SCAMP: A SUBMARINE-MOUNTED GEOPHYSICAL SURVEY SYSTEM FOR USE UNDER THE ARCTIC ICE

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Abstract - US Navy nuclear submarines are being used for unclassified scientific missions in the Arctic under the terms of a memorandum of agreement between the Navy, the Office of Naval Research, the National Science Foundation (NSF), the U.S. Geological Survey and the National Oceanic and Atmospheric Administration. Thus far, the tools for geophysical survey have been limited to a BGM-3 gravity meter and a narrow beam echo sounder. With support from the NSF, the Palisades Geophysical Institute, the Geological Survey of Canada and Columbia University, we have completed the design of and are in the process of building and testing the Seafloor Characterization and Mapping Pod (SCAMP) which consists of a Sidescan Swath Bathymetric Sonar (SSBS), a High Resolution Subbottom Profiler (HRSP), Bell Aerospace BGM-3 gravity meter and a physically compact Data Acquisition and Quality Control System (DAQCS.)

Shallow towed SSBS designs are readily adapted for the unique requirements of submarine operations under the pack ice of the central Arctic. In addition to the physical installation requirements (including the requirement for sequential installation on multiple vessels) for the submarine mounted application, significant effort has been made in the transducer array design to minimize the influence of the ice canopy and pressure ridges on the sidescan and bathymetric data. The arrays have four rows of elements with beam steering on transmit and receive. Anticipated performance of the SSBS includes swath imagery over a 150°
with good bathymetry over at least 130 in

beam width will be 1.2 degrees with an

A Bathy-2000P FM modulated subbottom

An array of 9 transducers driven by the

beam pattern of 30 . Seafloor penetration of

centimeters is anticipated.

systems will be mounted in independent pods

increasing the draft or modifying the

electronics for the SSBS will be mounted
foredeck with the

penetrators required for power and telemetry
existing hull

The system will be tested in a towed

part of the acceptance trials. Deployment of

SCICEX cruise in the summer of 1998 after

shakedown cruises.

Introduction

The Arctic Ocean is the least known of all the ocean basins. This is one of the few areas in the world's ocean where it is still possible to explore. To date, oceanographic and geophysical work has been carried out from ice islands, icebreakers, airplanes and satellites. Each of these methods has revealed more of the Arctic Ocean basin but each of these approaches suffers from limitations that can be overcome with surveys utilizing a submarine.

Ice islands drift, following the circumpolar gyre that characterizes the near surface circulation of the Arctic Ocean.

Icebreakers can only go where the ice permits. A submarine is independent of surface conditions and a nuclear powered attack submarine can operate autonomously anywhere in the Arctic Ocean basin for extended periods. The submarine offers the opportunity to sail a survey grid of arbitrary position and orientation to collect co-registered data sets for mutual analysis. In principle, any of the underway datasets collected from surface ships can be gathered from a submarine.

Underway measurements, water sampling programs and measurements taken with expendable probes highlight the greatest strength of the attack submarine as a science platform. Submerged, the submarine can collect unclassified data while traveling at speeds up to 25 knots for an indefinite period of time, operating at depths down to 800 feet. The speed, stability and silence of the submarine make it an ideal platform for underway geophysical measurements, offering opportunities not available from surface ships or aircraft.

Wilkins [1] was the first to realize the potential of a submarine as a science platform in the Arctic. In the early 30's, he obtained a surplus diesel submarine and outfitted it for a science cruise. At the edge of the ice pack, mechanical failures forced their return to port. Diesel submarines rely on regular contact with the atmosphere to recharge battery banks from diesel motors. Successful transit of a submarine under the pack ice and through the Arctic Ocean was not achieved until the nuclear power plant was developed and implemented on US Navy submarines in the late 50's. Cruises by the Nautilus, Seadragon and others added unique bathymetric profiles to the Arctic database, complementing data collected from icebreakers and ice islands (Lyon [2]).

The present geophysical database for the Arctic Ocean is composed of spot measurements, profiles from drifting ice islands and icebreakers, and single-beam profiles collected from icebreakers and submarines. Collecting swath bathymetric data from icebreakers in pack ice is difficult because broadband noise generated by ice contact against the hull swamps the bottom echoes, by maneuvering difficulties, and by speed limitations. The independence of the submarine from surface conditions makes it the ideal platform for collecting swath bathymetric and backscatter images of the seafloor from beneath the ice pack.

