NOAA Scientific Computer System (SCS)

by

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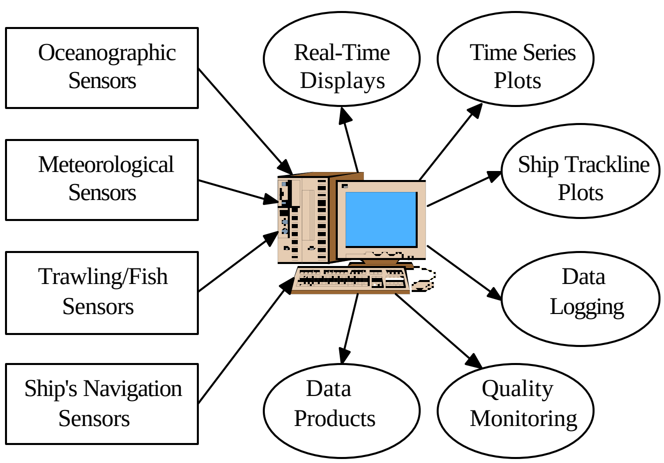
The National Oceanic and Atmospheric Administration's environmental science mission requires the use of highly specialized ship platforms and a wide variety of shipboard and deployed sensors to acquire data on the oceans and atmosphere.

To meet the demands of collecting this diverse sensor data and make it available to scientists on a real-time basis, engineers from the Office of Marine & Aviation Operations (OMAO) in conjunction with NOAA scientists have developed and implemented a Scientific Computer System that can be quickly configured to utilize new sensors and mission parameters without requiring software modifications. SCS is currently installed on eleven NOAA ships with missions that range from fisheries stock assessments and research to global deep-ocean and atmospheric research.



The benefits of SCS are manifold. The system provides users with real-time data products, event logging and management, data collection, data visualization, and quality assurance. It is a valuable tool to scientists as they conduct their research, providing them with rich background data sets, the ability to make immediate decisions based on visualization of real-time data, and tools to detect interrelationships among the data. Whether a scientist is searching for whales on a warm water core boundary, towing a CTD across a volcanic vent, or collecting plankton in a bongo tow, SCS provides insitu data to make decisions about the progress and quality of the operation.

To ensure consistent data throughout the community while providing these important capabilities, SCS utilizes manufacturers' sub-systems, where appropriate, to collect complicated data sets such as ADCP, EK500, and CTD. SCS interfaces to the sub-systems, acquiring sub-sample data to visualize the process while relying on the manufacturers' software to provide the full data sets. However, SCS collects data directly from multiple navigation, meteorological, oceanographic, and fisheries sensors, utilizing the standard digital interfaces available in the industry.

SCS was originally designed and certified operational on the NOAA ship *Malcolm Baldrige* in 1989, and has since been installed incrementally throughout the fleet. The original systems were complex, requiring significant training in operating system and software operation. However, the basic paradigms of flexible sensor configuration, acquisition, and real-time data access and display have remained constant to the present time.

SCS has become a mature scientific data acquisition system, its software evolving as technology has become available. In 1993, the system was enhanced to include a GUI (Graphical User Interface) based on the X-window OSF Motif window standard. With this technology and increase in CPU power, the user could more easily interface with the system and perform more tasks simultaneously. The system was ported to the Microsoft Windows NT operating system in 1997/98 and is now running on Pentium Class PCs. This has furthered enhanced the user-friendliness of the system and its general utility while reducing the cost of implementing a system. The advantages of operating SCS in the NT environment include portability, scalability, cost savings, and access to off-the-shelf products that enhance SCS without burdening it with additional code. Individual scientists will be able to run the SCS post-processing suite of software in their labs on a Windows 95/98/NT/2000 PC platform without requiring expensive workstation hardware.

The SCS system is presently based on two redundant Pentium Class PCs. One system serves as the primary data acquisition platform; the other acts as a hot spare and provides a dedicated platform for scientists to review the collected data. Each system is identically configured with four 18GB RAID disk drives, a 20/40GB DDS4 tape drive, a 21″ monitor and 512MB of memory. Table One describes a standard hardware configuration.

