANO.

3.1.3 Products

The products produced by each launch are: plot of position fixes and tracks keyed by fix number, sounding log containing navigation and depth data, and the annotated depth sounder graphic record.

3.2 TRAINING

The naval personnel presently assigned to the Electronic Department of OCUNIT FIVE are Electronic Technicians and Data System Technicians. The Electronic Technician's assignment is to operate and maintain a wide variety of electronic eqiupment such as: receiver-transmitter units in the VHF, UHF, and HF range; bathymetric shallow and deep water systems; navigation and precision positioning equipment.

A great part of the Electronic Technician's time is spent operating a fathometer and positioning equipment aboard the 36-foot Hydrographic Survey Launches in sea states that range from 1 to 3. They must have complete knowledge of the operation and electrical/electronic parameters of the equipment to ensure quality surveying data. This knowledge for the most part is obtained from on-the-job training and word of mouth. Though this type of training is useful, it leaves a gap that widens as people are reassigned to other commands after a one-year tour of duty, and new personnel are assigned as replacements. If the Electronic Department elects to send personnel TDY for training on any of the non-Navy standard equipment, the training time is counted as part of their one-year tour of duty. Although the U.S. Navy has trained the personnel in electronics for a minimum of 36 weeks, few, if any, have had previous training on surveying equipment.

The Data Systems Technician group, which is currently at 50% of its full contingent, is used for Survey Control watch standing and on-call maintenance for the ship's HDAS computer and peripherals.

3.3 SUPPLY/PARTS

Because of the use of non-Navy standard equipment, most of the spare parts are procured by NAVOCEANO. Oceanographic Unit FIVE has an allowance of six DSF-600 fathometers and six mobile and six remote Trisponder stations. Also, the ship is given a full complement of plug-in cards for the DSF-600 as replacement parts. There were no spare parts in stock for the Del Norte Trisponder Positioning System aboard the survey launches.

3.4 DATA PROCESSING

Data processing is performed by NAVOCEANO personnel. The final sounding sheets delivered to DMA are signed by the NAVOCEANO personnel who produce them; therefore, any error in the final chart can be traced to the NAVOCEANO employees who process the data on board the ship. The impact on reputations and careers in the event of a marine accident is obvious. Therefore, the NAVOCEANO personnel take a very cautious approach to data processing. Each step of the process is checked, point by point, by a separate analyst. Also, NAVOCEANO personnel normally disregard the plots prepared by the boat operators so that they can control the quality of the data products for which they are held accountable. Thus, the primary function of the charts produced by the boat operators is quality control during data acquisition.

Typically, each day's data is processed during the following night and checked during the next day. However, two-day processing turnover is not infrequent. Some Senior NAVOCEANO Scientists prefer to have original data analysis and checking performed during the same shift to increase the opportunity to rotate assignments of very tedious work.

The following data processing steps are performed:

- Tracks of all launches are plotted on a single sheet. Soundings are identified by fix number, and tracks are identified by launch, date, start time, and end time.
- Graphic depth sounder records are scaled with a digitizing table. Readings are taken in even time increments, typically three or four per minute. (Note: The constant chart speed of the depth sounder simplifies this task.) Also, peaks and valleys of major features are scaled. The Wang calculator used for this purpose adds corrections for draft and observed or predicted tide (depending on availability of tide measurements), and numbers are rounded off according to a documented round-off procedure that produces a bias toward shoaler readings. A listing is produced and indexed by position fix number and time.
- Depth readings are copied from the listing onto an overlay of the navigation track.
- A second overlay is produced and contains marks that are color-coded according to depth intervals for each sounding. Contour lines are then drawn between areas of the overlay that contain different color marks.
- Data holidays are then identified, and appropriate instructions are prepared for the boat officers.
- If predicted tides are used for data correction, much of the process must be repeated once observed tide data becomes available.
- For the Haiti priority 1 area, the line spacing was 250 m most of the time, except when shoal areas were being developed. The range of line spacing was 125 to 500 m. The data was plotted on a scale of 1:25,000.

3.5 VARIABILITY OF SURVEY PARAMETERS

The scale, track spacing, and frequency of navigation fixes and soundings are characteristic of the priority 1 areas for the Haiti SURVOPS. In general, these parameters are selected on the basis of specific guidance contained in the Hydrographic Project Instructions which are issued by the Commanding officer, U.S. Naval Oceanographic Office, for each survey. The Hydrographic Project Instructions normally cite specific paragraphs in the following basic references: U.S. Naval Oceanographic Office (NAVOCEANO) Publications SP-4 "Hydrographic Office Technical Specifications for U.S. Naval Surveys and

Supplementary Data" and "Hydrographic Guidelines"; and National Oceanic and Atmospheric Administration (NOAA) "Hydrographic Manual," Fourth Edition.

4.0 PRODUCTIVITY

In the broadest sense of the term, productivity is the measure of end results produced with given resources. The most significant end result of the NAVOCEANO/DMA coastal survey effort is safety of navigation for military and commercial vessels. Thus, any action which decreases the likelihood of an accidental grounding in relation to the amount of survey effort can be said to increase the productivity of the survey effort.

Unfortunately, navigation safety is difficult to quantify and measure, especially in the time frame required to plan and manage a survey. Therefore, a more limited, but quantifiable, operating definition is needed. For purposes of this report, productivity will be referred to as the area surveyed per day by survey launches. When this limited definition is used, the broader implications of the navigation safety produced by the charts must be kept firmly in mind.

Productivity may be broken down into the three major components listed below. The product of these three elements times the length of the surveying day equal the productivity in area surveyed per day.

- The percent of time that the launch is fully operational and on a survey track.
- The speed of advance of the survey launch.
- The spacing between survey lines.

4.1 PERCENT OF TIME FULLY OPERATIONAL AND ON TRACK

No matter what the theoretical performance and efficiency of a piece of survey equipment, it will not contribute to productivity while it is down for unscheduled maintenance. Therefore, reliability and maintainability are essential ingredients of productivity.

Reliability is affected by the design, the construction, and the condition of the survey equipment as well as the physical environment on the survey platform. Maintainability is affected by equipment design, procedures and documentation, spare parts availability, test equipment personnel and their training, working conditions, and time available to perform maintenance. Some of these items can be impacted by technical development efforts; others are policy matters for NAVOCEANO and OCUNIT's. All of them affect the end result.

4.1.1 Observed Performance of Launches

The miles of track accomplished by each launch on the USNS HARKNESS during the period 14-26 May 1982 are tabulated in Table I. The location is a relatively well-sheltered area near Port Au Prince, Haiti. The average performance in miles of track per day was computed for all launches, using a 13-day averaging period for the 600 series launches and a 12-day averaging period fo the 711 launch. (May 20 was treated as a day of scheduled maintenance for the 711 launch and was not included in the average.)

Note the high day-to-day variation in launch performance. The standard deviation was 35% to 67% of the mean. Also, day-to-day variations correlated well with equipment problems (which will be discussed later) and with shoal area development requirements.

In order to isolate the effect of equipment problems on launch performance, the launch surveying capacities, in miles of track per day, were calculated for the conditions which prevailed during the measurement period. The results are presented in Table II.

