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Drinking From the Fire Hose - Stop Worrying and Love the Byte

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SEAFLOOR MAPPING
SONAR/VESSELS

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A Review of How to Deal With Seafloor Mapping, Data-Overload, Greater Resolution and Bandwidth

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The acquisition of seafloor mapping data has matured remarkably in the past decade. This article reviews some of these advances, with particular attention to how some new technologies have effectively dealt with data-overload, made possible by sensors with greater resolution and bandwidth.

Seafloor mapping - while admittedly potentially a complex, detail-intensive task, involving numerous electronic sensors, telemetry systems and logging/display devices - can be, and often is, best thought of as making pictures of the bottom of the sea. Pictures, as we all know, contain a lot of information. A typical 35 mm color slide, at 9,000 scan-lines per inch, and approximately a 4 x 3 aspect ratio, contains over 2.5 gigabits of information. Clearly, mapping the seafloor can be highly data-intensive, resulting in data overload on both operators and logging devices. The Matrix notwithstanding, people do not deal gracefully with scrolling alphanumeric byte-streams. Scrolling pictorial representations (waterfalls, graphic recorders, etc.) are the usual solution, but often with compression in both physical resolution, and data dynamic range. With recording mimicking display, loss of resolution, or reduction in survey coverage and pace, was considered inevitable. These mandatory losses are now a thing of the past. Sustainable, 24-7-365 reliable, logging and real-time processing of seabed mapping data at rates in excess of 10 mega-bytes per second is available in commercial, off the shelf PC-based packages today.

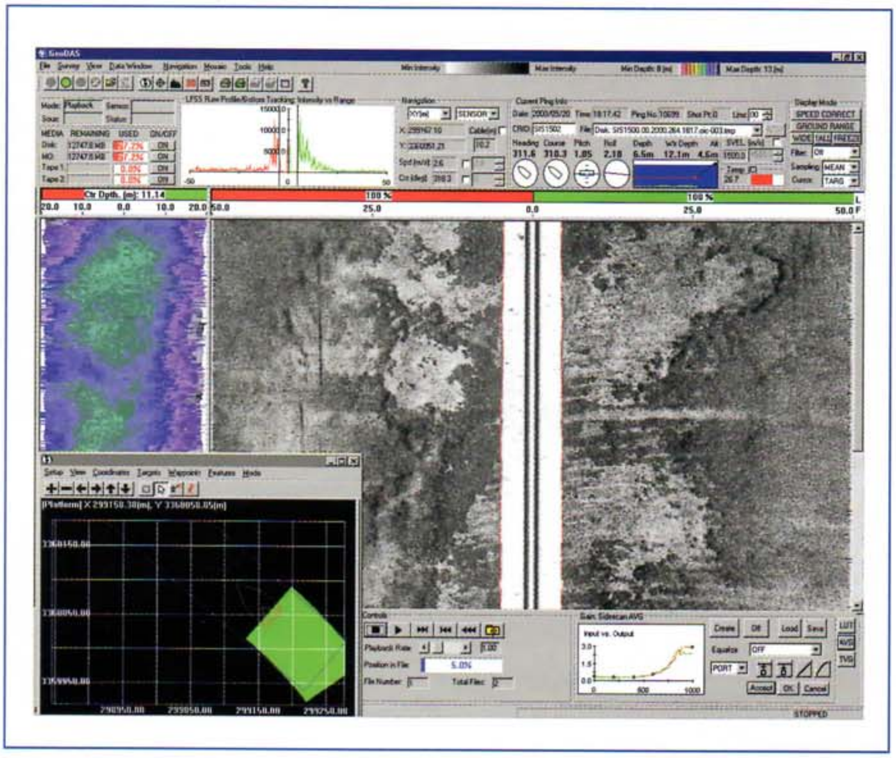
NAVOCEANO Hydrographic survey launch (34' LOA) above.

