

HMS *Scott*: United Kingdom Ocean Survey Ship

Fred Pappalardi, Steven J. Dunham, and
Martin E. Leblang
SSC San Diego

BACKGROUND

In 1963, the U.S. and the Government of the United Kingdom of Great Britain and Northern Ireland (UK) signed the Polaris Sales Agreement. The U.S. agreed to sell to the UK Polaris missiles (less warheads), equipment, and supporting services related to support of the UK Polaris submarine fleet.

As part of this support effort, the U.S. also shared, with the UK, ocean-bottom maps generated by a U.S. Navy developed wide-swath, multi-beam bathymetric navigation system. This system, the first of its kind, was installed aboard three deep-ocean U.S. Navy survey ships and, for a period of more than 35 years, produced the highly accurate bathymetric charts required by the U.S. and UK Fleet Ballistic Missile (FBM) submarines.

In 1987, the UK Ministry of Defense (MOD) decided to update its ocean-surveying capability. After evaluating several candidate systems, the MOD concluded that the only system capable of meeting its FBM submarine requirements was the system developed and used by the U.S. Navy. Therefore, in 1995, the UK MOD approved construction of the 13,500-ton HMS *Scott*, shown in Figure 1, and specified that the ship was to be designed and built specifically to accommodate the U.S. Navy developed, fully integrated Ocean Survey System (OSS).

ABSTRACT

Minimizing the cost per survey mile while ensuring that survey products meet required standards is a prime consideration when evaluating oceanographic surveying systems. This was one of the prime factors that led to the United Kingdom Ministry of Defense Procurement Executive (UK MOD PE) selection of a U.S. Navy designed ocean survey system to be installed aboard a new construction ship. The 13,500-ton HMS Scott was designed and built specifically to accommodate the U.S. survey system and is considered the UK's premier survey ship. The mission of HMS Scott is to gather, process, and record time-correlated bathymetric, gravity, magnetic, and other oceanographic data as a function of latitude and longitude. Since deployment in early 1998, HMS Scott has successfully conducted highly accurate bathymetric surveys at an average sustained speed of 12 knots in ocean depths ranging from 50 fathoms to approximately 2500 fathoms in various types of terrain, from flat to very high relief.



FIGURE 1. HMS *Scott*.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE AUG 2001	2. REPORT TYPE	3. DATES COVERED -	
4. TITLE AND SUBTITLE HMS Scott : United Kingdom Ocean Survey Ship		5a. CONTRACT NUMBER	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)		5d. PROJECT NUMBER	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Space and Naval Warfare Systems Center, 53560 Hull Street, San Diego, CA, 92152-5001		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)	
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited			
13. SUPPLEMENTARY NOTES The original document contains color images.			
14. ABSTRACT Minimizing the cost per survey mile while ensuring that survey products meet required standards is a prime consideration when evaluating oceanographic surveying systems. This was one of the prime factors that led to the United Kingdom Ministry of Defense Procurement Executive (UK MOD PE) selection of a U.S. Navy designed ocean survey system to be installed aboard a new construction ship. The 13,500-ton HMS Scott was designed and built specifically to accommodate the U.S. survey system and is considered the UK's premier survey ship. The mission of HMS Scott is to gather, process, and record time-correlated bathymetric, gravity, magnetic, and other oceanographic data as a function of latitude and longitude. Since deployment in early 1998, HMS Scott has successfully conducted highly accurate bathymetric surveys at an average sustained speed of 12 knots in ocean depths ranging from 50 fathoms to approximately 2500 fathoms in various types of terrain, from flat to very high relief.			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified	18. NUMBER OF PAGES 10
			19a. NAME OF RESPONSIBLE PERSON

HMS SCOTT DESCRIPTION

HMS *Scott*, built by Appledore Shipbuilders Ltd. of North Devon, England, was handed over to the Royal Navy in 1997. She was designed to operate in areas remote from normal shipping lanes, in changeable severe weather conditions, and on a schedule of nine 35-day cycles each year, surveying for 24 hours a day when tasked [1]. Table 1 shows HMS *Scott* principal characteristics.

Figure 2 is a profile drawing of HMS *Scott* showing locations of mission-related spaces. Within these spaces are housed the elements that make up the OSS that will be discussed in this paper.

MISSION SYSTEM DESCRIPTION

The mission of HMS *Scott* is to gather, process, and record time-correlated bathymetric, gravity, and other ocean-related data. This paper will address only the mission of gathering bathymetric data, as accomplished by the OSS.

The entire OSS is supported by a dedicated, regulated power system, also developed by the U.S. Navy. Figure 3 is a simplified block diagram of the OSS.

NAVIGATION SUBSYSTEM

The Navigation Subsystem provides precise and accurate platform attitude, position, and velocity information as a function of time for correlation with depth and other recorded survey data to produce specialized charts. Figure 4 is a simplified functional block diagram of the Navigation Subsystem.

The heart of the Navigation Subsystem is the navigation computer that performs the data integration, monitoring, and control functions that coordinate overall operation of the Navigation Subsystem.