Sample calculations for the 671 launch are discussed below: the 671 launch has a speed capability of 6 to 8 knots, and a mid-range value of 7 knots was used to calculate its survey capacity. Sonar did not limit the speed, so that surveying could actually be performed at 7 knots. The 671 launch operated for 8 days in deep water. It spent 5 days developing shoal areas and islands at an assumed average speed of 3 knots. The survey area was close enough to the ship to permit 8 hours on track, assuming that everything was fully operational 100% of the time. On the basis of these figures, it should have been possible for the 671 launch to survey an average of 43.7 nautical miles per day. Since the actual performance was 31.7 miles per day, the 671 launch was operating at 73% of its capacity. This was the best performance observed. Note that the 674 launch only surveyed at 31% of its capacity.

The 711 launch was analyzed twice using both the 12 knot speed at which it could obtain good soundings and 17 knots to represent the top speed of the new LCP(L) MK12 derived launches which NAVOCEANO is currently procuring.

The survey capacity of the fleet of four launches is 247.5 nautical miles per day if the 711 is considered to be a 12 knot boat, or 285.8 nautical miles per day if the 711 were able to operate at 17 knots. The fleet actually surveyed an average of 119.4 nautical miles per day (using a 12.75 day averaging period to compensate for one boat day of scheduled maintenance). Therefore, the fleet operated at either 48% or 42% of its capacity, depending on whether the 711 launch is treated as a 12 knot boat or a 17 knot boat.

The significance of these figures is the potential for increasing launch productivity. If all launches were fully operational 100% of the time and, therefore, capable of spending 8 hours per day on track at sonar-limited speed, the productivity of the fleet would have doubled. If the 711 launch had been fully operational 100% of the time and, in addition, if it had the ability to survey at 17 knots without deterioration of the fathogram, its productivity would have increased by a factor of 3.4 (a 240% increase). Finally, if all four launches had this 100% reliability of high (17 knots) speed capability, fleet productivity would have improved by a factor of 4.1

(a 310% increase). Thus, the potential exists to increase productivity with the new fleet of LCP(L) MK12 launches by 310%.

It is important to emphasize that the potential improvement factor of 4.1 (a 310% increase) for fleet productivity, is based on a limited period of observation during the Golfe de la Gonave Survey. It would be misleading to interpret this figure outside the context of this report because of the following specific conditions which existed during the Golfe de la Gonave Survey:

- Sea states did not adversely affect attainable launch speeds or crew endurances.
- Lengthy transit times were not necessary; therefore, on-track survey time available for each launch was 8 hours per day.
- Only 48 boat-hours out of a possible 408 boat hours, or 12%, were spent developing shoals at three knots.
- Survey speeds other than in shoal developments were not adversely affected by slowing for hazardous waters or for the effect of rapidly changing bottom topography on depth sounder operation.
- Since data requirements were primarily for shallow water, USNS HARKNESS did not conduct any surveying of her own, and could support launch surveys to the maximum extent.

4.1.2 Conditions Affecting Daily Mileage

Tables III, IV, V, and VI summarize the conditions which affected the daily mileage of launches Numbers 671, 672, 674, and 711, respectively.

4.1.2.1 Sequence of Events

Launch No. 671 was assigned to shoal and island surveying for a significant amount of the the observed period. This is reflected in the variation of survey miles during the period 14 May through 18 May. On the dates of 20 May and 26 May, the launch had electrical problems. The crew corrected these problems at sea on 20 May, but were unsuccessful in their repair effort on 26 May and returned to USNS HARKNESS for repairs at the end of the day.

Launch No. 672 operated in nonshoal waters for the observed period. The operation of the launch was hampered by electrical and electronic problems on the following dates: 14 May, 16 May, 19 May, and 23 May. On 22 May, no notes were taken on the reason for the low mileage. On 14 May, minor problems with the Trisponder occurred throughout the day. On 16 May, the launch was forced to return to USNS HARKNESS for Trisponder repair and was returned to survey operations at 1235. On 19 May, the launch did not leave USNS HARKNESS until 0800 due to electrical problems. Later in the day, the electrical system became erratic in operation. The boat officer decided to turn the air conditioning off and to continue operation without air conditioning. The electrical system became inoperative late that afternoon. The crew attempted to repair the electrical system without success. It was then decided to return to USNS HARKNESS for repairs. On

23 May, the launch did not survey until 1300 due to Trisponder problems.

Launch No. 674 was plagued with electrical and electronic problems. The correlation between the two classes of problems was one-to-one as shown in Table V, with the Trisponder completely dependent on an adequate electrical system. It was found that the starboard side of the launch was wired differently than the port side, the latter not being grounded to the dynaplate as per ONAN specifications. This fact was not discovered until 25 May. Another problem that occurred is that the ONAN generator would be loaded down by the air conditioning unit after a number of hours of operation. This would drop the AC voltage to 100 volts resulting in the DSF-600 echo sounder responding erratically. This would be corrected by turning the air conditioning off, thereby enabling the AC voltage to stabilize at 110 volts.

Launch No. 711 was not deployed on 20 May for surveying due to transmission problems. On 23 May and 24 May, the Trisponder positioning system was the major source of low survey miles.

The data in Tables III, IV, V, and VI are an attempt to show some of the conditions that affected the daily mileage of the hydrographic survey launches. All conditions were not noted because they were not always of the nature that stopped a launch from surveying for a longer period of time. Sea states that slowed the launch speed, the operation of the Trisponder when used in the time-sharing mode, the electrical system configuration, and the care and testing of the wave guide on the Trisponder are all conditions that could have affected the surveying operations.

4.1.2.2 Sea State

On 16 May, all launches were deployed late due to high seas. The morning of 17 May, Launch No. 711 had to slow to 1500 rpm to collect data in rough seas.

4.1.2.3 Trisponder Operation

The operation of the Trisponder was a factor that contributed to low efficiency when used in the time-sharing mode. The changing of base numbers and the engaging of the reset switch during the launch operations would set the stage for a series of events. First, the display unit indicator light would give an update or no data signal on one of the H.S.L.'s. The launch personnel would observe the light and change the base switch or engage the reset switch. This would cause the remote unit to try to establish a new time-sharing sequence giving all the launches a no-data/update light. Second, the other launches would then attempt to establish a new position fix by changing their base numbers. This would result in a radio communication from the launches to the ship about Trisponder problems. This would generally go on for a few minutes before the launch operators would stop changing base numbers or resetting the display unit.

4.1.2.4 Wave Guides

The care of the Trisponder wave guide connection and the antenna on the master unit is an area of concern. At night, the antenna was removed from the master unit and the wave guide can of the master unit was covered with a loose piece of plastic to keep moisture out. The master unit was then placed inside the launch for the night, though sometimes it was taken into the shop. The cabins on the launches were not secured from the sea environment due to leaks in the cabin area. Also, the launch air conditioning systems were not run at night. This allowed moisture to get into the cabin and into the wave guide cavity. Some of the antennas had noticeable dings and minor twists. All of these conditions can be expected to change the electrical impedance characteristics of the antenna, resulting in inefficient loading of the antenna by the transmitter or reduction of the antenna's efficiency for receiving. In extreme cases, these changes in the antenna's electrical characteristics could produce damage to the transmitter. Therefore, the antennas should have been checked; this could not be done due to lack of microwave test equipment.