Table One : SCS Hardware Configuration

Dell PowerEdge 1400 (1.0GHz Pentium III)
54GB RAID-5 Disk Sub-system (4 18GB Ultra3 SCSI disk drives)
512MB RAM
20/40 GB DDS4 4MM Tape Drive
Writable CD-Rom Drive
21 inch Monitor
Digi International 32 Serial ports (Direct Connected)
Digi International 16 Serial port server (Network Connected)

All 10 NOAA vessels running the original OpenVMS X-Windows version of SCS have been converted to the Windows NT data acquisition platform as of August 1999. Table Two describes the SCS-capable ships within NOAA, their primary missions, and general operational areas:

Table Two: NOAA SCS System Deployments

MILLER FREEMAN	Fisheries (NE Pacific/Alaska)
DAVID STAR JORDAN	Fisheries and Oceanography (West Coast / Tropical Pacific)
TOWNSEND CROMWELL	Fisheries Mid-Pacific (Hawaiian Chain)
McARTHUR	Fisheries and Oceanography (West Coast, U.S.)
KA'IMI MOANA	Oceanography (Whole Pacific)
RONALD H. BROWN	Oceanography (World's Oceans)
ALBATROSS IV	Fisheries (East Coast, U.S.)
DELAWARE II	Fisheries (East Coast, U.S.)
OREGON II	Fisheries (Gulf of Mexico/SE U.S)
GORDON GUNTER	Fisheries (Gulf of Mexico/SE U.S.)

SCS is also installed in a van for rapid deployment on a charter vessel.

System Capabilities

The SCS system utilizes a single high-priority acquisition process (ACQ) to collect all of the sensor data. When a sensor message has been acquired by the system, ACQ time stamps the message data, breaks the message into sub-components, stores this data in a large circular buffer for access by the remaining SCS processes and logs the data to disk. A Client/Server architecture is employed to provide access to the data via the network and allow any PC running Windows 95/98/NT/2000 to display or plot the data in real time. This improves the reliability of the system by removing user programs from running concurrently with acquisition on the same computer.

The entire system is operated from a single pull-down menu that provides the user a consistent interface for all activities from both local and remote computers. The menu is password-protected to isolate management functions that may affect data quality from the generic user. All items within the SCS menu are supported by detailed context help, as well as specific help within each application. Time synchronization on the SCS computers and ship network is provided by a GPS clock interface to a network time server. This ensures that all data collected may be easily related. The SCS system capabilities may be broken down into six functional areas. These areas are discussed below in some detail.

Data Acquisition

The foundation of SCS is the concept of a flexible sensor configuration file (SENSOR.SCF). The idea here is that the user categorizes a new sensor into one of a set of sensor types, and then describes all of the salient characteristics of the sensor in this configuration file. When an acquisition session is started, the system automatically configures itself to accept this data and to perform the necessary functions on the data based on the user's configurations. This file controls such basic characteristics as physical interface port, name, units, logging rate, acquisition rate, and specific sensor-type information that describes the sensor's format and key synchronization characteristics.

Each piece of sensor data is treated independently and is received from the sensors in a "when ready" asynchronous fashion. Typical industry sensors are complex and include multiple pieces of information that need to be tracked and utilized independently of the main message. Therefore, the user also describes how the parent sensor message should be broken down into components, and then each component is assigned its own sensor ID number and treated separately. For example, a GPS sensor typically includes latitude, longitude, ship's speed, course, and other satellite-specific components. The user would determine which components to track, and describe where each component would be found in the parent message. SCS would then acquire the data, automatically break out each component, time stamp the data, and make it available to be logged, checked, displayed and/or transmitted to the user on demand.

SCS typically interfaces data to the system via serial connections. This data may be a continuous stream of periodic data or data that is requested with a poll command to the sensor from SCS. Non-RS232 serial sensors are typically converted to serial data and transmitted periodically or buffered for polling. Based on this strategy, RS422, RS485, Analog 0-25v, and BCD sensors may be interfaced to SCS via inexpensive converters and described as one of the following sensor types:

Serial Sensor	Periodic ASCII data messages
Polled Serial	Data sent when command is received at the sensor
NMEA	Periodic ASCII data message conforming to NMEA-183 standard
RS485	Interfaced via converters as serial data

A new sensor type has been developed for SCS that acquires data over the network using TCP/IP sockets.

