Data Management Systems for
Digital Side Scan Data and Shallow Water Multibeam Data

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Abstract

The Coast Survey, Hydrographic Surveys Division is developing data management systems to handle large volumes of digital data on board NOAA's hydrographic survey vessels and at NOAA's hydrographic processing centers. The need for these data systems is predicated on the deployment of new acquisition systems aboard NOAA hydrographic vessels, and the expected data load from recently initiated contracts for hydrographic data. This paper reports on the Coast Survey's approach to hydrographic data management systems capable of terabyte-level capacities and fast data throughput.

1. General Discussion

1.1 Impact of New Hydrographic Technologies

The rapid development of modern hydrographic acquisition systems such as high speed, high-resolution side scan sonar (HSHRSSS) and shallow water multibeam (SWMB) systems is remarkable. With these systems, the hydrographer can pursue efficient coverage surveys. However, these systems generate tremendous amounts of data, and in the NOAA charting paradigm, every sounding and target must be processed or accounted for.

In the field, the processing problem compounds as most HSHRSSS or SWMB data still require intensive operator review and interactive editing on workstations. Processing software used by Coast Survey typically provides capabilities for data conversion, playback, editing, and visualization. Since a hydrographic project is cumulative, data needs to be easily recalled throughout the field season; data collected at the beginning of a survey needs to be periodically reviewed or compared with later data. Multiple operators must be able to quickly and efficiently retrieve, process, visualize, and export data during concurrent sessions. Processing of the data is task-oriented, with a majority of the early tasks to be accomplished by fairly inexperienced personnel in such a way that senior hydrographers can review the final products quickly and efficiently. Finally, the data processing infrastructure must fit aboard a variety of vessel sizes, must be flexible in capacity and configuration, and must be affordable.

Ashore, the Coast Survey hydrographic processing centers require a similar data processing infrastructure. When the field unit or contractor concludes a hydrographic project and submits digital side scan or SWMB data to the processing centers, operators perform a variety of interactive workstation-oriented tasks. These include data quality assurance, water level data application, and verification of compliance with project instructions. The processing centers also require archival and data translation services embedded into their systems for both in-house data serving and outbound transmission of digital information.

1.2 New Technology Data Sources

The impetus for Coast Survey's development of hydrographic data management systems was the deployment of the Klein T5000 HSHRSSS system in 1997. The NOAA Survey Vessel (S/V) BAY HYDROGRAPHER now operates the Klein T5000 HSHRSSS for wreck and obstruction detection in Chesapeake Bay as part of it's hydrographic survey mission. At towing speeds of five meters per second (10 knots), the T5000 generates up to one gigabyte (GB) of data per hour. During 1999, the T5000 will be deployed aboard NOAA Ship WHITING as a T5500 for 24-hour per day operations. Also, the WHITING's two launch-based Edgetech 272T side scan sonars are being outfitted with the Triton Elics International (TEI) Isis digital acquisition system. All digital side scan data will be processed aboard WHITING using Universal Systems Limited (USL) Computer Aided Resource Information System/Sidescan Image Processing System (CARIS/SIPS) software.

During 1998, three launch-based RESON SeaBat 8101 SWMB systems became operational aboard the NOAA Ship RAINIER. The data from these SWMB systems is processed aboard RAINIER immediately after acquisition using USL's CARIS/HIPS (Hydrographic Information Processing System) software. A fourth multibeam, a SeaBeam Instruments 1050/1180 MKII dual frequency sonar integrated with a TEI Isis system, is to be installed aboard RAINIER in early 1999. Raw data from these four systems is estimated to approach one gigabyte per day total, depending on survey depths and daily platform usage.

During 1999, Coast Survey hydrographic processing centers in Seattle and Norfolk expect to receive deliverables from approximately seven contracts for SWMB and/or digital side scan sonar hydrographic data in addition to data from in-house field units. For the purpose of estimating data production (and therefore processing capacities), each contract can be considered equivalent to a project for a single-platform vessel. The hydrographic processing centers are using USL's CARIS/HIPS and SIPS for SWMB and digital side scan data processing.

Robust and scaleable data management systems with common hardware are necessary to ensure efficient processing throughput and data storage, and reduce the complexity of supporting the entire data stream from field units through the processing centers.

2. Data Management System Design

2.1 General Objectives

An analysis completed in December 1996 explored various data management configurations. Table 1 summarizes the primary objectives of this study (ITI 1996).