4.1.2.5 Ground Systems

Ground systems must normally be designed so that large ground currents, such as from the ground of the ONAN generator, do not induce noise voltages in the outlets used for sensitive electronic equipment. This normally requires the use of separate wires for the grounds of generators and the grounds of instruments. A standard ground system should be considered in relation to the types of equipment being installed in the H.S.L.'s. Presently, the ground design in each H.S.L. is different and could present a problem when noise-sensitive equipment is installed. The use of series, parallel, and multipoint ground connections are used, depending on the location of the equipment and the dynaplates. In the case of Launch No. 674, a definite deterioration in performance of the Trisponder was noted; the Trisponder problem cleared up once the grounding was corrected.

4.2 SPEED ALONG TRACK

Speed along track is affected by the top speed of the platform, sonar limitations, shoal area development requirements, and environmental factors such as wind and sea.

NAVOCEANO has taken a major step forward in the area of top platform speed by adopting the LCP(L)MK 12 as a survey launch, which has a top speed of 17 knots. This will affect speed along track only to the extent that the survey speed of the launch is not limited by the design, construction, and installation of the sonar. In this respect, the design of the transducer housing and its location and installation on the hull are of critical importance. In addition, the launch must operate with a level trim so as to keep the transducer in the water and clear of bubbles.

Launches must run slowly in shoal areas for safety reasons. How slowly and for how long can be impacted by items such as coxswain's visibility and the availability of obstacle avoidance sonars.

4.3 LINE SPACING

The choice of line spacing is based on a consideration of the depth and character of the bottom, the purpose of the survey, and policy regarding percentage of bottom coverage. If side-scan sonars, sector-scan sonars, multibeams, or any other sonar capable of detecting navigation hazards or making soundings between survey lines become available, the swath width of the sonar will also be a consideration.

With existing technology, line spacing is a compromise between the ideal of 100% navigation safety and the economic necessity of completing a survey with limited time and resources. For example, if 20 m deep water is surveyed with a depth sounder with a 20° conical beam, and line spacing of 125 m is used, less than 6% of the bottom will be searched. Thus, there is some risk that a wreck or other navigation hazard between survey lines will not be detected. On the other hand, tightening up line spacing to insure that the entire seabed is examined will increase the survey workload by a factor of 17, which is clearly not practical. Side-scan sonars have the capability of detecting navigation hazards between survey lines. However, their use is not always economical because they limit the speed of advance of the survey launch.

5.0 ALTERNATE APPROACHES

The three major components of launch productivity have previously been described as: The percent of time that the launch is fully operational and on a survey track, the speed of advance of the launch, and the spacing between survey lines.

Four alternate strategies for increasing launch productivity which will be discussed are:

- Use multibeam sonars to increase the line spacing.
- Use side-scan or sector-scan sonars to permit more complete coverage of the sea floor.
- Minimize the limitations on launch survey speed imposed by the depth sounder.
- Increase the reliability and maintainability of all launch systems so as to maximize the time that the launch is fully operational and actually acquiring data.

5.1 MULTIBEAM SONARS

A variety of multibeam sonars has been proposed to perform the coastal hydrographic surveying mission (Purvis Systems, Inc., 1981). These systems take soundings with a multiplicity of narrow beams arranged in a downward-directed, athwartships-oriented fan. Slant ranges to the bottom are measured, and the measurements are converted to athwartships distance and depth. Usually, the data is presented in contour strip chart format and recorded on magnetic tape for additional processing on shore or on the mother ship. Since multibeam echo sounders typically acquire 16 to 40 depth soundings per sonar ping, they produce substantial quantities of data. The resulting data processing requirements are non-trivial.

The greatest swath width proposed by any of the manufacturers discussed in the Purvis report was 120°. Figure 1 shows the swath width which could be achieved by such a system as a function of depth. For comparison, Figure 1 also shows the line spacing used by NOS and by NAVOCEANO. NOS line spacing for harbors and restricted areas (such as bays, passages, channels, and rivers) was taken from the NOS "Hydrographic Manual," Fourth Edition, 1976, paragraph 4.3.4.1. NOS line spacing for smooth bottom along open coasts was taken from paragraph 4.3.4.2 of the same document. NAVOCEANO line spacing for 1:50,000 and 1:100,000 scale surveys was taken from Project Instruction No. 8/Archive No. 825018/HAITI. NAVOCEANO line spacing for 1:25,000 scale surveys was taken from message traffic to OCUNIT FIVE, USNS HARKNESS (T-AGS-32), during March 1982.

Figure 1 shows that NOS and NAVOCEANO normally survey at line spacings that are greater than the swath width of a state-of-the-art multibeam sonar. The only exception is the relatively narrow range of 145 to 200 m depth. Therefore, a multibeam with a 120° swath width will not permit full coverage surveying at track spacings greater than current practice.

If a multibeam sonar was used in conjunction with a line spacing of 750 m, the unsurveyed area between lines would be less than 500 m for depths between 75 and 200 m. This 500 m gap should be acceptable if a 500 m line spacing is acceptable when single-beam depth sounders are used in the same range of depths. Thus, multibeam sonar technology would support a 50% increase in line spacing for depths between 75 and 200 m, or a 100% increase in line spacing for depths between 145 and 200 m. This is a very limited potential for improvement. Any further increase in line spacing would require a major advance in multibeam sonar technology to increase the angular swath width beyond 120°.

Multibeam sonars could perform the function of detecting navigation hazards between normal survey tracks. This would enhance the navigation safety which would result from the survey effort, and would therefore contribute to productivity in the broad sense of the term. However, the ability of the multibeam sonar to measure depth quantitatively at a distance is not essential for this function.

Multibeam sonars could also make a contribution to mapping the perimeters of hazardous areas. However, their performance in this area would be severely limited by the 120° angular swath width which represents the present state of the art.

The electronic portions of existing multibeam sonars are physically too large to install on NAVOCEANO's 36 foot survey launches.

Recent advances in electronic technology are available to substantially reduce the size of these electronic units. The effort would be nontrivial, and considerable thought would have to be given to reliability, maintainability, and human engineering factors because of the complexity involved. The benefits which would result from such an effort are questionable.

5.2 SIDE-SCAN AND SECTOR-SCAN SONARS

Side-scan sonars and sector-scan sonars represent a class of hydrographic instruments which, in their present state of development, produce imagery of the sea floor rather than quantitative depth soundings. It is assumed that their use during routine surveying operations will not serve as a justification for increased line spacing, at least until considerable advances have been made in the processing and interpretation of their data. Therefore, their contribution to launch productivity must come from their use for detection of navigation hazards between survey lines, mapping the perimeters of hazardous areas, and reconnaissance and survey planning.

Side-scan and sector-scan sonars have considerable potential for the aforementioned uses provided that: (a) their use does not interfere with acquisition of soundings by requiring the launch to slow down, (b) appropriate displays are provided, (c) the data is recorded in a format which makes it available and useful to the NAVOCEANO data analysts aboard the mother ship, and (d) the equipment is human-engineered for the NAVOCEANO/DMA operational scenario.