Position data from Loran-C receivers, the Global Positioning System (GPS), and the Miniature Ship's Inertial Navigation System (MINISINS) are prioritized and filtered by the navigation computer program to produce the best present position (BPP) output. BPP is supplied in terms of latitude and longitude to the Sound Velocity System (SVS), Gravity System, and the Mission Control and Processing Subsystem (MCAPS). The MCAPS consists of the Survey Control System (SCS), System Analysis Station (SAS), and the Data Refinement System (DRS).

TABLE 1. HMS *Scott* principal characteristics.

Length	130 meters
Beam	21.5 meters
Design survey draft	8.3 meters
Displacement	13,300 tons
Survey speed	15 knots
Machinery plant	Diesel/Single screw
Endurance	35 days at survey speed
Thrusters	Bow
Crew	65

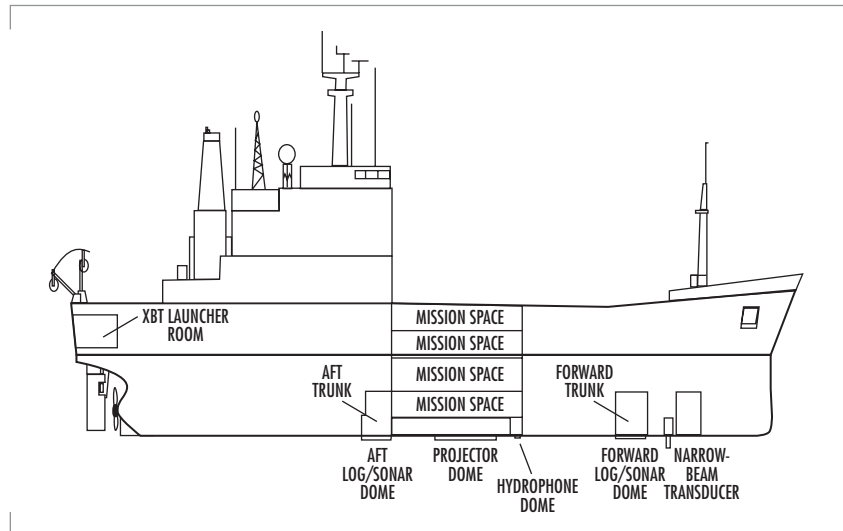


FIGURE 2. HMS *Scott* profile.

Velocity data, including vertical velocity, are received by the navigation computer program, and those inputs from the selected velocity source are distributed to the wide-swath-array sonar and to the Gravity System.

Attitude data are provided from both the MINISINS and the MK-29 Gyrocompass, a backup to the MINISINS. Source selection and distribution of the data are accomplished by the Ship's Attitude Data Converter (SADC). Heave data, developed in the heave processor, are distributed along with attitude data.

Roll, pitch, heading, and heave data are supplied to the Sonar Subsystem. Roll, pitch, and heading are also provided to the navigation computer to compensate for antenna lever arms to the ship's reference point. Heading is supplied to the shipboard heading indicators, ship's auto-pilot, and the SCS.

Heading corrections are developed by the navigation computer program and supplied to the ship's auto-pilot for use during track-keeping operations. The heading corrections are combined with the auto-pilot steering commands and cause the ship to steer over a prescribed ground track instead of steering to a prescribed heading. This capability provides high-quality, tight track control.

SONAR SUBSYSTEM

The Sonar Subsystem consists of a wide-swath-array sonar and a single-beam sonar. Figure 5 is a simplified block diagram of the entire Sonar Subsystem. The wide-swath-array sonar obtains rapid acquisition of high-resolution sonar data as a function of time as the ship progresses along a desired track. The system employs a 120-degree, fan-shaped acoustic swath pattern that is transverse to the ship's track (see Figure 6) and operates in depths ranging from 50 fathoms to beyond 6000 fathoms.

To obtain depth measurements, the system transmits a 7-ms pulse every 12 or 15 seconds in deep water, and a 3-ms pulse every 3 or 6 seconds in shallow water. The transition from 12 to 15 seconds takes place at approximately 2000 to 2400 fathoms to allow for increased processing time. The transmit frequency is 12 kHz with each ping consisting of a 7-ms pulse. The returning echoes, received by the 144 hull-mounted hydrophones, are sampled every 3-ms to give time snapshots of the