A. The Arctic Submarine Science Program (SCICEX)

Civilian Arctic scientists have long dreamed of using nuclear powered submarines for Arctic exploration. Recently, the US Navy has made Sturgeon class nuclear-powered attack submarines available for scientific cruises in the Arctic Ocean.

The great advantage of the submarine is its independence from surface conditions. Even the most distant regions of the deep Arctic basin can be reached in a submarine.

The US Navy operated widely under the ice from the late fifties on. Declassified cruises for civilian science are a recent innovation. The first unclassified submarine science cruise in 1993 (Coakley [3]) was an unexpected opportunity that linked a set of opportunistic proposals to form a science program. The first attempt was successful for demonstrating that the academic community could collaborate with the US Navy and obtain access to previously remote sectors of the Arctic. Each cruise has been a learning experience, as we came to understand the advantages and limitations of the submarine.

In 1994 a memorandum of agreement was signed by the Chief of Naval Research and Chief of Naval Operations, the heads of NSF, NOAA, USGS and submarine force type commanders to allow use of U.S. Navy nuclear-powered submarines for scientific research in the Arctic Ocean. These agencies and the Office of Naval Research support and direct the scientific aspects of the program. Under this program, a Sturgeon class fast-attack submarine has been deployed to the Arctic Ocean in 1995, 1996, and 1997. Two additional cruises are scheduled in 1998 and 1999. The durations of each cruise is approximately 80 days with 40 to 45 days in the operating area in the central Arctic Ocean (Figure 1).

The pilot cruise for the SCICEX program was carried out in late summer 1993 on board the SSN PARGO. The first three SCICEX cruises took place on the SSN CAVALLA in the spring of 1995 (Figure 1), the SSN POGY in the late summer of 1996 and the ARCHERFISH which is currently at sea. These cruises were highly successful; yielding a large amount of data in a wide variety disciplines. Approximately 100 science days in the Arctic Ocean operational area (Figure 1) have yielded about 50,000 kilometers of continuous underway bathymetry and gravity data. Although gravity and bathymetry data collected on previous legs substantially expand our knowledge of the Arctic, we have not yet used the full potential of the submarine as a research platform.

While the US Navy is providing a nuclear submarine as a "ship of opportunity", it is an exceptional opportunity. A submarine is designed to be stable, fast and quiet, making it an ideal platform for efficient geophysical surveys. On the PARGO, CAVALLA, POGY and ARCHERFISH cruises, instrumentation for geophysical measurements consisted of a narrow beam bottom sounder (standard shipboard equipment) and a BGM-3 gravimeter. Although these instruments have returned important new data from previously unexplored areas, the information they provide on the morphology and structure of the sea floor is meager compared to the output of a modern research vessel equipped with swath bathymetric and high resolution seismic reflection systems. The power of these systems to reveal the volume of ocean basins, the fabric of the ocean floor and stratigraphy of the ocean crust has profoundly changed our view of the earth and our understanding of processes that shape it.

The Office of Polar Programs at NSF (OPP) is funding the development, fabrication and testing of optimized geophysical instrumentation, known collectively as SCAMP, for the remaining SCICEX cruises. Three newly designed, tested and fabricated components will enhance the geophysical data acquisition on future cruises, beginning in 1998. Two sonars, an optimized SeaMARC™-type Sidescan Swath Bathymetric Sonar (SSBS, is being built by Hughes Naval and Marine Systems Division, Mukilteo, WA) and a chirp type High Resolution Sub-bottom Profiler (HRSP; which is an adapted Bathy-2000P from Ocean Data Equipment Corporation (ODEC) and an integrated Data Acquisition and Quality Control System (DAQCS; integrated and tested by LDEO) computer system. The transducers for the two sonars will be carried in instrument pods attached to the underside of the submarine. Cables, routed through the ballast tanks will carry signals from the instrument packages to an outboard processing module in three pressure tight cases secured below the top of the steel outer hull of the submarine in a free-flood space. After initial processing, the signals will be brought in board, processed, logged and archived by the DAQCS.

SCAMP will be deployed on the 1998 and 1999 cruises. The future of the program after 1999 is uncertain. The MOA that governs SCICEX is open-ended. Continuation of SCICEX beyond 1999 is currently under consideration.