Before discussing the side-scan and sector-scan sonars separately, it is appropriate to mention some of the acoustic characteristics which support their use for navigation hazard detection, mapping the perimeters of hazardous areas, and reconnaissance. First, they transmit sound in beams that are fan-shaped and extend from near-vertical to near-horizontal, or approximately conical beams which can be pointed in near-horizontal directions. Therefore, their range is not severely limited by water depth as in the case of multibeam sonars. Also, they distinguish between objects at different distances from the launch by means of the arrival time of the echo rather than through beamforming. Therefore, they have greater spatial resolution in at least one direction and consequently greater ability to detect small navigation hazards such as wrecks.

5.2.1 Side-Scan Sonars

Side-scan sonars manufactured by Klein, EG&G, and Edo Western have tow fish which are typically 48 to 66 inches in length, weight 48 to 75 pounds in air, and have horizontal beamwidths of 0.2 to 1.5°. Claimed swath widths vary from 50 to 1200 m, depending on the particular model. The actual range of any given model will depend on bottom conditions, thermal gradients in the water, bubbles in the water, and sources of outside interference.

All of these units are capable of producing imagery that clearly delineate wrecks, probable shoals, and (for the higher resolution units) pilings, provided they are towed slowly enough. Manufacturers' brochures sometimes claim towing speeds up to 16 knots, but this refers to tow fish stability. If an attempt were made to utilize these side-scan sonars by towing them rapidly from the survey launches, the following problems would occur: (a) The tow fish would ride aft of the launch by nearly the full length of the tether. (b) It would be difficult to ascertain exactly where the tow fish was located during data analysis because of the length of its tether. (c) The tow fish would sink if the launch slowed down to avoid grounding on a shoal; this would be an undesirable time to have the tow fish sink. (d) Extra line handling to avoid the previous problem would complicate operations. (e) Gaps in the data would result from the combination of narrow horizontal beamwidth and high speed.

Variable Depth Sonars (VDS's) on destroyers can be towed, launched, and recovered at very high speed. However, the deck equipment required to handle this, including winches capable of handling the rigid fairings on the tow chains, is massive. Therefore, VDS technology is not likely to lead to an acceptable solution to the speed problem on survey launches.

The gaps in the data can be understood by considering a hypothetical side-scan sonar towed from a 20-knot platform (assuming, for the sake of discussion, that the mechanical towing problems could somehow be solved). If this sonar were designed for a swath width of 250 m, the minimum pulse repetition period would be 0.33 seconds, which is the round trip travel time for sound. Good record clarity and high detection probability requirements would make it desirable to look at each reflection 5 times. At extreme range, this would require 1.67 seconds, during which time the platform would advance 17.2 m. Keeping this target within the beam for 5 successive pings would therefore require a horizontal beamwidth no less than 3.9°. Along-track resolution would be proportionately degraded. By comparison, an off-the-shelf side-scan sonar with a 1.5° beamwidth would only look at each target (at extreme range) an average of 1.9 times, and gaps in the data would appear at ranges less than approximately 130 m.

If the tow fish were towed by a very short tether (possibly off the bow) or were rigidly fastened to the hull of the launch to avoid or reduce the high-speed towing problems discussed above, it would pitch and yaw in response to the motions of the launch. This would require an even wider beam or motion compensation by either electronic or mechanical beam steering. The motion measurement package would be located in the launch if the sonar was hull-mounted, but would have to be located in the fish if it were towed on a short tether. In either case, we are talking about a sonar that is substantially more complex than the conventional off-the-shelf side-scan sonar.

To summarize, the goal of operating a side-scan sonar on a launch at 20 knots leads very quickly into complexity. The trade-off is between mechanical complexity and electronic complexity. The alternative of towing slowly with a very long range side-scan sonar leads to high sensitivity to thermal gradients in the water in coastal areas (Moss, 1982). The oceanographic effort to support this would divert manpower from the primary hydrographic mission.

5.2.2 Sector-Scan Sonars

Sector-scan sonars are active sonars which scan the sea floor in azimuth and display a plan view of the area scanned on a cathode ray tube (CRT) screen. Edo, Ametek-Straza, and Wesmar have marketed this type of sonar as obstacle-avoidance sonars.

5.2.2.1 Ideal Characteristics

For operation on a high-speed survey launch, the ideal sector-scan sonar would have the following characteristics:

- Small hull-mounted transducer to reduce drag and minimize flow noise and the signal-quenching effects of bubbles.
- Low cost.
- Easy to interpret displays.
- Data recording capability supported by simple playback equipment onboard the mother ship. Hardcopy generation on playback as an option.
- Rapid scanning to minimize speed-related image distortion, minimize launch motion compensation requirements, and maximize the number of looks at each target.
- Sufficiently wide beam to avoid gaps in data at high speed.
- Easy to operate and maintain.

5.2.2.2 Advantages

A sector-scan sonar with these characteristics would have the following advantages:

- The area between survey lines could be scanned for navigation hazards without reducing the launch's survey speed.
- Targets detected between survey lines could be investigated in more detail without deviating from the survey line by concentrating the scanning in the direction of the detected target.
- The sonar could be used for obstacle avoidance, thereby increasing both the speed and the safety of shoal area development.
- The perimeters of hazardous areas could be mapped without the deck operations or maneuvering restrictions of towed side-scan sonar.
- Side-scan sonar operation would also be available.
- Hardcopy output printed on the mother ship, if printed to the same scale as the transparent boat sheets, would be easy to use as a reasonableness check on the data and contours.

5.2.2.3 Commercially Available Sector-Scan Sonars

Several commercially available sector-scan sonars are shown in Table VII. The characteristics of these sonars will be briefly compared with the ideal characteristics discussed above:

The Wesmar units have the thinnest soundheads. Because of their high length-to-width ratio, they can protrude well into the water so as to reach the undisturbed, relatively bubble-free portion of the flow stream. The Edo and Ametek-Straza soundheads are much wider and are less compatible with good hydrodynamic design on a high-speed survey launch.

The Edo unit and the Ametek-Straza Model 250A need domes to protect the exposed mechanisms from damage from the water flow since they were designed for slow-moving submersibles. The Wesmar units are equipped with hoist mechanisms which can retract the soundhead into the hull to reduce drag when the launch is transiting or to prevent damage when the launch is being hoisted aboard the mother ship. Consequently, they need sea chests. Fairing requirements will be minimal if two Wesmar units are used on each launch to scan the port and starboard sectors, respectively. Engineering efforts will be required to synchronize the two units and to avoid mutual interference. If only one unit is used, the sea chest will have to be extended into the water sufficiently to give the soundhead a clear view under the keel when extended; this will induce drag.

The Wesmar units have a decided cost advantage even if two units are used. The price has to be kept low because Wesmar markets these units to commercial fishermen. Modifications to the video processor, in the form of microprocessor code, would be needed to enable the unit to cope with the high launch speed, but it is anticipated that these costs would be primarily developmental. The price of the Wesmar units includes soundhead, hoist unit, electronics, and video monitor.

The Edo and Wesmar units have video processors which can produce a flicker-free display that is much easier on the operator than conventional sonar displays which flicker at the scan rate. The Ametek-Straza units partially compensate by means of a faster scan rate. The Wesmar unit has a color display that makes contrast differences much easier for the operator to see. The Edo and Wesmar units would exhibit an image distortion related to a discrepancy between the relatively slow scan rates of the sonars and the relatively fast (20 knots) speed of the survey launch. This would require some microprocessor code plus a speed input.