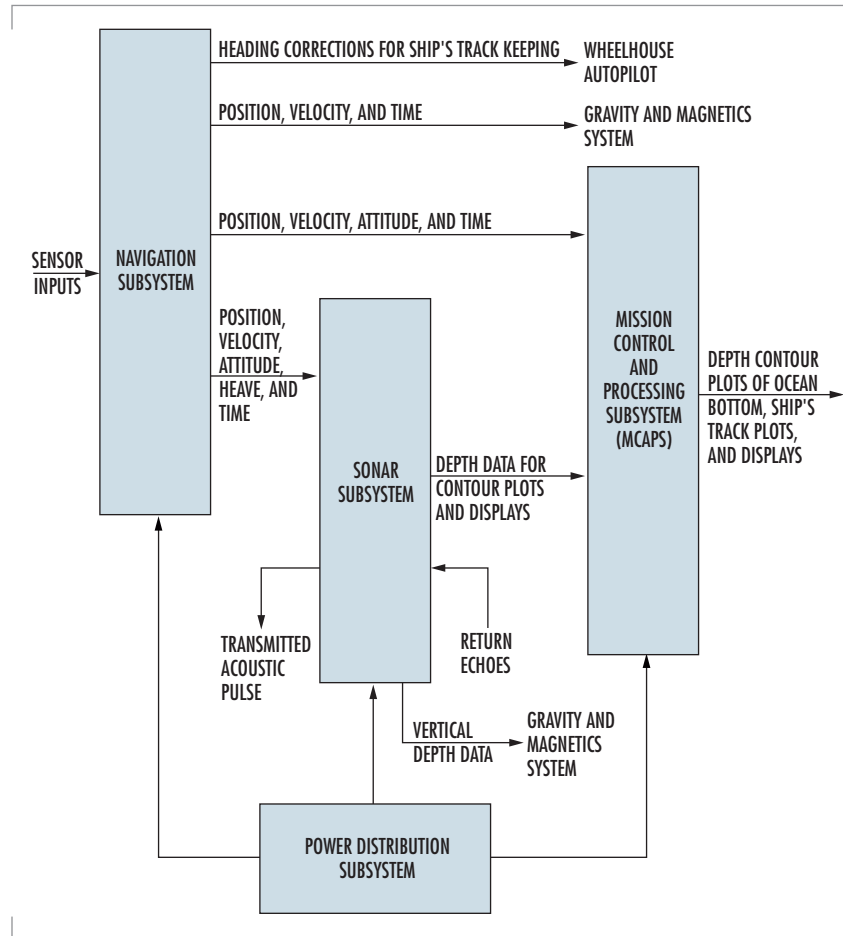


FIGURE 3. Simplified Ocean Survey System block diagram.

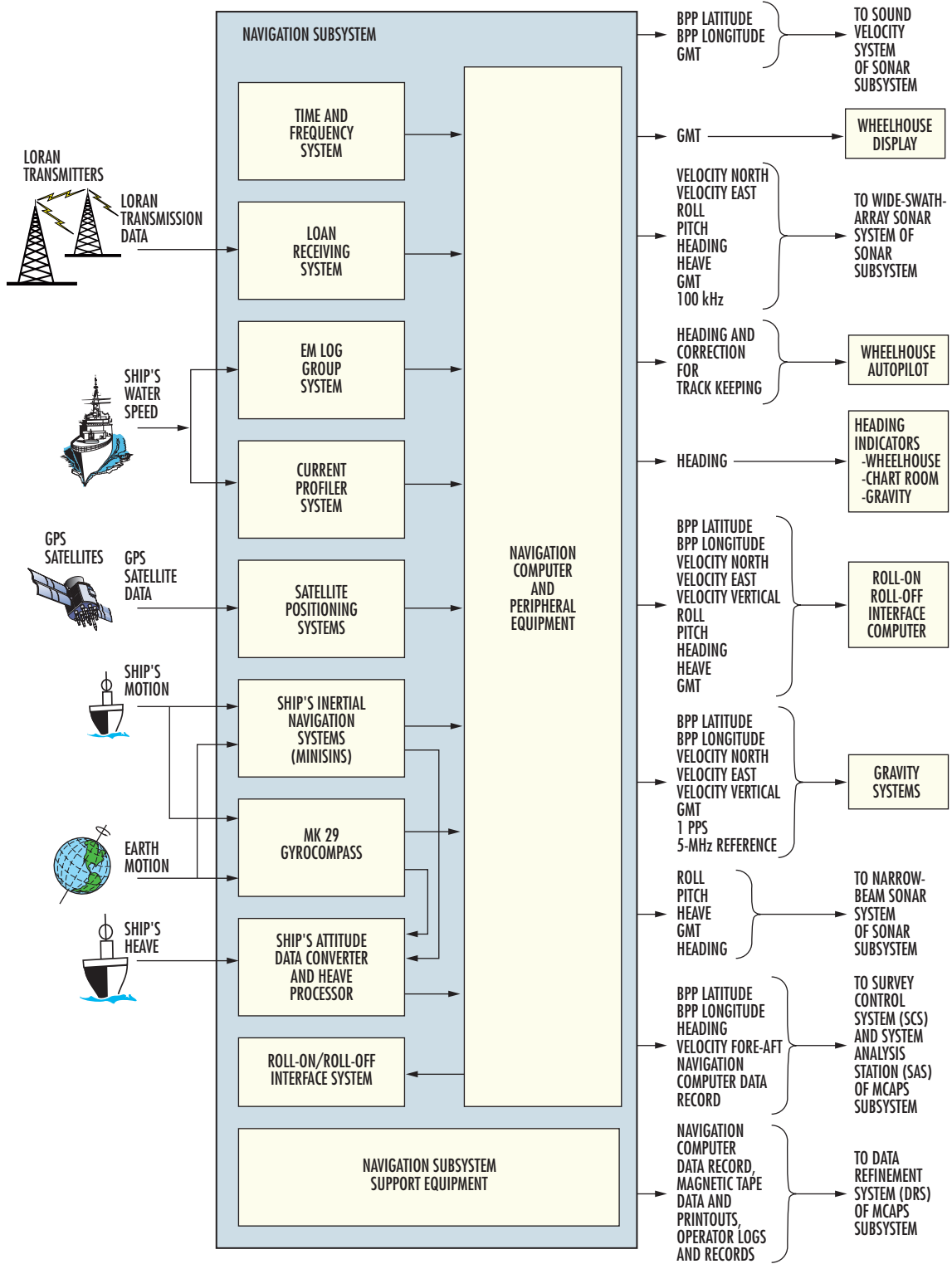


FIGURE 4. Navigation Subsystem.