II. SCAMP Instrumentation

Each of the SCICEX cruises has sailed with a Bell BGM-3 gravimeter and utilized the ship's own bottom sounder to collect bathymetry data. The approximately 50,000 km of data collected to date are the largest addition to the unclassified data base for the deep Arctic Ocean since the drifting ice island programs almost 30 years ago.

With the submarine's sounder, this program has made the first systematic bathymetric surveys in the Arctic Ocean. Recognizing the potential of the submarine for geophysical data acquisition, the NSF sponsored a workshop to discuss how best to exploit this unusual opportunity. Arctic geophysicists and geologists, familiar with the ocean and the adjacent continents, were invited to Washington to discuss the most appropriate instrumentation to address the outstanding problems of Arctic geophysics. The clear sense of this workshop was that swath mapping was the highest priority. Sub-bottom profiling was a strong second choice. Working with these priorities and the restrictions imposed by submarine operations, we have developed an instrument package that is appropriate to support a wide variety of research programs in the Arctic, presents tractable engineering challenges and has been optimized for Arctic submarine operations.

A. Design Constraints

We began with the existing, proven hardware and software. We are adapting these devices and code for Arctic operations and installation on submarines. Towed systems are relatively portable, pressure tolenrant by design and require only a few conductors to transmit data from the hull-mounted arrays to the logging and control computers inside the pressure hull. These characteristics fit with the operational restrictions imposed by submarine installation and the Arctic cruise program.

The SeaMARC™ design has been optimized for Arctic submarine operations. Lamont-Doherty Earth Observatory, Hughes Naval and Marine Systems and the Arctic Submarine Lab were initialy funded by NSF (and Columbia internal funding) to develop a conceptual design. We have been subsequently funded (largely by the NSF) to build the system.

The submarine is the optimal platform for active sonars. Submarines have been designed and maintained to minimize their sound signatures, making them nearly ideal for many sonar techniques. Mounting the transducer arrays on the underside of the hull will eliminate the uncertainty in the position of the arrays relative to the seafloor, the largest error source in sonar measurements from towed systems.

B. Operational constraints

The submarine is an unusual platform for science operations. While the mobility of the submarine opens the Arctic for the first uniform geophysical surveys, it also imposes restrictions on the proposed installation. These restrictions are defined by the operational possibilities of the Sturgeon class submarine both in and out of the deep Arctic Ocean operational area (Figure 1).

Within the operational area, the submarine is limited to depths less than 800 feet and speeds less than 25 knots. Data collected at greater depths or speeds will be excised from the unclassified post-cruise data release. The pressure at 800 feet and the drag imposed at 25 knots are obvious design constraints for any instrumentation installed outside the sub's pressure hull

The primary restrictions on any installation outside the pressure hull are defined by drag of the projecting transducer package, tolerance to sea pressure of these components and, because we will to mount the transducers below the keel, changes to the draft are minimized.

Sea pressure is not a major concern. The SeaMARC™ transducer arrays are prepared for any pressures encountered by the submarine in transit or in the operational area. In the open ocean and all of the operational area, draft is a minor concern. The 1998 cruise (planned for a Pacific Fleet submarine) will transit through the Bering Strait. Through this tight passage the submarine is restricted both by the shallow seafloor and the ice cover above. The 1998 cruise is planned for the summer season, minimizing the ice cover, but the bottom clearance remains a major concern. The proposed pods for the various transducers will not change the overall ship draft.

Portability of this system is a primary design constraint. The Navy prefers to use different submarines for each cruise to spread training across the submarine fleet. Our design exploits the portability of a SeaMARC™ system, while adapting it for the submarine and the Arctic..

Crosstalk between the various Navy devices and the proposed sonars is not expected to be a serious problem. The submarine community prefers passive to active sonars. Crosstalk between the chirp system and the swath bathymetric imaging system is not expected to be serious due to the wide separation of frequencies, but may require some synchronization of activity. The submarine will be provided with an interface to allow blanking of the SCAMP sonars as necessary for submarine operations.

1. Why an SSBS instead of an Multi-Beam Swath Bathymetric System (MSBS)?

On a submarine, the MSBS would have a V-shaped receive array that extend nearly two meters to each side of the keel, well beyond the range that could be directly connected to the hull, requiring custom fittings or a very heavy sub-frame to be rigid enough to minimize the bathymetric errors.