1. COTS	◆ Use commercial-off-the-shelf hardware ◆ Minimize development of specialized software ◆ Use modular components
2. NT or UNIX Operating System	◆ Meet Windows NT to match current PC standards, or ◆ POSIX UNIX Specifications to support CARIS workstations
3. Limited Physical Environment	◆ Optimize equipment to limit heat, space, and power requirements.
4. Reliable & Cost Effective Network Infrastructure	◆ Size bandwidth to projected requirements ◆ Maximize user availability; use switched network ◆ Reduce possible failure points ◆ Use existing vessel network infrastructure; upgrade as required
5. Distributed Processing	◆ Support work load balancing between read, write and process tasks ◆ Maximize user availability
6. Scaleable	◆ Easily expand to add I/O channels, memory, storage capacity
7. Affordable	◆ Align capacity and performance as needed to meet budget

Table 1 Objectives for Data Management System

These objectives were used to guide market searches and query vendors. The study included reviews of server technologies, server operating systems, network technologies, and storage technologies. The study became a starting point for the design of a data management system consisting of three elements; 1) a data server system, 2) a data storage system, and 3) data management software.

2.2 Data Server

The data management systems are built around dedicated data and application servers configured to local area networks (LAN) aboard the vessels or in the branch facilities. The Silicon Graphics Inc. (SGI) Origin 2000 server was selected because of its open architecture, high data throughput capability, and expandability. Origin 2000 servers are now in place aboard RAINIER and at the hydrographic processing centers in Seattle, Washington and Norfolk, Virginia. Another Origin 2000 server, to be installed aboard the WHITING in mid-1999, is now being used for data management system development at Coast Survey headquarters in Silver Spring, Maryland.

Selection of an SGI Origin 2000 server based on the UNIX operating system was preferable for several reasons. These included 1) compatibility with Coast Survey's chosen processing software (USL's CARIS/HIPS and CARIS/SIPS), 2) ease of integration with the proposed (and existing) SGI processing workstations, and 3) Coast Survey's familiarity of the SGI operating system (Irix, SGI's proprietary UNIX). Alternate servers based on VAX/VMS and Windows NT were eliminated after detailed evaluations of vendor proposals. A key criterion was the compatibility of file sharing (using network file service, or NFS protocol) between the server's operating system (OS), the existing Windows NT networks already in place aboard the vessels, and the SGI processing workstations. Another important criterion in selecting a server OS was the desire for automated storage management software (discussed below). And finally, the capacities for system growth with additional CPU power, memory, storage, and IO channels were critical.

Figure 1 Installation of data management system aboard NOAA Ship RAINIER (SGI Origin 2000 at bottom left of equipment racks)

2.3 Data Storage

Fast-Access data storage can be expensive, particularly storage systems with capacity for hundreds of gigabytes. Analyses of data logging rates were projected over time to determine storage requirements for the various vessels during a typical field season. Because of this (and budget compromises), data storage capacities vary at each of the implementation sites. The following paragraphs discuss the general approach taken with all the data management systems.

Connected to the Origin 2000 server via differential SCSI are large (300+ GB) redundant arrays of inexpensive disk (RAID) systems and multi-gigabyte disk subsystems. The RAID systems operate at RAID level 5 to ensure data integrity and fault tolerance. RAID 5 fault tolerance is achieved by storing parity information across multiple disks and is best suited where read requirements outweigh write requirements. Raw data from vessel or launch acquisition systems are transferred to the RAID systems in preparation for processing. This operation typically occurs during vessel transits, or after launches return to the mother ship when time is not at a premium. The raw data is then read from the RAID systems during conversion for processing; after conversion, the raw data is moved off the RAID systems for archiving. The somewhat better read performance of the RAID level 5 systems supports the data conversion requirement. Conversion was determined to be the processing step where operators would be least patient and time was critical. Converted data, readied for processing, is written to the multi-gigabyte disk subsystems. The disk subsystems are configured across multiple SCSI channels to minimize bottlenecks and allow several operators to process the day's work.

Eventually, a vessel or site will run out of disk or RAID storage space. In the worst-case example for Coast Survey, the WHITING 24-hour operations of the HSHRSSS, this limit is estimated to occur after approximately 30 to 45 days. In the case of RAINIER SWMB operations, estimates indicate disk and RAID storage capacities will be sufficient for an entire project (typically two months to three months). Additional disk subsystems for HSHRSSS data storage aboard WHITING were judged to be too expensive and space-consuming, so alternative solutions were investigated.