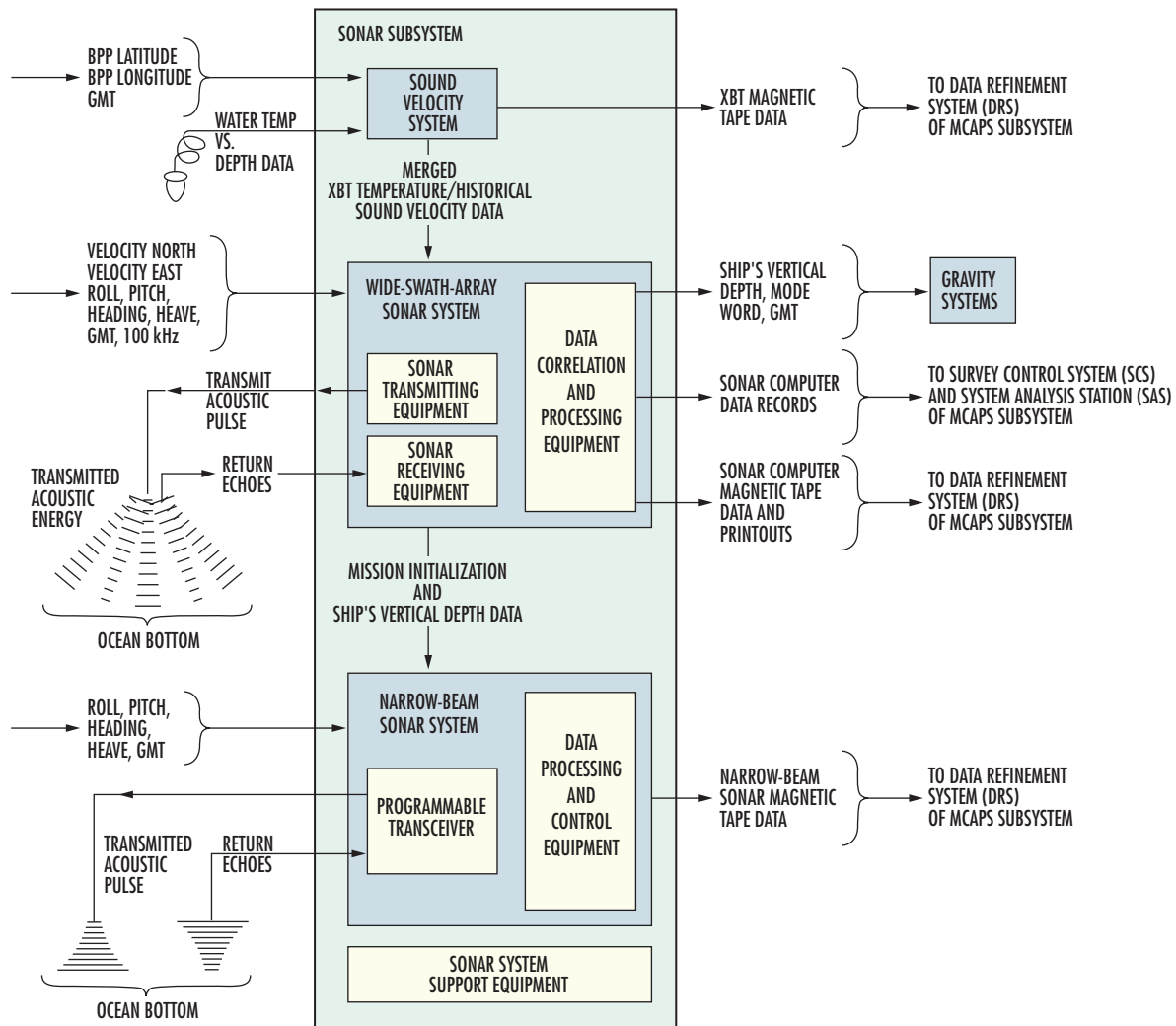


FIGURE 5. Sonar Subsystem.

acoustic pulse reflected from the bottom. Digital signal-processing algorithms process up to 1664 time snapshots of the returning signal to develop an across-track profile of the bottom, with an average internal resolution of a third of a degree across the swath. The profile is then decimated to 121 bottom points spaced 1 degree apart. Each point is then corrected for sound-velocity variations and for roll, pitch, heading, and heave variations between time of transmission and reception. The data are then checked for validity and reasonableness by the on-line software.

Transmission takes place with the projection of a burst of acoustic energy (from 58 projectors mounted in the fore-aft direction along the ship's centerline) that ensonifies a narrow strip of the ocean floor. The width of the ensonified strip extends beyond the 120-degree swath pattern. Compensation for pitch angles of up to ± 10 degrees is applied during

transmission to steer the projected acoustic energy beam to the vertical about the pitch axis. Acoustic echoes returning within the 120-degree swath pattern are captured by an array of 144 hydrophones (mounted athwartship and forward of the projector array) for processing. The swath pattern is roll-corrected to the vertical. Compensation for roll angles of up to ± 15 degrees is applied to returns upon reception to keep the swath pattern fixed relative to the vertical about the roll axis.