The lack of substantial athwartship dimension

smaller and lighter underhull installation.

adaptable to different boats in a class, and to

The external electronics for the SSBS

for installation in pressure cases, requiring

hull. Any version of
would require in excess of one hundred

130), or redesign of the signal processing

these options would significantly increase the

Because the transmitters and the initial signal

the hull, the SSBS systems will have a

already crowed space available inside the

converted to a towed configuration for use in

require re-mounting on a hull.

The initial concept for SCAMP was to be

as has been done for other
frequency selected for SCAMP and the

too long and too wide to mount by clamping

The inability to use the flood grates

requiring that we weld threaded mounting

while the boat is in drydock. Once the pucks

in-water installation (and removal.)

(HRSP) and the swath mapper (SSBS) would

mapper arrays such a pod would have been

between blocks should there be a requirement

the approximate location of the two

a 637-class submarine.

A. Optimized SeaMARC -type Sidescan Swath

The proposed swath bathymetric imaging

based on the SeaMARC design. This system

previous side-looking systems, optimized for

consists of outboard, hull-mounted projectors

outboard electronics module, and inboard

improvements have been implemented in

The ITC-5458 transducer arrays are designed

underside of the submarine. Figure 3 shows

arrays are approximately 5 meters long and

horizontal rows of elements to allow transmit

determination of phase differential in the

through the ballast tank, connects the arrays

mounted in a pressure case, below the

The outboard transceiver conditions, samples,

of information onto a single high-speed

provided, via two conductors in an available

electronics. The inboard electronics

operator settings, receives and logs
data, provides an operator interface, powers

recorded data. This unit consists of a

cpu Sun
associated peripherals. A second

capability and a back-up logging computer.

algorithms provided by the
Research Group (HMRG) provides color-

for quality monitoring and
display.

The maximum swath width of this system will be about 20 km. The basic sample rate is five thousand complex data samples per second per channel. Data will be collected beyond the first multiple until just before the next transmit instant. This will result in the maximum data collected per unit time. Backscatter data will be collected over the entire width. Bathymetric data will be acquired over approximately 75% of the swath.

The operating specifications for the optimized SeaMARC™-type 12 kHz swath mapping bathymetric sonar currently under construction at the Naval and Marine Systems (NAMS) group of Hughes Aircraft in Mukilteo, Washington, are included in Table 1. The SSBS is a combination of sonar system transducers, transmitters, receivers, telemetry, power, and digitizers from Hughes/NAMS, real-time and post processing software from HMRG, and real-time data logging and system integration from Lamont-Doherty Earth Observatory. ASL will handle the mechanical and electrical interfaces to the submarine and the development of TEMPALT documentation.

Frequency	12 kHz
Pulse Length	83 µS to 10 mS
Modulation	CW or
Repetition Rate	2 to 20 seconds
Source level	233 dB re 1 µPascal @ 1 m
Power	115 VAC
Backscatter Swath Width	~160°
Bathymetry Swath Width	~140°

Table 1 Major specifications for the Sidescan Swath Bathymetric Sonar (SSBS). These specifications are design goals.

B. High Resolution Sub-bottom Profiler (HRSP)

Because no systematic surveys of Arctic Ocean sediments have been made, we have included an adapted chirp sub-bottom profiling system in the SCAMP package.

The source signal generated by a chirp system sweeps a band of frequencies. It will provide the highest possible resolution and good penetration in favorable conditions.

The system will provide on the order of 100 meters penetration and resolution at the 10 cm. level. We anticipate that the low acoustic noise and stability of the submarine platform will substantially improve the data relative to what would be collected from a surface ship.

The transducers and hydrophones for this system will be connected to the inboard logging and processing electronics in a manner similar to the swath bathymetric imaging system. Two conductors in an existing through-hull penetrator will be used. The HRSP data and meta-data will be logged on the same SPARC 20 as the swath bathymetric imaging system. A real-time depth corrected display will be provided on the flat panel display in the Bathy-2000P.

With an appropriate installation and good technical support the system should perform well. An array of nine elements (in a 3 by 3 pattern) of ITC-5465 transducers will provide a beam pattern of approximately 30 degrees with a four kHz bandwidth in the range of 2.5 to 6.5 kHz. This array will be installed in an independent instrument pod illustrated in Figure 4. A connectorized junction box will be mounted in MBT-1A from which a single cable will be routed up the pinger pipe into the forward line locker and then aft through an existing cable way into the ESM well to the external hull fitting.