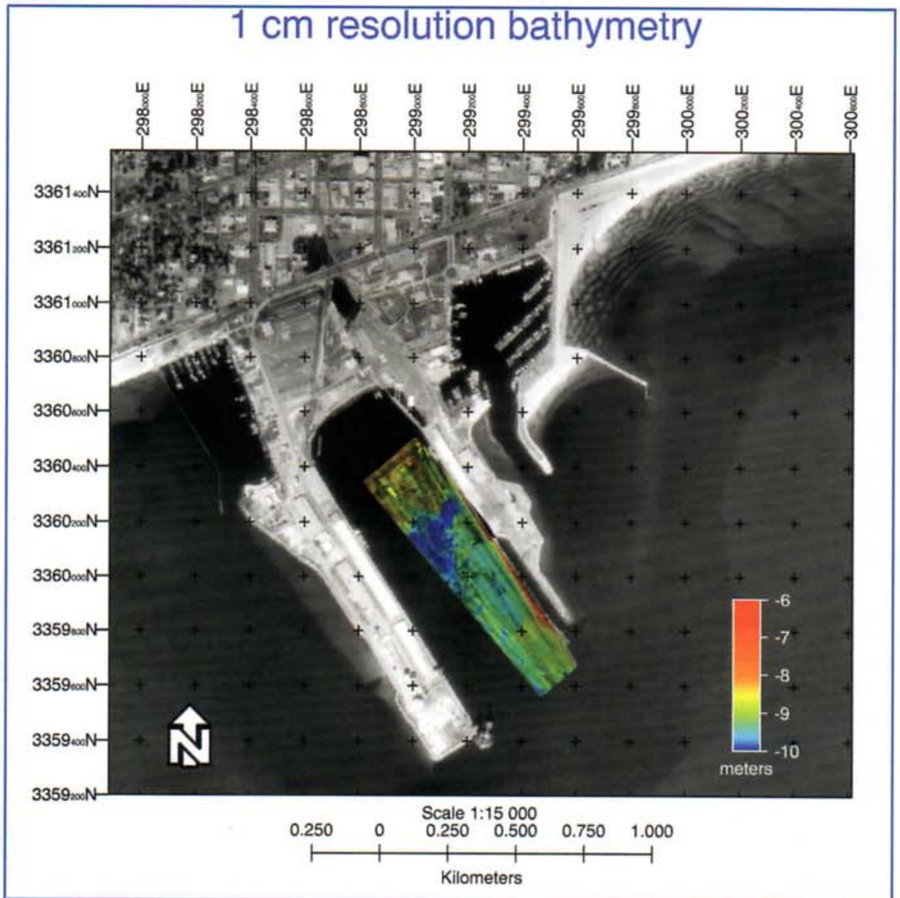
GeoDAS equipment rack (right) aboard NAVOCEANO ship, with dual 1,280 x 1,024 monitors, rack-mount keyboard, CPU, Sonar MUX and printer, plus integrated winch controls, USBL tracking unit and deck cameras.

Historical Perspective

At a first glance, seabed mapping systems can be categorized into two families: acoustic systems, such as echo-sounders, sidescans, multi-beams and swath-interferrometric devices, and non-acoustic devices, such as traditional cameras and videos, electronic still cameras (ESCs) and laser line scan systems (LLSs). We recognize that profiling systems such as single and multi-channel seismics, magnetometers and gravimeters are equally important mapping tools, but for the moment restrict our analysis to systems providing imaging in the traditional planimetric format.

A typical two-channel analog sidescan system actually provides a large amount of information. Fortunately, roll-paper records are quite efficient at gathering this, albeit somewhat difficult to carry around in significant quantities. When taken to the digital domain, a quantitative notion of the data available to us becomes apparent. Assume a reasonable digitization rate of 24 KHz, yielding a constant slant-range resolution of three centimeters. Assume 16-bits sample resolution to encompass the likely range of raw backscatter variations in amplitude. This implies a data rate from a simple two-channel sidescan of approximately 100 Kbytes per second, or 360 megabytes per hour. This will fill a zip-disk in 15 minutes, and a 1 GB optical platter in less than three hours. To people planning a 30-day cruise, this begins to look expensive. In steps down sampling.