Figure 7 shows wide-swath-array sonar depth versus bottom coverage. For depths down to 1000 fathoms, each transmission, or ping, provides 121 depth points over a data-acquisition swath that is 3.5 miles wide. As depths go beyond 1000 fathoms, the number of measurable data points captured within the 120-degree swath pattern gradually begins to diminish. At a depth of 5000 fathoms, each ping provides 91 depth points over a data-acquisition swath that is 12 miles wide. To allow for the varied acoustic-signal travel times associated with shallow and deep depths, the system employs operator selected ping rates of 3, 6, 12, or 15 seconds.

Sound-velocity corrections are applied by using periodic expendable bathythermograph (XBT) casts to measure the ocean water temperature as a function of depth. These water temperature versus depth measurements provide the means to detect a significant change in the sound-velocity structure of the local ocean area of interest and to determine the applicability of the sound-velocity-versus-depth profile in current use by the Sonar Subsystem. The XBT cast data are merged with historical sound-velocity data and sent to the Sonar Subsystem for use during returned echo data processing.

The single-beam sonar uses a 9-degree conical pattern (see Figure 8) and obtains and records the ocean depth directly beneath the ship. This sonar provides an independent method of monitoring the vertical-depth data output of the wide-swath-array sonar. When the wide-swath sonar is off-line, such as when the ship is in water less than 50 fathoms or when it is inoperative, the single-beam sonar performs the depth-acquisition function of the OSS.

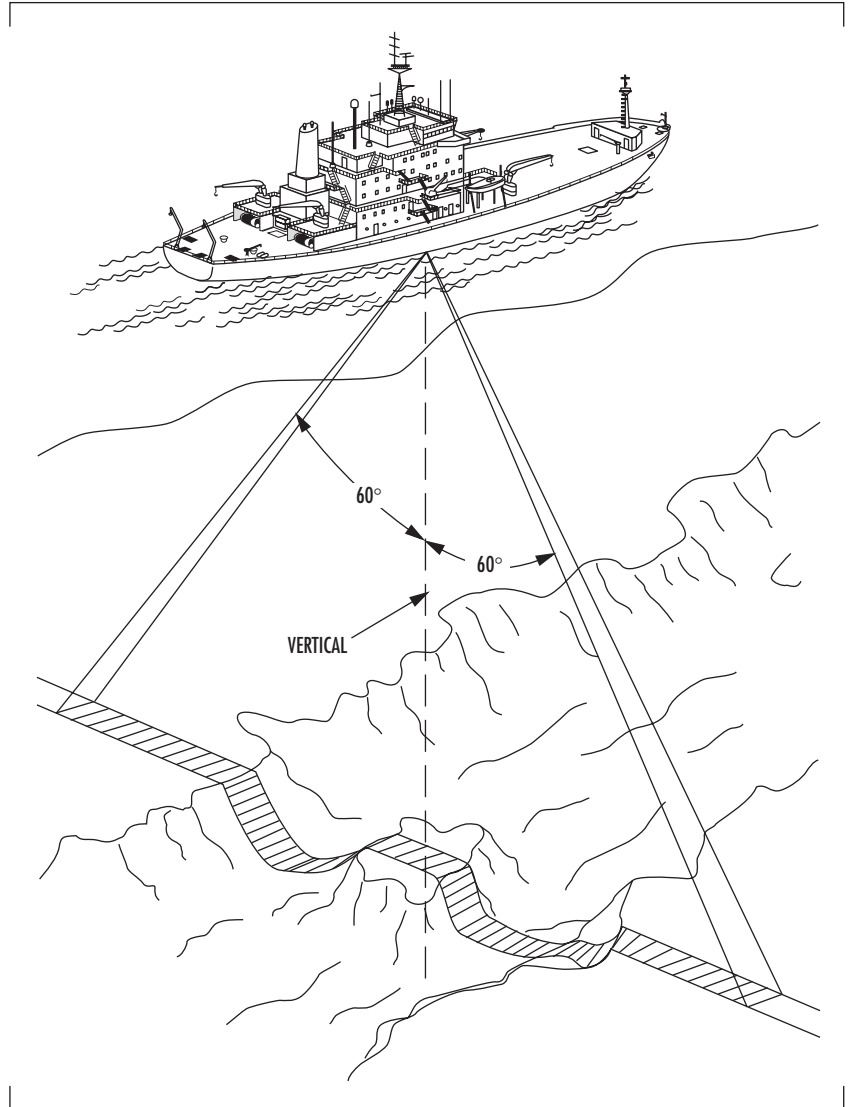


FIGURE 6. Wide-swath-array sonar beam pattern.

MISSION CONTROL AND PROCESSING SUBSYSTEM

The MCAP Subsystem (Figure 9) provides centralized control and performance monitoring of overall OSS operation. The MCAP Subsystem consists of three systems: Survey Control System (SCS), Systems Analysis Station (SAS), and Data Refinement System (DRS), all interconnected over a Local Area Network (LAN).