Recording and playback equipment would have to be specially configured for the Ametek-Straza units. The video processors in the Edo and Wesmar units would enable standard, mass-produced video cassette recorders and video monitors to be used for this purpose at a considerable saving in cost and complexity. Also, Image Resource Corporation markets a device which produces hardcopy images from video signals; such a device could be used to produce hardcopy upon playback on the mother ship if desired. Polaroid previewed another such device at the recent National Computer Conference in Houston, Texas.

Ametek-Straza is clearly in the lead in the area of scan rate, because they use continuous Transmission Frequency Modulation (CTFM). CTFM is a modulation technique which permits the transmitter and receiver to operate continuously rather than in a pulsed mode. As a result, it is not necessary to wait for a pulse to travel the full round trip distance to the most distant range for each few degrees of beam motion. The beam can be scanned as rapidly as the mechanical or electronic beam steering mechanism will allow. In the case of the Ametek-Straza Model 300 SWAP, electronic beam steering permits a virtually instantaneous scanning rate so that a 120° scan can be obtained within a single range resolution cell. They call this mode of operation Scan Within A Pulse (SWAP).

The 6.5° horizontal beamwidth of the Wesmar Model SS265 appears to be a good compromise between resolution and probability of detection; at 20 knot speed, each target at maximum range can be insonified 8 times. Its angular resolution is less than that of the 3° beam Ametek-Straza units which are not capable of 5 ensonifications of an athwartships target at 20 knots, but greater than any of the other Wesmar units. The Wesmar soundhead is roll and pitch stabilized.

The Wesmar unit has the most compact electronics. The total electronic package, TV monitor not included, occupies 3 inches of standard 19-inch rack space. Wesmar markets this unit to commercial fishermen and therefore has the motivation to make it simple to operate and maintain. Field testing will be needed to determine how simple it is in reality.

The Ametek-Straza Model 300 SWAP is limited to a 120° sector-scan. The Ametek-Straza Model 250A can scan a 90° (±45°) sector or full 360° scan. The Edo and Wesmar units have many options, including a 180° sector (±90°), which may be optimum for detection of navigation hazards between survey lines (with one sonar).

In summary, the Wesmar sector-scan sonars appear to have all of the characteristics of an ideal sector-scan sonar except for the rapid scan rate. The Ametek-Straza Model 300 SWAP has the highest rate by a wide margin because of the CTFM mode of operation combined with electronic beam steering; it is also expensive. The ideal sector-scan sonar would combine the best features of both of these units.

The Wesmar sonars could be adapated for a rapid scan rate by means of the following rather extensive modifications:

- Replace, rewire, or modify the motor in the soundhead to provide a faster mechanial transducer motion,
- Add a second omnidirectional transducer to permit simultaneous transmission and reception,

- Increase the stroke of the hoist mechanism as required to accommodate any increase in the length of the soundhead (unless the second transducer is mounted separately on the hull), and
- Re-design the transceiver portion of the electronic unit for operation in the CTFM mode.

A less ambitious alternative would be to modify the Wesmar sonar for high-speed operation. As presently programmed, image distortion would result from the discrepancy between the scan rate and the high speed of survey launches. For example, if the sonar is set to a range of 300 m, the scan rate will be 10° per second. Thus, it will scan a 180° sector in 18 seconds. During this time, the 20-knot launch will advance a total of 180 m, which is 30% of the diameter of the semicircle scanned. This distortion can be corrected by modifying the sonar's microprocessor program, (possibly) adding a small amount of memory, and providing a speed input. This speed input could be shaft turns, a knob adjusted by the operator, or (preferably) an input from the navigation unit. This effort should be preceded by in-water tests at slow speed to assess the performance of the sonar and the utility of the data collected.

5.3 LIMITS ON SURVEY SPEED IMPOSED BY THE DEPTH SOUNDER

The Launch No. 711 on USNS HARKNESS was unable to survey at 20 knots despite its ability to physically move that fast. Satisfactory depth sounder operation required a slower speed around 12 knots. It is important to point out that depth sounder performance is critically affected by the location and method of installation of the transducers, the shape and size of the dome or fairing which (hopefully) deflects bubbles away from the transducer, the smoothness and shape of the hull forward of the transducer, and trim of the launch when it operates at speed. Therefore, "depth sounder performance" does not only refer to the performance of the electronic unit supplied by Raytheon.

The sonar performance on Launch No. 711 appears to be the result of two factors: (a) a reported trim tab problem that results in the launch riding bow high causing the transducer to ride too close to the water surface; and (b) a smooth blister type of transducer fairing that allows bubbles to cross the face of the transducer causing noise and quenching the signals.

Tests on the 700 class of survey launch performed by NAVOCEANO (Marshall and Barnes, 1979) have demonstrated that extension of the transducers 5.5 inches below the hull would substantially improve the sonar performance and would permit operation at 18 knots in depths of 220 to 270 meters and at the maximum speed of 20 knots in shallow water. The test data implied, but did not prove, that use of extensions of less than 5.5 inches would be likely to produce marginal results. Also, review of the analog records published by Marshall and Barnes (1979) indicates that the quality of the digital data would depend even more critically on extension of the transducer.

It is essential that transducers on the LCP(L) MK 12 launches be extended from the hull or otherwise be protected from the bubble stream by a properly designed fairing if reliable depth sounder operation at high speed is desired.

When transducers or fairings are extended from the hull of high speed launches that don't have deep skegs to protect the transducers from grounding, a break-away type of attachment is recommended. In the event of an accidental grounding, the transducer or fairing should break away from the hull leaving the hull intact.

5.4 INCREASING RELIABILITY AND MAINTAINABILITY

Reliability and maintainability are complex issues. Various launch subsystems such as instrumentation, power, grounding, and air conditioning interact and affect each other's performance. Also, reliability and maintainability involve an interaction of hardware and people. Thus, reliability and maintainability problems have what one might call (for want of a better word) a people dimension as well as a technical dimension.

The people dimension of the reliability/maintainability problem is more difficult to write about than the technical dimension because one runs the risk of being perceived as critical of the personnel or of the management system which determines their working conditions. Therefore, it is important to emphasize that the authors are attempting to formulate a technical contribution to the solution of a complex problem, and that they believe it is important to understand the people dimension of the problem in order to do so.

The technical dimension of the problem has already been discussed. Observations during May 1982 indicated that substantial amounts of survey time were being lost due to technical difficulties with Trisponder navigation units, launch electrical subsystems, and launch grounding subsystems.

The electrical and grounding problems were complicated by a lack of documentation; this in turn placed demands on the OCUNIT personnel for detailed knowledge of the subtle effects of the wiring of the power/grounding system on the performance of the instrumentation connected to it. The Trisponder problem was complicated by lack of sufficient instrumentation and procedures to assess the unit's readiness for survey. (For example, there was no radio frequency testing capability, yet some of the units had physical damage of a type that often knocks transmitters and receivers out of adjustment.) Another complication was the tendency of the air conditioning unit to load down the ONAN generator causing a reduction in AC line voltage and frequency, which in turn alters the characteristics of the instrumentation. All of these factors complicate the job of the OCUNIT personnel and create a demand for detailed knowledge of a type usually acquired through specialized experience supplemented by specialized training.