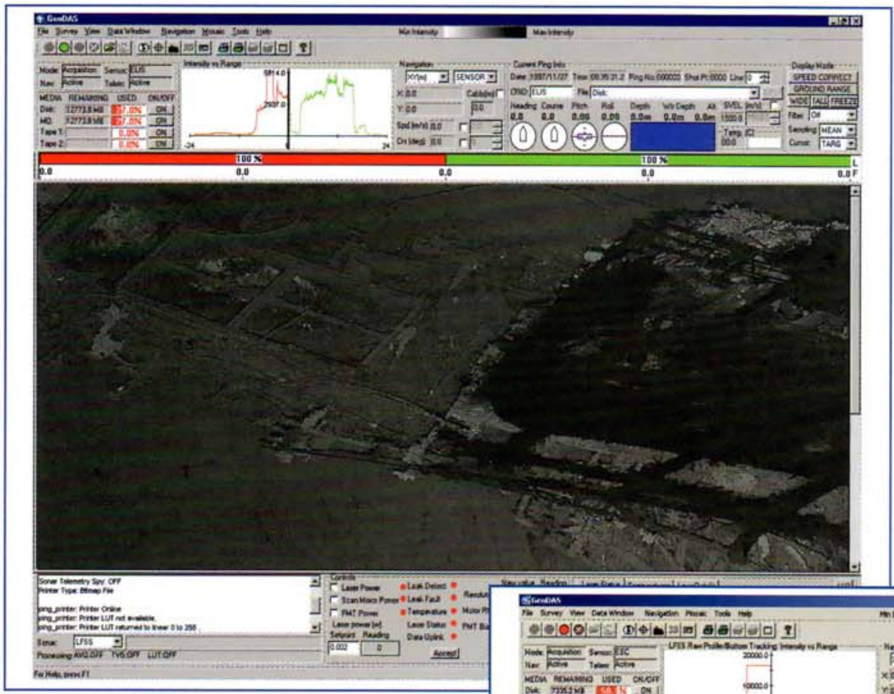


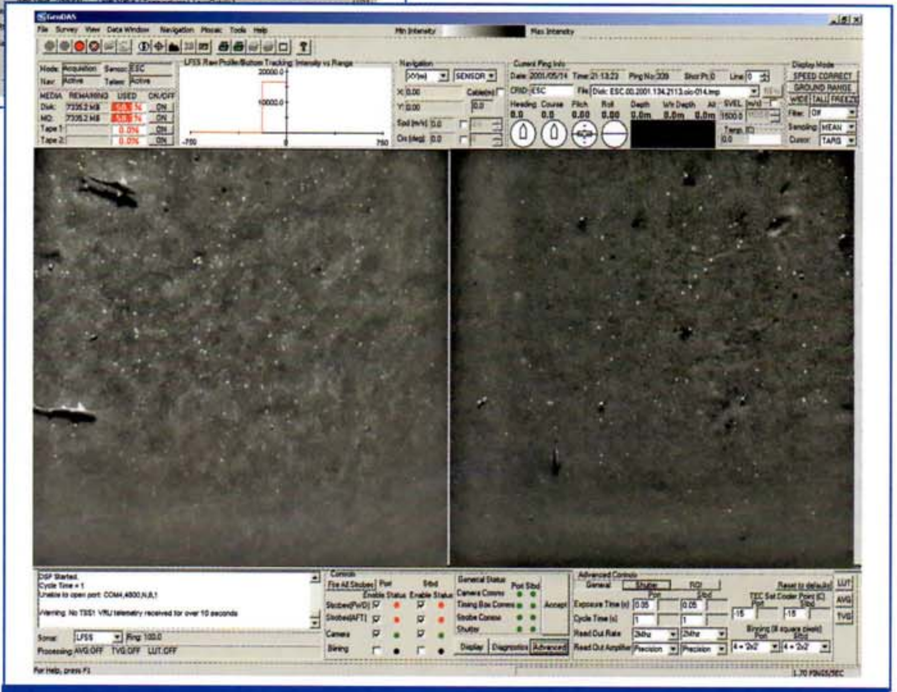


GeoDAS (top, right) user interface, showing color-contour bathymetry in parallel with sidescan (100 or 500 KHz).

Quick-look mission product created from HSL bathymetry and sidescan, mosaicked at one centimeter resolution and merged with available air-photo data for the surrounding region (above).

Perception is everything, they say. A high-quality roll-paper recorder can display 4,096 samples across a scan, and you do not need to hire a programmer to show your boss the data. For the typical sidescan mentioned above, this would allow you to show full resolution data for any swath of 50 meters range or less. At any range greater than that, you would have to throw away some of the data. At 100-meter range, you would have to throw away half the data, for example. Furthermore, the human eye can only distinguish between 16 and 32 shades of gray. This translates to retaining, at best, one third of the original dynamic range. If you take this same data to an XGA computer monitor, you are limited to only 1,024 samples across a line, and a depth resolution of 8-bits. Let us assume you may have two screens, so now, in theory, you would need to log only 1,024 samples per side, 8-bits per sample, to make maximum use of your digital display system. If you operate at 100 meters range or greater, and only log what you display, you have





GeoDAS-LLS, showing data from the Raytheon LS-4096 (top, left).