SURVEY CONTROL SYSTEM

The SCS provides remote-operator control functions for the navigation and sonar computers along with graphical data displays necessary to support on-line survey operations. The SCS provides a centralized, on-line, survey-system control workstation that provides the following four major functions: (1) initialization of the navigation and wide-swath-array sonar computer programs, (2) performance of system mode changes, resets, and parameter updates, (3) survey data collection, and (4) displays of graphical and tabular data providing high-level representations of the current navigation and sonar data being collected, as well as a display of ship's progress along the prescribed survey track.

SCS display functions include the high-level graphical and tabular data displays necessary for the operator to quickly assess and ensure that data collected by the Navigation and Sonar Subsystems meet survey mission requirements.

SYSTEM ANALYSIS STATION

The SAS serves as the central workstation for control of plotting functions, and on-line system performance analysis, monitoring, and troubleshooting through a comprehensive set of graphic displays. Some of the graphic displays that the operator can select to examine system performance, both in near-real-time or post-time are plots of position, velocity, ship's track, or depth contours. A database of up to 50 days' worth of data can be accessed by the operator for review and analysis.

DATA REFINEMENT SYSTEM

The DRS provides post-time data refinement functions for data collected by the OSS. This off-line, computer-based processing system post-time

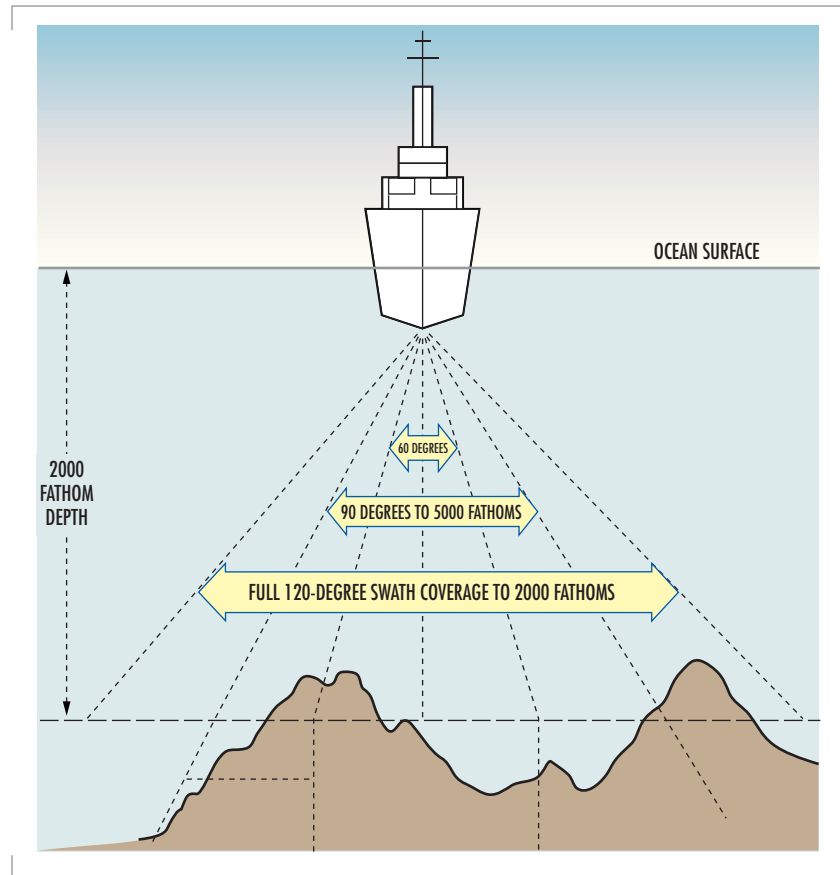


FIGURE 7. Wide-swath-array sonar coverage vs. depth.

processes shipboard-gathered sonar and navigation data and produces the final, fleet-ready bathymetric chart product. Specifically, the DRS develops refined position and velocity navigational data; generates hard-copy and screen displays of bathymetric navigation charts; and edits, analyzes, displays, and compresses the wide-swath sonar data.

POWER DISTRIBUTION SYSTEM

The primary function of the Power Distribution System (Figure 10) is to provide precision-regulated and signal-conditioned 60- and 400-Hz power to all OSS equipment. A secondary, but equally important function is to maintain a continuous emergency back-up power supply for critical equipment if the main power supply should fail. The 60- and 400-Hz power distribution systems receive power from the ship's service diesel generators via the ship's main service power panel.

The 60-Hz power distribution system provides 120-V, 60-Hz, three-phase power to the 60-Hz regulated power panels of the OSS. The 60-Hz power distribution system consists of two regulated power systems and one uninterruptible power source (UPS). The 400-Hz power distribution system provides 120-V, 400-Hz, three-phase delta output power to the OSS. The 400-Hz power distribution system consists of two separate and independent systems. Each system uses one 400-Hz UPS equipment cabinet and one 400-Hz UPS battery cabinet. Only one 400-Hz system is on at a time. The second system is maintained in an active standby operating mode.