Digital data from the sub-bottom profiler will be time stamped, merged with real- time navigation and pressure depth and recorded in SEG-Y format on high density tape for display and possible post.

Frequency:	2-8 kHz
Pulse Length:	1 - 100 mS
Modulation:	CW or FM
Source level:	230 dB re 1 µPascal @ 1 m
Athwart ships beam width:	~30°
Fore/Aft beam width	~30°
Repetition Rate:	1-10S
Penetration	~100 m
Resolution	~10s of cm

Table 2 Basic specifications for the High Resolution Sub-bottom Profiler (HRSP).

C. Bell BGM-3 marine gravimeter

The Bell Aerospace BGM-3 underway marine gravimeter consists of a gyro-stabilized, gimbaled platform, which supports and maintains the prime accelerometer in the direction of local vertical. In addition to the platform and sensor, two additional drawers of external electronics and a data interface (all 19" rack mountable) are required. The gravimeter is a reliable underway instrument, which will continually generate data without operator intervention. Drift rates are typically low. A BGM-3 is made available to this program by NAVOCEANO in Bay St. Louis, Mississippi under a loan agreement negotiated with NSF.

D. Data Acquisition and Quality Control System (DAQCS)

The DAQCS will consist of a pair of Sun UltraSPARC computer systems with disk drives, high density tape drives, a CD-ROM drive and the necessary interconnection hardware an software. One of the computers will act as the prime data logging computer for all the instruments. The second workstation will be used for off-line data processing and act as a spare, should the prime computer fail. Spares will be carried for all system hardware. Integration of data logging into a single computer permits consistent time tagging of all data and sharing of data between process. A block diagram of the full system is included in Figure 5.

The DAQCS will also generate real-time displays of all data streams, which will assist greatly in the quality control effort. Seeing the data in real-time will permit the rapid identification of anomalies and the adjustment of the cruise track to sample the unexpected. A laptop computer will be used, if desired by the ship's captain, to echo the real-time display in the command center.

E. Common ship's equipment and data sources

Quality SSBS data acquisition will require precise synchronization of the ship's position and attitude data to know the position of the transducer arrays during the transmit and receive cycles. Because the transducers are mounted to the keel of the submarine, proper positioning of each pixel collected by the SSBS on the seafloor will require precise, real-time knowledge of the orientation (pitch, roll and heading) and position (latitude, longitude and depth). Proper correction for variations in the acoustic properties of the ambient environment will require sound velocity profiles collected while underway. Existing facilities on board Sturgeon-class submarines can be exploited to provide the necessary positional and environmental information.

F. Submarine Data Recording System (SDRS)

Integration of the data with the geophysical data streams is crucial to the success of this project. Data from the ship's inertial navigation system, gyro compass, GPS receiver, bottom sounder, ship's depth and other data streams are captured from a number of locations throughout the ship by the Navy's Submarine Data Recording System (SDRS). The SDRS digitizes analog signals captured from the ship's position, orientation and environmental sensors and records it on a QIC-150 cartridge tape, which is used by the National Imaging and Mapping Agency (NIMA) to reconstruct the track of the cruise. A record is written every second.

After the Pargo cruise it took some time to receive six minute sampled navigation data from DMA. For the Cavalla and subseqquent cruises we were able to tap into the SDRS output, capture the binary data and interpret it in real-time on the same computer used to log the gravity data. This real-time integration permitted consistent time-tagging of all geophysical data and simplified and improved gravity data reduction.

G. Sound velocity in water

Two measurements made from the submarine will be useful for this purpose. While underway, an external sound velocimeter continuously measures the ambient velocity of sound in water. Periodically, the ship will launch an expendable bathy- thermograph (XBT) to support their sonar activities. During the science cruises, an expendable CTD (XCTD) is launched through the signal ejector at least once every day. Data from either expendable device can be used to construct a sound-velocity profile to approximately 1000 meters depth. This data will be necessary to properly estimate depths with the SSBS data and properly position individual backscatter pixels on the seafloor.

H. Software

LDEO and HMRG both bring extensive experience with data acquisition and reduction to this project. This experience is partially reflected in the accumulated software base at both institutions. This software is written to a professional standard in "C" for UNIX-based platforms. It is stable, having been used extensively at sea, on a number of platforms, well documented and adaptable to various instruments and circumstances. While adaptation of this software to the planned instrumentation is funded by the OPP instrumentation grant that covers the acquisition of the SSBS, we expect to improve and modify the software over the course of the program.