GeoDAS-ESC, in the dual-camera configuration (above).

irretrievably discarded more than 75 percent of your data. No amount of post-acquisition signal processing magic can bring this lost data back. Furthermore, any operator-induced changes to gains, contrast stretches, etc. are likely to be permanent. Logging raw data at full resolution and full dynamic range obviates these problems. It just requires media space, and throughput bandwidth.

New Developments

In 1997, the United States Naval Oceanographic Office (NAVOCEANO) embarked upon a fleet modernization program for its T-AGS 51, T-AGS 60 and T-AGS 45 class oceanographic survey vessels and accompanying Hydrographic Survey Launches (HSLs). Mission requirements included high-resolution sea floor mapping and object location/identification in littoral areas of the world, typically under adverse environmental conditions. Specific requirements included simultaneous acquisition, display and logging of dual-frequency sidescan sonar data, single and multibeam bathymetry, and beam amplitude and backscatter. Per the specification, the maximum anticipated data rate would be up to 1 Gigabyte per hour, which the sonar data acquisition workstation would be required to log to both tape and hard-drive. Anecdotally, this prompted the requirement for, at best, a 9 GB hard drive, as it was mentioned that "...no government worker was ever required to work more than an 8 hour day..."

Oceanic Imaging Consultants (OIC) was selected to provide GeoDAS as the sonar data acquisition and processing workstation for the T-AGS ships and HSLs, interfacing to the Datasonics SIS1502 dual-frequency sidescan, as well as the Simrad EM3000, for multibeam bathymetry and backscatter.

The rack-mount GeoDAS workstation was delivered with dual 1,280 x 1,024 monitors, dual 18-GB hard-drives and dual 20 GB Exabyte Mammoth tape drives. A quad-port Ethernet card allows simultaneous receipt of both the broadcast Simrad multibeam bathymetry and TSS-PosMV navigation and motion sensor data, as well as re-broadcast of processed OIC records of merged sidescan and bathymetry to client workstations, either on the launch, or at a remote location, via Ethernet radio link. The latter technique allows observers back on the host T-AGS ship or land to view raw or processed data from the HSLs as the data are being acquired, offering both immediacy of analysis, and easy remote trouble-shooting of any data quality issues which might arise.

The sidescan on the HSLs is a Datasonics SIS1501/2 dual-frequency system. The 1501 model indicates CW technology, while the 1502 indicates that the sonar can operate in both CW and chirp mode. GeoDAS interfaces to and controls the SIS1501/2 through the Datasonics multiplexor and proprietary .dll, which allows full control of sonar range, wet-gains, pulse type, length and power, and also provide both sensor telemetry and a continuous 192 Kbytes per second data feed. GeoDAS logs all this data raw, without any filtering or down sampling, and then applies user-specified processing to allow real-time data display in a variety of views (profile, waterfall, mosaic).

The multibeam on the HSLs is the Simrad EM3000s, a 300 KHz sounder which provides 127 beams over a

ROVer's Eye view of the bottom of Honolulu Harbor, with TargetView mode on, providing automatic notification of proximity of previously marked targets.

swath of up to 200 meters, or four times water-depth, in waters from 0.5 to 150 meters deep. The system outputs both raw and corrected bathymetry datagrams over a 10 Mb/sec UDP link. It can also broadcast both beam amplitude (average backscatter per beam) and the raw time-series backscatter data at full resolution (3 cm). GeoDAS catches all these datagrams and logs them in parallel with the SIS1501 sidescan data, and offers the user options for both processing and display selection. By default, the console will present a waterfall showing platform and sidescan attitude, course, etc., along with synchronized color-contoured bathymetry, and either low or high frequency sidescan. The user may modify views and processing on the fly without interrupting data logging, to optimize onboard analysis such as target detection and survey status.