The alarm and monitoring equipment associated with the Power Distribution System consists of the following items: (1) a power disturbance analyzer that monitors, measures, records, analyzes, and prints the type of disturbances that occur in the 60- and 400-Hz power distribution systems; (2) 60- and 400-Hz alarm and monitor panels that monitor AC voltages, AC current, and frequencies of the vital equipment power panels; (3) 60- and 400-Hz UPS remote status panels that monitor and provide a visual operating status of the UPS systems including battery condition and that provide visual and audible alarms for system changes.

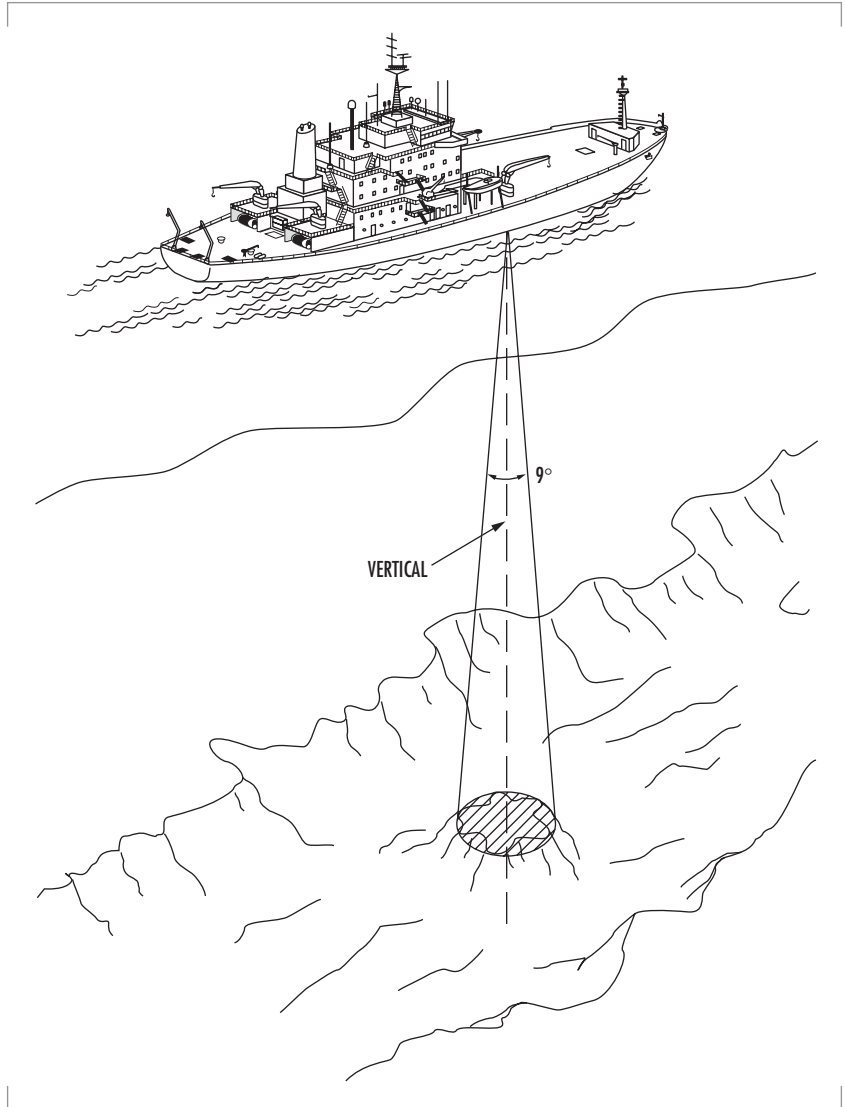


FIGURE 8. Single-beam sonar system beam pattern.

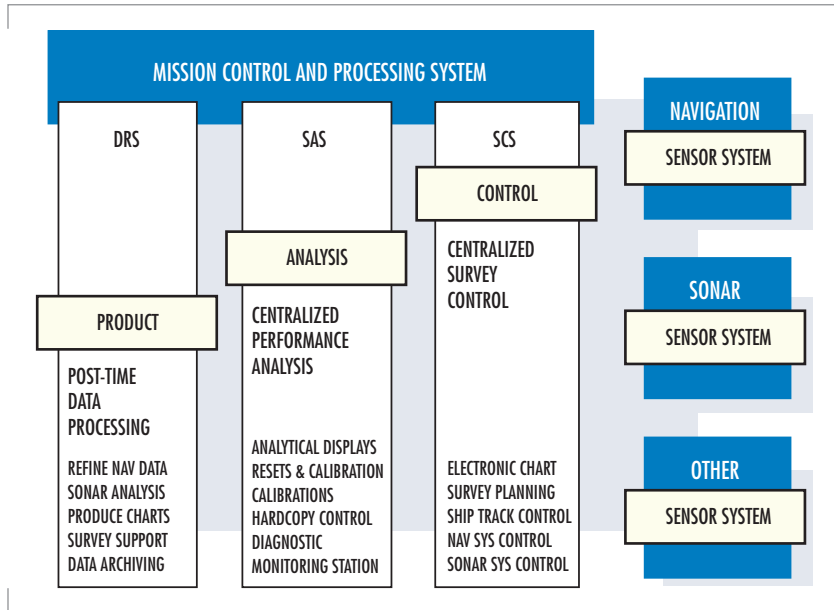


FIGURE 9. Mission control and processing system.