I. R/V Ewing real-time logging system

Development of the data acquisition software package that is in use on the Ewing was begun on the R/V Conrad in 1985. This software is used to acquire, interpret, archive and do "first-cut" processing on all of the underway data streams collected on the Ewing. It is also in use on the R/VIB Nathaniel B. Palmer and will soon be installed on the R/VIB Gould. A small subset of it has been used for previous submarine cruises.

The basic principle that underlies this package is that the highest priority task is to acquire, time tag and write exactly what is received from each device to a file specific to that device. Each device is handled by an independent process which writes an independent day file, which resides in a specific directory, which is opened each day at midnight GMT. This structure of directories, day files and time tags ensures that data is archived systematically and can be found readily as needed for analysis. Among other advantages of this system, the independence of the processes facilitate debugging and makes it possible to update a running system while only effecting one data stream.

Data from some devices is broadcast to the system, where it can be captured by other, concurrent processes. Broadcast of data will be necessary to take the orientation parameters from the SDRS or sound velocity profiles estimated from XCTDs or XBTs and incorporate them into the calculations necessary for the SSBS.

Quality control checks can be done by concurrent real-time processes, which monitor system status, do range checking, and check for data consistency.

Automated data logging and quality control monitoring will be necessary on the submarine to minimize the time watch standers have to spend checking system performance. This also ensures minimum data lost to malfunctioning equipment.

J. Hughes Naval and Marine Systems real-time data acquisition

Under their contract to build the SSBS, Hughes will provide the code to handle data transfer from the outboard processing modules to the DAQCS. This code will deliver the data stream to the HMRG processing and display software and return operator control to permit adjustment the sonar control parameters in the outboard electronics modules.

K. HMRG real-time data acquisition and display

The acquisition system will be built from three cooperating programs: Hughes software, which directly controls the sonar and saves the acoustic data acquired by the instrument to disk files on the host computer, a display program (from HMRG), which maintains continuous screen displays of bathymetry and sidescan data generated from the acoustic files, and a logging program (from HMRG), which copies all of the raw data onto high-capacity tapes for future transfer to the post-processing computer system and long-term archival storage. All three programs are X11 Window System applications which run simultaneously on a single computer and display and are intended to be monitored by a single watch stander.

The real-time display program provides the operator with continuous and near-instantaneous visual feedback that may be used to monitor data quality. The acoustic data generated by the sonar is processed into bathymetry and sidescan plots which are displayed on the workstation screen.

Information conveyed by this display could lead to an adjustment of the sonar control parameters or argue for a course change to further observe an anomalous feature.

We expect that about 55 megabytes of data will be generated every hour from the SSBS. At this rate, the on-line data storage facilities of the host computer could quickly be exhausted. The logging program transfers these files to secondary storage (high-capacity DLT tapes) and removes this data from disk to make room for new files. The program is normally configured to copy twelve hours' worth of data to each of two tapes, an prime archive and a back-up. It is robust in the event of defective media or operator inattention by virtue of a difficult-to-ignore audio-visual error reporting system.

These tapes, which contain all status logging files and the raw acoustic data, constitute the input to the post-processing system.

L. Reduction

Reduction of data, independent of the particular principal investigators is crucial to maintaining consistent standards of data quality for the entire program. This is particularly important if data from different years is to be composited into maps. In keeping with our institutional strengths, the gravity, navigation and HRSP data will be reduced and prepared for release at LDEO. At HMRG the bathymetry and backscatter data will be processed and prepared.

IV. Status

The following sections provide a brief overview of the status of this project.

A. SSBS

The SSBS is being built and tested by the Naval and Marine Systems (NAMS) division of Hughes Aircraft Company (formerly a part of Aliant TechSystems (ATK.) The sidescan transducers International Transducder Company (ITC) model 5458 units. The transducers have been finished and tested. The sonar system is in the final stages of construction. In-water testing will be done in Puget Sound in the late fall.

B. Software development

The core DAQCS system is currently at sea on the Archerfish for SCICEX-97. Additional software to accommodate the two sonar systems will be integrated starting in November.

C. HRSP

The HRSP is a modified Bathy-2000P from Ocean Data Equipment Company. Most of the modifications for SCAMP are additional software to accommodate the submarine operation. The new software is currently being developed. International Transduer Corporation (ITC) is supplying model #5465 that are currently being manufactured. Delivery of the HRSP is anticipated in the late fall. A second unit will be installed on the R/V Ewing at the end of October and serve as a test platform for evaluating the updated software.