As part of the system design analysis in late 1996, Coast Survey personnel investigated hierarchical storage management (HSM) designs. In an HSM, data retrieval speed is essentially a trade-off between storage media and storage cost. The Coast Survey's approach for the WHITING was to add a robotic tape library with terabyte-level capacity behind the more costly RAID or disk subsystems. Data files are periodically moved (or migrated) during non-critical hours to the tape library, making room for newly acquired data on the better performing disk drives. Selection of a robotic tape library using digital linear tape (DLT) was determined to be a cost-effective and well-performing alternative over additional disk storage or other media (such as magneto-optical, compact disk, or other tape technologies).

2.4 Data Management

To help automate data migration between the disk storage systems and the tape library, an HSM software solution is required. HSM software manages data across storage systems automatically and keeps system administration tasks to a minimum. The HSM software selected is an SGI product called Data Migration Facility (DMF) recently ported over from Cray Research, Inc. DMF manages data between the disk storage systems and the tape library such that location and retrieval of data is transparent to an operator. The operator, for example, can select files from a virtual file system where some data may be on disk, and other data may be on tape. The only obvious difference is the increased access time required when retrieving a file from the tape library. DMF migrates files automatically across storage media based on criteria such as disk space used, file age, or file type.

Selection of SGI's DMF software was carefully considered during the server selection process. In late 1996, there were very few commercial HSM products available which were affordable and met Coast Survey criteria. Other products available were primarily backup software with marginal HSM functions, required VAX/VMS or Windows NT as a server OS, and required licensing payments based on storage capacity increments.

3. A Case Study of the WHITING Data Management System

Developing a data management system for the WHITING was based on the design objectives discussed above, tailored to the WHITING's acquisition scenario of three digital side scan systems. In the interest of brevity, only the WHITING's system will be presented here as a case study.

3.1 Essential Requirements

The objectives boiled down to three requirements for the design of WHITING's data management system. They were 1) an initial terabyte-level capacity with capability for future expansion, 2) a minimum of operator actions to move data across storage systems, and 3) keep the current (newly acquired) data ready for immediate processing. The WHITING's data management system is unique from the others in two aspects. First is the application of a terabyte-level tape library. Second is the implementation of DMF software. Tape libraries and DMF software are presently not being used with the other data management systems.

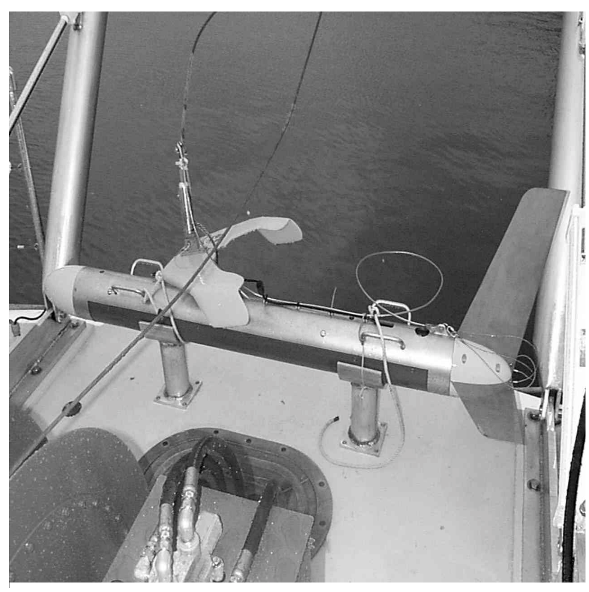

Figure 2 Klein T5000 HSHRSSS aboard NOAA S/V BAY HYDROGRAPHER

3.2 WHITING Data Sources

By mid-1999, WHITING digital side scan data will be acquired by the ship equipped with the

HSHRSSS, and by both of WHITING's launches equipped with standard Edgetech 272T side scan sonars. For all three platforms, digital side scan data will be logged using the TEI Isis system in the extended Triton data format (XTF). In September 1998, the first Edgetech-Isis equipped launch became operational. The second launch will be outfitted in January 1999. The Klein T5500 HSHRSSS, along with the full data management system, is scheduled for installation aboard WHITING in June 1999.