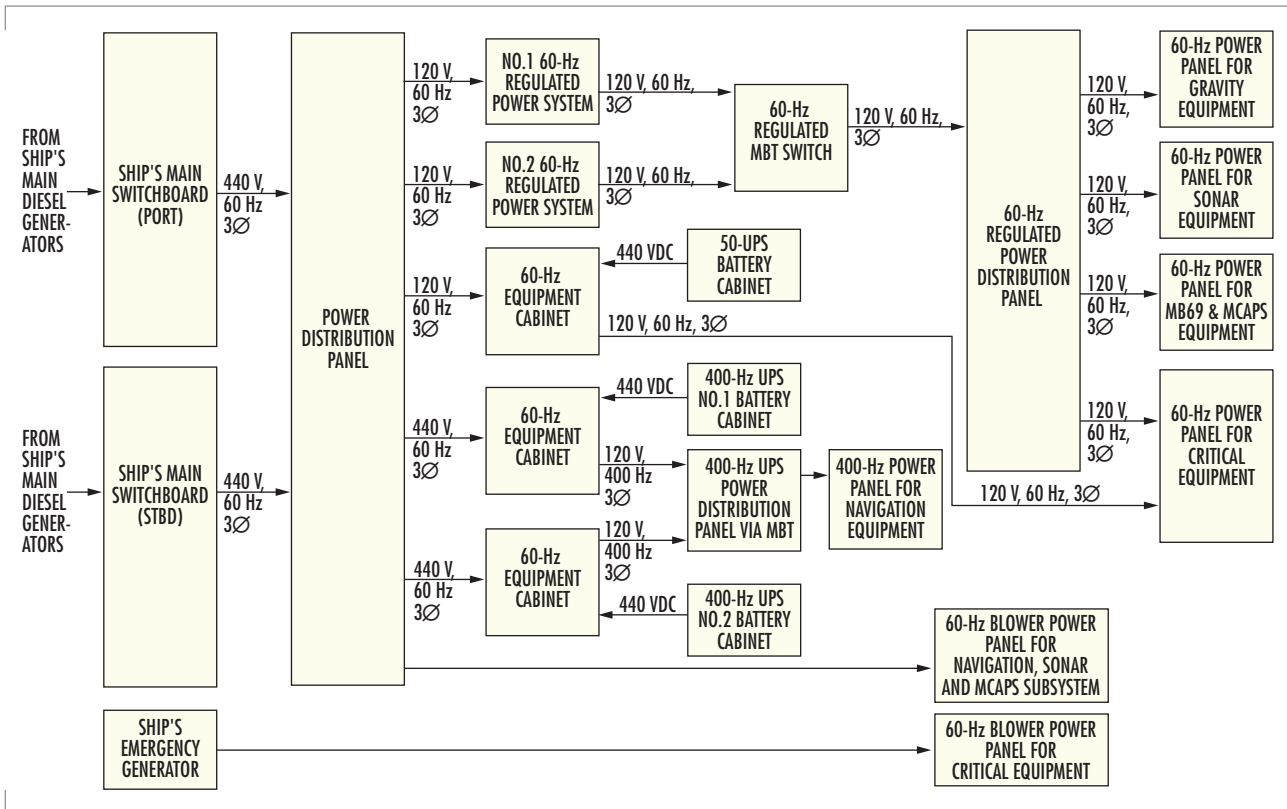


FIGURE 10. Power Distribution System.

CONCLUSION

The HMS *Scott* OSS described in this paper has been in operation since January 1998 and has provided the UK with a large volume of exceptionally accurate and detailed ocean-bottom data. At an average speed of 12 knots, approximately 10,000 survey miles can be achieved during a 35-day survey operation. Since the proven reliability of the OSS is greater than 99 percent, and given a specified minimum ship life of 25 years, it is expected that HMS *Scott* will provide large volume, very cost-effective, highly reliable, and very accurate oceanographic and bathymetric data over its operational lifetime.

ACKNOWLEDGMENTS

The authors would like to thank Mr. Gordon Smith, United Kingdom Ministry of Defense, who provided key information critical to the preparation of this paper and Eric Matsuo, SSC San Diego, for his invaluable assistance in formatting this paper.

AUTHORS

Steven J. Dunham

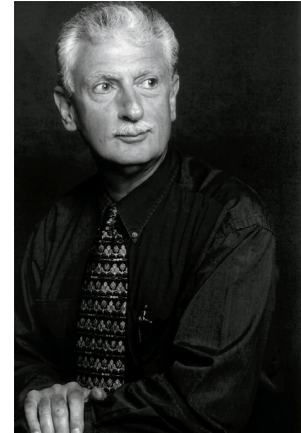
BS in Electrical Engineering, State University of New York at Buffalo, 1971
Current Research: Deep ocean survey system, HMS *Scott*; data refinement system, UK Hydrographic Office.

Martin E. Lablang

MS in Electrical Engineering, New York University, 1971
Current Research: Navigation system, HMS *Scott*.

REFERENCE

1. *Shipping World and Shipbuilding*, 1997 (May).



Fred Pappalardi

BA in Electrical Engineering,
Pratt Institute, New York City,
1963

Current Work: Business Manager
for the Marine Navigation
Division; development of new
business opportunities in marine
navigation.