The combined data streams from the sidescan and multibeam comes to just under 1 GB per hour, which GeoDAS logs continually to dual Exabyte 8900 tape drives, and optionally prints to a rack-mounted roll-paper recorder. The operators may also elect to create real-time mosaics of both the sidescan and bathymetry data, in a variety of projections, at user-definable scale and orientation. The geo-coded mosaics can be exported to an on-board GIS package, and merged with existing data for quick-look mission products.

Double or Nothing

In the fall of 2000, OIC began work on an interface to the Raytheon LS-4096 Laser Linescan system. The LS-4096 provides continuous 14-bit imagery from a scanning laser mounted on an underwater vehicle. Resolution is configurable from 512 to 4,096 samples per scan line, at scan rates up to 4,000 rpm. At maximum resolution, the LS-4096 delivers 2.2 Mbytes per second, at approximately 267 scan lines per second. This data rate doubled that which had been required of GeoDAS in the past, and exceeds conventional sonar imaging requirements by at least a factor of 100, if not more. The original top-side processor allowed saving of user-selected snapshots, but any continuous data logging could only be accommodated on video tape, which could not take advantage of the full imaging resolution potential of this system. Any geo-coding of data required manual cut-and-paste operations post acquisition.

GeoDAS-LLS provides a complete control, processing and display interface to the laser linescan system, treating the data stream as a single-channel sidescan (albeit, a very fast sidescan). This includes full resolution raw data logging, as well as real-time and post-acquisition processing, targeting and geo-coding.

The laser data can even be merged with co-registered sidescan data, to provide an ultra-high resolution gap-filler directly beneath the track of the sonar. Co-registration of sidescan and laser imagery provides significant improvements for search and recovery, bottom characterization and mine-hunting operations, with the laser data offering the potential of on-the-fly target identification, augmenting the sonar's extended abilities for target detection.

Not Just Another Pretty Picture

This spring, OIC completed its modifications to GeoDAS to support electronic still camera imaging. The completed interface retains the look-and-feel of the original GeoDAS user interface, while allowing continuous acquisition, processing and display of single or dual camera imagery, at data rates up to 10 MB per second. The interface supports multiple modes of display, including scrolling, binocular and single image view, to accommodate images up to 1,280 x 1,280 pixels on a side, at 16-bit dynamic range. A dual camera configuration at one Hertz frame rate in continuous operation mode will fill a 60 GB 8-mm tape in just over two hours. Dual tape-drives allow automatic roll-over, for uninterrupted logging (provided you brought a lot of tapes). Retaining the basic GeoDAS format, while accommodating data records easily 1,000 times more than your average sidescan record, proved challenging, but the result provides the same processing, targeting, logging and QA/QC interface as available for scan-line based systems, minimizing operator re-training and maximizing product reliability.

Data Integration

While the above examples demonstrate available solutions for the mechanics of multi-sensor, high-rate data acquisition, there remains the issue of operator overload, and interpretation. Simply put, someone has to look at all this. If we can now simultaneously acquire swath acoustic data, providing a half-kilometer swath of acoustic imagery and bathymetry, and optical data, providing sub-centimeter scale imagery over a patch, which might barely cover the nadir footprint of the sonar, how are we to co-register and compare the two modalities?

ROVer's Eye, a real-time terrain visualization package developed by

OIC under DARPA funding, provides one option. ROVer integrates a high-speed 3-D rendering package with GeoDAS's real-time-processing and target analysis package to provide an interactive immersive experience wherein underwater vehicle operators can work not only with existing models, but see new data from on-board sensors evolve into the current model in real-time. ROVer accommodates simultaneous inputs from sidescan, bathymetry and navigation systems, while accessing a database of existing data, targets and as-built structure models. Operators see new data evolve in a model before them, just as headlights reveal the road ahead to nighttime drivers. Road-signs in ROVer reveal not gratuitous advertising (nor Burma Shave ditties), but full resolution images of proximal targets, which pop-up as the vehicle passes by. The combination of synoptic swath data with detail-rich target imagery in a fully geocoded environment provides a whole new level of data interpretation experience.

Summary

Seafloor imaging is a data-intensive process. Down-sampling strategies compromise both image resolution and quantitative information potential. GeoDAS, an off-the-shelf solution for acoustic and non-acoustic seabed data acquisition and processing, can provide a uniform interface to sonar, laser and camera-based imaging systems, handling raw data rates up to 10 MB per second with no down-sampling losses, while retaining real-time interactivity. Examples are provided from working installations. /st/

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