Aboard WHITING, HSHRSSS data will be logged by the TEI Isis data acquisition system (DAS) directly to the Origin 2000 server across a dedicated switched 100BaseTx Fast Ethernet network. As usually configured, a TEI Isis system writes data to local media such as Exabyte tape or a 4GB hard disk. At an estimated rate of 1GB per hour, logging directly to the Isis 4GB hard disk would require data acquisition to be stopped and data to be transferred by some operator action approximately every four hours. Logging to Exabyte tape was not considered for normal operations because of complications which could arise from manually managing many data tapes and the time required to load data into the processing environment. Logging the very dense HSHRSSS Isis data across a network was validated aboard BAY HYDROGRAPHER in the fall of 1997. When the HSHRSSS is fully operational aboard WHITING, breaking off survey operations to move data to the Origin 2000 server will not be required. Processing operations can begin as soon as the logging file is closed.

Aboard the WHITING's two launches, the TEI Isis systems will each log up to 2.8GB per day of side scan data to their local hard drive. Data transfer occurs at day's end, when the launches are back aboard ship. Each launch is then connected to the ship's 100BaseTx network, and an operator copies data over to the Origin 2000 server using simple click and drag actions.

3.3 WHITING Configuration and Data Flow

WHITING's SGI Origin 2000 server is configured as a data server with two R10000 180 MHz MIPS processors, 256 MB of RAM, five fast Ethernet ports, and twelve differential SCSI ports. Connectivity between the Windows OS and the SGI OS is achieved using freeware called SAMBA. SAMBA uses the Server Message Block (SMB) protocol to share files, printers, etc. between UNIX-based and Windows-based computers. The two 35GB RAID systems attached to the Origin 2000 server via differential SCSI are shared across the network and mapped to each of the three Isis computers as network drives.

Data from the shipboard HSHRSSS Isis system is logged across the network to one of the two RAID systems (Figure 3). The shipboard operator can use the Isis Windows 95 browse feature to specify which of the two RAID systems is used for daily data logging. Similarly, launch-acquired XTF data is copied across the shipboard network into one of the two RAID systems.

A full day's XTF data can be backed up to a DLT7000 tape drive. Each RAID system or one DLT7000 tape cartridge has a 35GB capacity (uncompressed on the tape). Both devices can store 24 hours of HSHRSSS data and 16 hours of launch digital side scan data. At the end of a 24-hour period, the system operator selects the second RAID system for logging and changes the data cartridge in the DLT tape drive. The tape backups are the raw data archive. As data acquisition resumes logging to the second RAID system, processing can begin on the previous day's data stored to the first RAID system. Changing between RAID systems every midnight ensures that during processing, data can be quickly accessed (read) without contention from any logging (write) operations.

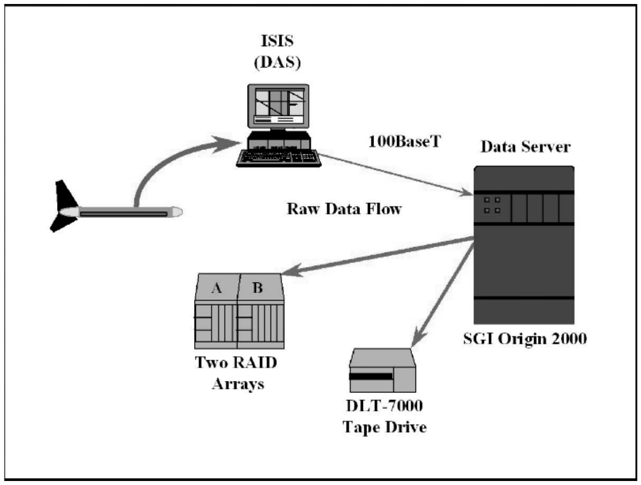

Figure 3 Digital SSS data flow during write operations (data logging)

The CARIS/SIPS software is installed on two SGI Octane workstations that are connected to the Origin 2000 server via dedicated 100BaseTx fast Ethernet (Figure 4). Each Octane workstation is configured with an R10000 180 MHz MIPS processor, 384MB RAM, and SGI's high-end graphics processor. The processing and graphic horsepower of an Octane workstation, along with the dedicated network connection, allow very rapid read, playback, and processing operations in SIPS.