SCS also provides a mechanism to create calculated parameters based on the raw data that has been acquired at a specified interval. This data type is called derived sensor and is used to calculate such parameters as True Wind, Averages, Salinities, etc. The algorithms are pre-installed in the acquisition program and the user simply identifies what pieces of data are to be used in the calculation. SCS provides a mechanism for users to enter data manually from the keyboard and have that data integrated with SCS as if it were received by a physical sensor.

Data Logging

Two primary types of data logging are supported by SCS -- continuous data logging (ACQ) and event-triggered data logging (EVENT LOGGER). ACQ logs all sensor messages received from each sensor for the entire cruise. This data is stored on disk in separate time-stamped files with one file per sensor message. Smaller compacted files are also written simultaneously and are used for quick access to critical pieces of the sensor data. EVENT LOGGER is used to capture data that is specific to a given event and allow the user to manage this type of data efficiently. An example would be a CTD tow or a mooring deployment.

The development of Event Logging resulted from a need to focus on data specific to an operation on the ship. This included not only the sensor data but the operational times of specific sub-events such as a CTD in the water, a net at depth, a mooring deployed, a Pod sighted, and the success or failure of the operation. Key user information such as sensor information (meta-data), watch stander, sea conditions, problems, etc. are typically recorded. Each step of the event, including start, stop, and interim marks, is recorded, and snap shots of key sensor data are automatically recorded. When the event is terminated, the user has a complete digital record of the event and a set of data collected specifically during it.

The Event Logging functions include a QA tool and a report generator that enables quick generation of event summary reports and tracking and documenting an ongoing project. The Event Logger may be configured by the user to operate in three modes: 1) a Manual Event requires operator input to start and stop the event and to enter key data items; 2) a Snap Shot Event is triggered by the user, resulting in a single set of data samples and user data input; and 3) an Automatic Event is triggered by proximity to a navigation position or when a sensor range is being exceeded. Data logging automatically starts and continues while within the specified parameters.

The Event Logger program is also an excellent tool for specifically tracking long-term sensor quality history and sensor meta-data and calibrations. It may also be used to produce lower density data sets that are easily plotted and manipulated.

Currently, the Event Logger suite of applications is under modifications, with some additional capabilities that will make the software more dynamic and configurable for more specific data needs.

Data Visualization

A key aspect of SCS is the ability to provide scientists with text and graphical displays of the sensor data in real time. These displays and graphs may be customized easily by the user to focus on the specific parameters that are required. Real-time displays provide updated sensor values as they are acquired for all of the user-specified sensors. Sensors may be grouped into separate windows for ease of reading.

Time series plots may be configured to watch key sensors over time. Up to four sensors may be viewed at a time, providing a quick method for relating disparate data such as CTD depth, bottom depth, and winch line out.

Real-time Trackline plots provide a quick visualization tool for referencing the ship relative to stations, coast line, and historic track lines. This functionality is rapidly being superseded by the GIS trackline, which incorporates not only coastline and stations but also satellite images, bottom contours, and other geo-referenced operational products.

Real-time Gauges provide yet another method of viewing sensor data. Dial and bar gauges take on the appearance of actual analog gauges typically found on the ship's bridge.

Time series plots and tracklines are also available as post-processing tools to review the collected data and identify problem areas.

Data Access

The explosion of PC technology has made it easy for scientists to develop and use custom DAS systems while at sea to monitor specific sensors or experiments. Quite often these systems need access to permanent shipboard sensor data in real time. SCS provides a means for scientists to configure a custom serial message composed of specific sensor parameters, and have this serial message transmitted at regular intervals to the scientist's PC or instrumentation.

The SCS acquisition system is a central node on the ship's network. The network consists of multiple PCs that are interconnected utilizing TCP/IP and Microsoft NETBUI protocols. Logged data is available to the scientists via network shares configured as Microsoft shares or NFS shares. Standard TELNET and FTP access is available to interface guest computers to the ship system.

In addition, access to real-time SCS data is now possible via a high-speed Inmarsat satellite connection (for those vessels that have a high-speed 65Kbps connection) using standard WWW browsers.

Quality Assurance

Real-time Quality Assurance (QA) checks are performed by the SCS system to check for sensor time-outs and data values out of range or delta limits. The user identifies a specific range for each sensor parameter, and each piece of data acquired is checked. If an error is detected, the error is written to a log file and the user is notified of an error condition. The user may then acknowledge the error after correcting the problem.