The launches and their equipment are operated and maintained by military personnel who, during the period they were observed by the authors, appeared to be both competent and motivated to do a good job. However, they find themselves in a work situation where much is demanded of them in terms of specialized knowledge in an area where they have very little training. Their short tours of duty work against acquisition of very much specialized training, and they are not on the job long enough to fully exploit the specialized experience which they do acquire. The authors assume that increasing their tour of duty is not feasible. Therefore, it is important to find a technological means of simplifying the demands of their work situation.

A major asset of the surveying effort is the availability of NAVOCEANO civilian survey personnel to provide continuity. These NAVOCEANO personnel have experience with measurement (in the scientific rather than the electronic sense of the word) plus a very strong motivation to insure that any data submitted to DMA is correct. This is evidenced by the fact that each step of their data analysis process is double-checked by separate people.

The OCUNIT is responsible for maintenance and adjustment of the instrumentation. However, the NAVOCEANO survey personnel, because of their responsibility for and dedication to the accuracy and validity of the data, have a need for reliable knowledge that the instrumentation is in calibration and ready for survey and will not produce invalid data. Instruments that are calibrated for a particular range of environmental conditions (temperature, line voltage, line frequency, etc.) cannot be assumed to be accurate if the environmental conditions are outside of the specified tolerance. There is also the possibility that, through human error, an adjustment to an instrument will adversely affect its calibration. What the NAVOCEANO survey personnel need is some kind of alarm system which will alert them to system status problems which may affect productivity, accuracy, or data validity. Such an alarm system should be designed so that it is perceived by both NAVOCEANO and the OCUNIT as compatible with the present division of responsibilities. On the other hand, it should be capable of detecting subtle problem areas which boat officers, lacking years of specialized experience with surveying equipment, might miss. If an alarm system with these characteristics were available, it could serve as the basis for a dialog between the NAVOCEANO personnel and boat officers which could lead to the solution of identified problems.

Fault location capabilities built into many military systems provide a precedent for such an alarm system. The following discussion will be limited to the fault location capabilities of certain large destroyer ASW sonars with which one of the authors has some experience. In those systems, one of the electronic modules is dedicated to performing tests on all of the other modules. This testing is performed continuously during normal operation of the system. Failure to meet specifications at any test point causes a unique number to be displayed on a numerical display. This display sequentially cycles through numbers which identify each fault. The display is blank when the system is in perfect adjustment. (However, it flickers enough to give the operator confidence that this is not due to a bad display!) the size of the list of numbers which this fault location unit displays gives the viewer a rough idea of the battle readiness of the system, and the actual numbers direct the sonar technicians to particular locations in the system where maintenance is needed.

A repeater for the fault location unit display is located in the Sonar Control Room of the destroyer where it can be seen by the ASW Officer and the Combat Systems Officer. These officers, who are not normally trained in the detailed electronics of the sonar system, are able to use the information displayed to engage in meaningful dialog with the enlisted sonar technicians on the battle readiness of the sonar system, the amount of preventive maintenance required, and the performance of the sonar deparment. The fault location capability therefore gives the enlisted personnel visibility and accountability.

A key ingredient to the successful use of the fault location capability on these destroyer systems is the confidence of all parties that faults indicated are indeed maintenance problems, rather than design errors in the sonar or the test unit. This confidence was earned through a thorough OPEVAL and extensive service use.

To increase the productivity of the survey launches, it is proposed to apply the human engineering principles successfully implemented in the fault location systems discussed above. This can be accomplished through design, construction, test, installation, and evaluation of a fault location system specifically adapted to the survey launches. This system will consist of a single electronic chassis and a multiplicity of sensors. The chassis will contain a small printer, which identifies specific faults to the launch personnel and NAVOCEANO personnel on the mother ship. It will also utilize the hydrographic data product as a means of sending a status message to the NAVOCEANO personnel when feasible. For example, when a Trisponder with a printer is used, the fault location system will insert status messages periodically onto the printed navigation record. If an echo sounder with a numeric or alphanumeric printing capability (such as the Raytheon DSF-6000) is used, status information can also be printed on the fathogram. This status information should also be integrated into the data format of any digital data acquisition system. The NAVOCEANO survey team can use this information to engage the boat officers in meaningful dialog about the readiness of their launches for survey, the validity of the data collected, and the number of valid survey miles they produced. The boat officers will therefore be motivated to keep their launches in satisfactory survey condition because the results of their efforts will be visible to NAVOCEANO.

Some of the tests and measurements which should be considered for the fault location system are listed in Table VIII.

The navigation system antenna mismatch sensor is designed to detect deterioration of system performance most often caused by moisture or physical damage to the wave guide. This type of damage changes the distribution of current and voltage nodes in the wave guide, sometimes with destructive effects on the transmitter electronics. This kind of problem could be detected with bolometers mounted in the wave guide.

Navigation system transmitted field strength measurements would be performed by a small detector, probably located on the cabin top as far as possible from the mast. This measurement would supplement the antenna mismatch data by detecting abnormal changes in at least one sample of the antenna field pattern.

The navigation system receiver signal and noise measurement will give some insight on the reliability of the navigation data, especially at the fringes of positioning system nets. Both functions might be replaced with a single signal-to-noise sensor.

The navigation system calibration test is designed to detect any changes to the delay since the unit was last calibrated at a known position. The test unit would implement this test by echoing back the navigation system's signal and causing it to print the measured delay, or by taking the navigation unit's delay measurement (from its digital output terminals) and comparing it with recent values.

Echo sounder calibration would also be implemented by echoing back the echo sounder's signal and causing it to draw a line at a particular position on the chart. In addition, the test unit would take digital depth from the echo sounder's outputs and compare it with the amount of delay introduced.

Tests would be included to ascertain whether the AC line ground wire was properly connected to ground and whether excessive ground noise voltages existed.

Finally, the fault location system would have to print some positive indication that it is hooked up and operating.

The fault location system should be packaged in a way which discourages tampering in the field. On the other hand, interface functions should be separated from other circuits in a way which facilitates adapting it to new hydrographic sensors on shore.

One trade-off yet to be determined is whether the fault location system should shut down the survey system when a fault is discovered, so that it would be impossible to continue surveying until the fault is corrected. The authors believe that such a function should not be implemented until after the basic fault location system has proven itself through field use. To do otherwise would invite attempts to defeat its purpose. The fault location sytem could be designed to be compatible with addition of an automatic shutdown capability in the future if addition of this function was deemed feasible and prudent.

The fault location system will assist technicians in maintaining the hydrographic survey equipment, and will increase the reliability of the hydrographic data by alerting the technicians and the NAVOCEANO survey personnel to problem areas. It should not be regarded as a panacea or as a substitute for reliability, documentation, and human engineering of the basic hydrographic survey equipment.

All survey equipment should be sealed against the moist, corrosive environment. This could be facilitated by provision of an electronic annotation capability for the echo sounder; with electronic annotation, it would not be necessary to open the access doors during normal operation. In addition, the event mark on the echo sounder could be synchronized with the navigation unit's printer. NAVOCEANO has budgeted funds in FY85 to replace the DSF-600, and plans to incorporate these features into that procurement. Finally, navigation system displays should be buffered so that they don't change while being read and manually recorded. Both the Trisponder DDMU 520 (which NAVOCEANO has placed on USNS HARKNESS since the Golfe de la Gonave Survey) and the Mini-Ranger III Range Console have data-hold features that freeze the data display.