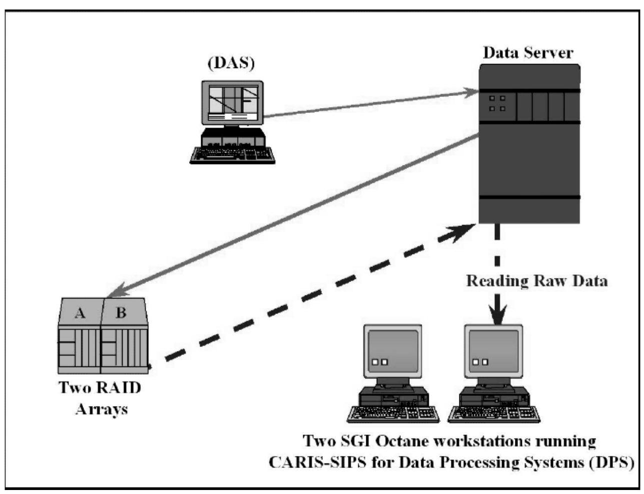

Figure 4 Digital SSS data flow during read operations (data conversion)

The first step in SIPS processing is data conversion. From the Octane workstation, SIPS reads XTF files from the RAID system and converts these to SIPS files. The converted SIPS files are written to a 340GB-disk subsystem connected to the Origin 2000 server via differential SCSI. The 340GB-disk subsystem consists of 37 9GB-disk drives configured as one virtual disk (Figure 5). During subsequent processing steps, data is reviewed and edited in SIPS. The operator searches for sonar contacts during data playback and interactively measures and describes them. Contact information such as size, description, geographic position, etc., are written into contact files for each survey line file. SIPS contact files are then exported in dBase-format across a fourth fast Ethernet link into the Coast Survey standard Hydrographic Processing System (HPS) used by all Coast Survey hydrographic units. Other digital side scan products, such as mosaics, are also supported in SIPS and are more fully discussed by Glang (1998).

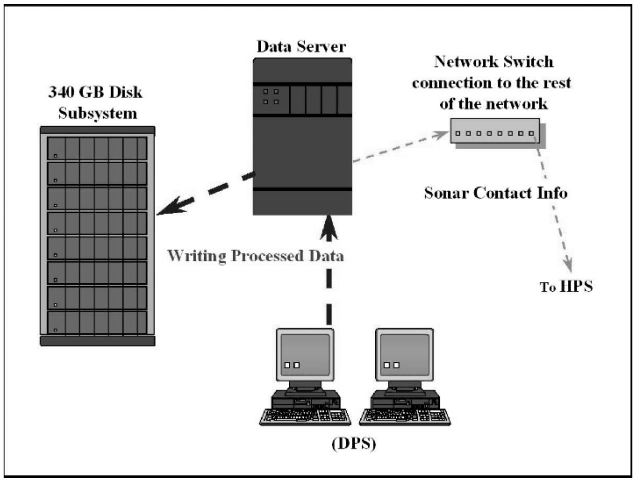

Figure 5 Digital SSS data flow during write operations (data conversion & processing)

SIPS data processing relies on the digital SSS data being available on the 340GB-disk subsystem. To keep space available on the disk subsystem for daily processing, DMF (see 2.3) migrates files to the secondary storage system (Figure 6).

The WHITING secondary storage system is a StorageTek 9730 rack-mountable tape library. The StorageTek 9730 is connected to the Origin 2000 server via differential SCSI; it consists of three DLT7000 tape drives and 30 tape cartridges for a total (compressed) capacity of 2.1TB. The StorageTek 9730 uses advanced rotational robotics with a camera-based vision system to accurately retrieve and load tape cartridges. The average cartridge access time (retrieve and load) is six seconds. The DLT7000 tape drive has a maximum throughput rate of 5MB per second. This speed allows data in the tape library to be returned to the disk subsystem very quickly. The StorageTek 9730 was selected because of its small size, expandability, and maintainability; all of its essential components are field replaceable. The Origin 2000 server was configured with sufficient SCSI ports to accommodate a second StorageTek 9730 tape library in the future.

A DMF configuration file specifies the amount of free space to be maintained on-line (in the primary disk subsystem). DMF migrates files to achieve the required free space using rankings specified in the configuration file. Rankings can include file size, file type, and file age. During an initial migration (copy), a file can exist both on-line and off-line (on the secondary tape storage system). When a file is both on-line and off-line, it is in a dual-state. When the minimum free space threshold is reached, DMF selects files based on their rankings and removes them from the primary disk subsystem. The file is now completely off-line (exists only on the secondary tape storage system). The larger and older files have increased ranking for removal. The file system structure of the on-line storage system remains intact, and the subdirectories and files continue to appear as if they are all on-line.