D. Pods

Detailed design of the two underhull pods is currently in progress at the Applied Physics Lab of Johns University. The conceptual designs are show in Figure 3 and Figure 4. The pod fabrication will be done by an outside machine ship commencing in November.

E. Drydocking

Threaded mounted pads for the pod foundations and for handling gear were installed on the submarine in June. At that time we also fitted and aligned both pod foundations and installed cables for the SSBS. Divers from the Norfolk Naval Shipyard will install the instrument pods, transducers, and junction in the spring of 1998.

F. TEMPALTS

The procedure for getting permission to make temporary modifications to nuclear submarines is a complex and somewhat tedious task. Johns Hopkins/APL is taking the lead role for the outboard TEMPALTS with assistance from the Electric Boat Corporation. The Arctic Submarine Lab is taking the lead for the inboard TEMPALTS.

1. Phase I

The TEMPALT package for the work that was done in drydock in June was expedited by the Navy due to scheduling constraints. Approval of this TEMPALT packages was expedited and the work was accomplished on time.

2. Phase II

The TEMPALT package for Phase II is being assembled by JHU/APL, EB, Lamont and the Arctic Submarine Lab. Submission is anticipated in November allowing adequate time for a full review. Approval expected in February to meet the target window for installation in March, 1998.

V. SCAMP operations

Once in the operational area (Figure 1) all equipment will be operated continuously. During previous cruises we have average approximately 476 track kilometers per day. The average speed over this time is about 20 km/hr (11 knots). The submarine has typically sustained an average speed of 28 km/hr (15 knots) but because of time spent at surface stations or submarine "house-keeping" functions (1 hour out of every 18) the average is somewhat lower. Assuming an average swath width of approximately 16 km (probably a low estimate, given the average depth of the Arctic Ocean) data acquisition will proceed at an average rate of 320 km2/hour, or 7680 km2/day. Over a cruise with 42 days in the operational area, this would mean roughly 323,000 km2 mapped.

Because the proposed swath bathymetric imaging system can only have one pulse in the water at a time, choice of an average cruising speed dictates the degree of overlapping coverage along track versus across swath. In the deep water that characterizes much of the Arctic Ocean basin equal along and across track resolution might dictate an underway cruising speed of 10-14 km/hr (6-8 knots). While particular problems or locations might benefit from this attention we feel it more important to cover as much of the basin as is possible in the remaining years of the program.

Real-time data displays for both the sub-bottom profiler and the swath bathymetric imaging system will be provided for the science party in the torpedo room. A second display will be provided to the ship's party in the command center.

Space on the submarine is limited. On previous cruises 4 or 5 berths have been available for the science team. Each rider will be assumed to be available to assist on any of the funded programs, subject to their abilities.

The HRSP and SSBS will require a minimum of one and possibly two riders. The geophysics riders will act as representatives of the funded PIs and for the community at large to ensure the data continuity and quality. A qualified engineer (the minimum) and a data analysis person will be necessary to ensure that sufficient technical expertise is available to correct problems with the hardware and do preliminary processing on the data.

The data will be continuously written to disk as it is collected. Dual tapes (prime archive and backup) will be updated regularly. The main duty of the watchstander will be to monitor the real time display, ensure that tapes are being properly written and advance the data processing. Data loss due to hardware failure will be minimized by a preventative strategy of regular, redundant back-ups.

VI. Acknowledgements

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Figure 1

Figure 2: View looking up at the bottom of a Sturgeon-class attack submarine showing the approximate locations of the instrument pods. The foreward pod which will house the High Resolution Subbottom Profiler (HRSP) transducers.

Figure 3: Assembly diagram of the Sidescan Swath Bathymetric Sonar (SSBS) showing the five array elements for one side, the supporting structure, cable routing and fairings. Cables are routed forward and up through a hole in the skin of the ballast tank to connectorized junction boxes.

Figure 4: An exploded view of the instrument

elements will be mounted from the bottom so that they can be changed by divers if necessary. Cables are routed forward and up into a hole in the skin of connectorized junction box.

And Mapping Pod (SCAMP). Note that the Remote display is an option that may not be installed for all operations. The I/O subsystem provides interfaces for synchronization of the sonars and implements the remote blanking capability.