Microwave wave guides should be protected against moisture. Some consideration should be given to operating the launch air conditioning systems around the clock to protect the electronic equipment. A special effort should be made to forecast future launch power requirements and to assure that generator capacity is adequate.

It is not likely that the ideal of 100% equipment availability can be achieved without a highly redundant survey suite, which would require elaborate preventative maintenance procedures. However, the proposed actions, combined with continuing effort on the part of NAVOCEANO, the equipment manufacturers, and the OCUNITS to improve equipment reliability, documentation, human engineering, and training, will reduce equipment down time sufficiently to substantially increase fleet productivity.

6.0 CONCLUSIONS AND RECOMMENDATIONS

NORDA was tasked to develop a sonar device that will improve the efficiency and productivity of the NAVOCEANO hydrographic survey launches, which acquire data for DMA charts. A major requirement for this sonar is that it must be compatible with and human engineered for the NAVOCEANO/DMA operational survey scenario. In other words, the nature of the survey operations must determine the type of technology which is developed, rather than the other way around.

A major effort went into learning the details of how NAVOCEANO performs hydrographic surveying and how the OCUNIT's on the survey ships conduct the actual data acquisition operations and perform maintenance. This effort included observations of actual operations at sea. The insights gained from this activity, which are documented in the body of this report, formed the basis for assessing alternate strategies for increasing launch productivity.

6.1 CONCLUSIONS

It was found that multi-beam sonars have the potential to increase productivity in terms of area surveyed per day per launch by 50% for water depths between 75 and 200 m, or possibly by 100% over the very limited depth range of 145 to 200 m. By contrast, under the operating conditions observed during the May 1982 SURVOPS in Golfe de la Gonave, if the launches were fully operational 100% of the survey, then productivity would increase by a factor of 2.1 (110%); and if the launches were the new LCP(L)MK12 type launches, fully operational 100% of the survey day and capable of surveying at 17 knots, then productivity would increase by a factor of 4.1 (310%).

Sector-scan sonars were found to have attractive potential for detecting navigation hazards between sound lines, mapping the perimeters of hazardous areas, and reconnaissance and survey planning because of their relatively high resolution, low cost, and the potential for adapting them for high-speed, hull-mounted use. However, it is important that sector-scan sonars be designed so as not to limit the survey speed.

The location and manner of installation of the echo sounder transducer and the size of the launch's generator were identified as important factors affecting productivity.

6.2 RECOMMENDATIONS

The following specific action is recommended:

- Design, construct, test, install, and evaluate a hydrographic launch fault location system designed to give both NAVOCEANO and the OCUNIT feedback on the status of the launch instrumentation and certain critical environmental parameters. This effort should be coordinated with NAVOCEANO's equipment procurement plans.
- Purchase an easy-to-use device for annotation of the echo sounder records without opening the access door. This will reduce corrosion damage.
- Synchronize the echo sounder event mark with the printing or recording of navigation fixes.
- Identify and execute other actions to increase overall reliability and maintainability such as the sealing of specific electronic units against the environment.
- Initiate an effort to evaluate the utility of sector-scan sonars for hydrography survey operations. The first step should be low-speed tests on the developmental 700 series launch presently stationed in Gulfport, Miss., using strut or "belly band" transducer mounting techniques. If successful, these tests can be followed by a permanent installation and high-speed tests. Next, design modifications to reduce the speed-related image distortion of the sector-scan sonar should be executed, and the high speed tests should be repeated.

6.3 RECAP OF RECOMMENDATIONS

The authors believe that the recommended technological development efforts will make strong contribution to the very complex problem of increasing hydrographic launch productivity. These efforts include the modification and adaptation of commercially produced sonars. However, the emphasis is on the use of modern electronic technology to simplify and human engineer certain critical operational and testing functions, and on the development of devices that facilitate communication between NAVOCEANO and the OCUNIT on launch system status.

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TABLE I

LAUNCH PERFORMANCE
MILES OF TRACK BY HULL NUMBER

HULL NO.	671	672	674	711	
Date					Total
14 May	17	34	36	32	119
15 May	42.5	44	23.5	41.5	151.5
16 May	13.5	14	27.5	28	83
17 May	30	45	23	49	147
18 May	12	42.1	3.4	64	121.5
19 May	56	22	26	76	180
20 May	43	48	7	Repair	98
21 May	53	25	1	35	114
22 May	38	17.5	24	37	116.5
23 May	11.3	19.6	4.7	11.5	47.1
24 May	33.4	46.1	19.7	7.4	106.6
25 May	51.6	32.5	1	37.2	122.3
26 May	10.3	39.6	21	44.5	115.4
MEAN	31.7	33.0	16.8	38.6	119.4
Standard Deviation	16.5	11.6	11.3	18.4	

TABLE II

LAUNCH CAPACITY ESTIMATE
MILES OF TRACK PER DAY, 14-26 May 1982

HULL NUMBER	671	672	674	711	711
Propulsion-limited speed, kts	7	7	7	17	17
Sonar-limited speed, kts	7	7	7	12	N/A
Days operating at full speed	8	13	12.5	11.5	11.5
Assumed speed in shoal water, kts	3	3	3	3	3
Days in shoal water	5	0	0.5	0.5	0.5
Hours per day fully operational and on track	8	8	8	8	8
Capacity, nm per day	43.7	56	54.8	93	131.3
Actual Productivity, average nm per day	31.7	33.0	16.8	38.6	38.6
LAUNCH PRODUCTIVITY AS A % OF CAPACITY	73%	59%	31%	42%	29%

TABLE III

PERFORMANCE OF LAUNCH NO. 671

DATE	HULL NUMBER 671	CONDITIONS THAT AFFECTED SURVEYING
14 May	17 miles	Shoal, Trisponder
15 May	42.5 miles	Shoal
16 May	13.5 miles	Shoal
17 May	30 miles	Shoal
18 May	12 miles	Shoal
19 May	56 miles	
20 May	43 miles	Electrical problem fixed by crew at sea without returning to chip
21 May	53 miles	
22 May	38 miles	
23 May	11.3 miles	Trisponder problems
24 May	33.4 miles	
25 May	51.6 miles	
26 May	10.3 miles	Electrical problems

TABLE IV

PERFORMANCE OF LAUNCH NO. 672

DATE	HULL NUMBER 672	
14 May	34 miles	Trisponder problems late in the day
15 May	44 miles	
16 May	14 miles	Trisponder problems; boat returned to ship for repair
17 May	45 miles	
18 May	42.1 miles	
19 May	22 miles	Trisponder and electrical problems
20 May	48 miles	
21 May	25 miles	
22 May	17.5 miles	
23 May	19.6 miles	Trisponder problems
24 May	46.1 miles	
25 May	32.5 miles	
26 May	39.6 miles	

TABLE V

PERFORMANCE OF LAUNCH NO. 674

DATE	HULL NUMBER 674	
14 May	36 miles	Trisponder problems late in the day
15 May	23.5 miles	Electrical overload. Trisponder signal lost at 1500
16 May	27.5 miles	Trisponder and electrical problems
17 May	23 miles	
18 May	3.4 miles	Trisponder and electrical problems
19 May	26 miles	
20 May	7 miles	Trisponder and electrical problems
21 May	1 mile	Trisponder and electrical problems
22 May	24 miles	
23 May	4.7 miles	Trisponder and electrical problems
24 May	19.7 miles	Trisponder and electrical problems
25 May	1 mile	Trisponder and electrical problems
26 May	21 miles	