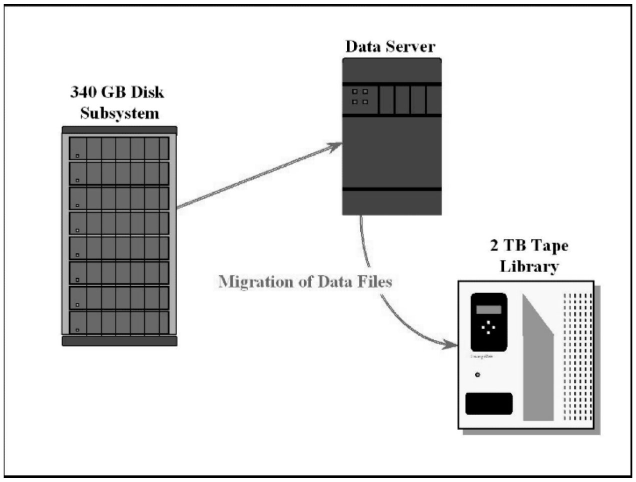

Figure 6 Digital SSS data flow during migration to tape library

WHITING's transition from operating two analog side scan systems to three digital side scan systems, including the HSHRSSS, represents an increase in digital data from approximately 3MB per day to an estimated 33GB per day. The increased capacity and data management responsibilities clearly require some automation. Effective data analysis by the hydrographer requires data to be easily and quickly accessible throughout the survey project's data acquisition and processing periods. The WHITING's data management system, when fully operational, will provide the infrastructure to manage these volumes of data, and allows for effective expansion.

4. Data Management Systems for RAINIER and Hydrographic Processing Centers

The WHITING data management system is mostly representative of the other systems now in place, differing only in complexity because of the additional robotic tape library, DMF software, and two SGI Octane workstations dedicated for SIPS processing. Although this was the first Coast Survey data management system conceived using an SGI Origin 2000 server, it has not yet been installed aboard WHITING. This was in part due to delays in the maturation process of the DMF software – SGI only made the first production released available in September 1998 (an admitted concession to one of our design objectives). A more significant reason for deferring the WHITING system was the higher priority of implementing data management systems aboard RAINIER, at the Norfolk, Virginia, and Seattle, Washington Coast Survey hydrographic processing centers.

The three Origin 2000-based data management systems now in operation are all very similar to each other. They are configured as both data management servers and as application servers. The RAINIER Origin 2000 server is configured with four R10000 195 MHz MIPS processors, 512 MB RAM, five fast Ethernet ports, eight differential SCSI ports, and three 9GB hard drives (branch systems feature only two processors in their Origin 2000 servers). RAINIER's primary disk storage consists of two SGI RAID systems. Each RAID system contains two RAID controllers, three power supplies, and forty 9GB drives. This gives RAINIER over 320GB of on-line fault tolerant disk storage. The processing centers have one SGI RAID system each configured with ten 18GB drives. DDS3 4mm DAT (digital audiotape) and a DLT7000 tape drives are also connected to all Origin

2000 servers for data backup and software transfer. The estimated volume of data collected by RAINIER does not warrant the additional expense of the StorageTek tape library or the DMF software at this time. In the case of the hydrographic processing centers, the quantity, rate, and processing scope of contract hydrographic data, combined with the expected data load from WHITING and RAINIER, will require further analysis before additional data storage or HSM-type software can be considered.

In these three systems, the Origin 2000 servers are also host to the CARIS/HIPS and CARIS/SIPS processing applications. Operators log onto high-end PC workstations aboard RAINIER, or at the processing centers, and run CARIS processing sessions. Each Origin 2000 server is currently licensed to host up to five concurrent CARIS x-terminal sessions using Hummingbird EXCEED X-Windows software. Glang, Noll, and Riley (1999) will cover in more detail the special requirements of RAINIER in Implementation of Shallow Water Multibeam Systems aboard a Multi-Platform Vessel for Alaskan Hydrography.

5. Conclusions

The data management systems now operational represent the second leg in what can be likened to an implementation triad of new Coast Survey hydrographic technology. In the first leg, the new SWMB and HSHRSSS became operational. The spatially dense SWMB data and voluminous HSHRSSS data acquired by multi-platform vessels require robust data management systems – the second leg. The third leg, not touched on in this paper, is the tremendous demand these systems place on hydrographic personnel. A significant key in the success of these data management systems, and in the success thus far of Coast Survey's new hydrographic systems, is the enthusiasm and energy of NOAA survey technicians, electronics technicians, and support personnel. The learning curve to maintain and operate the new hydrographic systems and these data management systems is steep. Additional training opportunities and funding are needed to further sustain this level of effort as new systems become fully implemented.

Disclaimer: Mention of commercial software or hardware products are not endorsements by the authors or the National Oceanic and Atmospheric Administration.

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