TABLE VI

PERFORMANCE OF LAUNCH NO. 711

DATE	HULL NUMBER 674	
14 May	32 miles	Trisponder problems late in the day
15 May	41.5 miles	
16 May	28 miles	
17 May	49 miles	
18 May	64 miles	
19 May	76 miles	
20 May	00 miles	Transmission repair
21 May	35 miles	
22 May	37 miles	
23 May	11.5 miles	Trisponder problems in the morning hours
24 May	7.4 miles	Trisponder problems all day
25 May	37.2 miles	
26 May	44.5 miles	

TABLE VII

SECTOR-SCAN SONARS

CONTRACTOR	EDO	AMETEK-STRAZA	AMETEK-STRAZA	WESMAR	WESMAR	WESMAR
Model	4059 OAS	250A	300 SWAP (AN/WQS-1)	SS270	SS265	SS190
Frequency, kHz	100	107-122	200	60	160	266
Range, meters	400	1500	500	1440	800	250
Horizontal beamwidth, deg.	2	3	3	14	6.5	8
Vertical beamwidth, deg.	50	Wide	15	9	6.5	8
Scan rate, degrees/sec	5.8 (@200 m range)	30	240000 (electronic)		10 (@300 m range)	
Soundhead width, in	17	9.5	14	7.6	5.8	3.1
Soundhead height, in	8.1	18.4	9.8	20	17.8	10.5
Dome or fairing needed?	YES	YES	NO	DEPENDS ON INSTALLATION		
Sea Chest needed?	NO	NO	NO	YES	YES	YES
Contractor's price, $K	51.4	30.5	50.0	10.0	7.2	5.8

TABLE VIII

FAULT LOCATION SYSTEM TESTS AND MEASUREMENTS

Cabin temperature

AC line voltage

AC line frequency

Navigation system transmitter output

Navigation system receiver signal level

Navigation system receiver noise level

Navigation system transmitted field strength

Navigation system antenna mismatch

Navigation system calibration

Echo sounder output

Echo sounder received signal level

Echo sounder noise

Echo sounder calibration

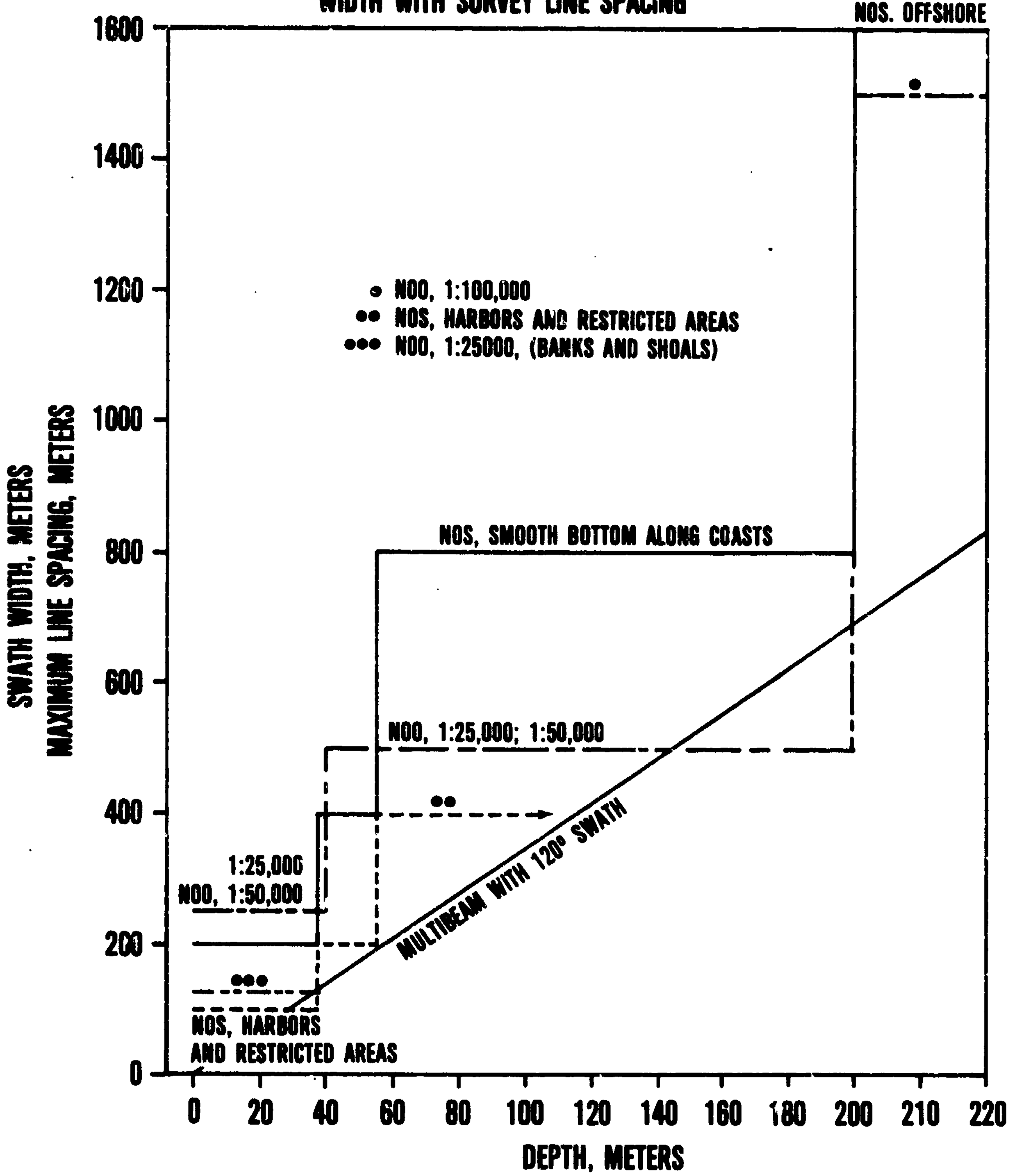
Connection of instrumentation ground wire to ground

AC noise level on instrumentation ground

Various instrumentation power supply voltages

Fault Location System operating

FIGURE 1
COMPARISON OF MULTIBEAM SWATH WIDTH WITH SURVEY LINE SPACING



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Technological options for increasing the productivity of hydrographic survey launches are reviewed, based on observations of the Naval Oceanographic Office survey operations in the Golfe de la Gonave, Haiti, during May 1982.

It was found that multi-beam sonars have the potential to increase productivity by 50% in terms of area surveyed per day for water depths between 70 and 200 meters, or possibly by 100% over the very limited depth range of 145 to 200 meters. By contrast, under the operating conditions observed during the May

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1982 operation in Golfe de la Gonave, major improvements in reliability and maintainability combined with use of the new LCP(L) MK 12 launches can potentially increase productivity by up to 310%.

Sector-scan sonars were found to have an attractive potential for detection of navigation hazards between sounding lines, mapping the perimeters of hazardous areas, and reconnaissance and survey planning. These capabilities will increase productivity provided the sonars are designed for operation at normal survey speeds.