Post-collection QA consists of automated plotting functions that produce time series plots of all collected data. These graphs are then carefully reviewed daily and problem areas addressed.

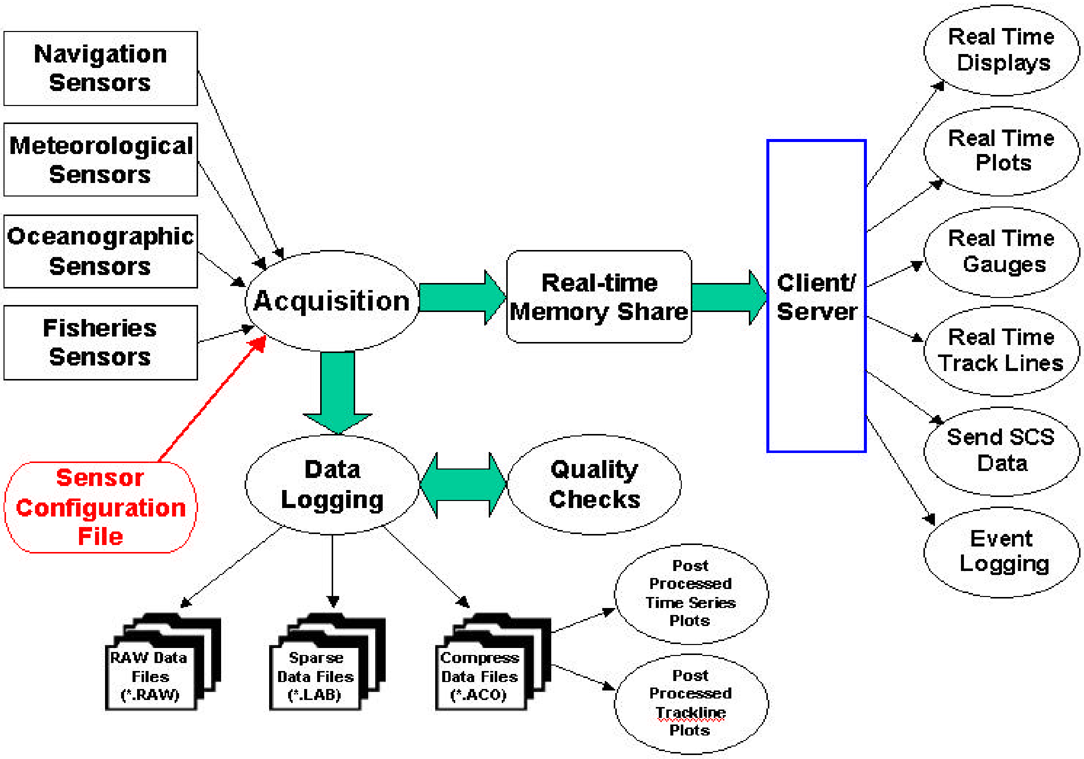
Data Management and Output Products

When the cruise is over, the scientist will have accumulated a set of data products that describe the operational activities, basic environmental and navigation conditions, and specific oceanographic- or fisheries-related sensor data. Summary time series plots and GIS track plots of the cruise with key satellite images and actual stations will be available. This data may be distributed by standard CD-R, CD-RW, 4mm tape, 1.44" floppy, or simply a direct network connection if the ship has access to the network while in port.

The SCS system manager manages the data, performs backups, and prepares the system for new cruises based on a GUI application designed to organize this process.

System Data Flow

The following diagram depicts how data flows through SCS. When Acquisition is first started, it reads in the latest Sensor Configuration File to determine how and where to acquire and log the sensor data from communication ports. That data is stored in a Real-time Memory Share (a portion of the page file) and it is logged to disk in raw ASCII form. During the logging, the raw data on disk is also being monitored for specific quality checks (range, delta, synch, and timeout). Data is also logged to separate smaller ASCII comma delimited files that are used for minimal post processing. The real time data is provided to remote clients via the Client/Server layer (aka SCS Data Server). This ensures that the data flows out to remote clients, but does not allow any remote client to adversely affect the Acquisition process.



Current Partnership Efforts

The Office Of Marine & Aviation Operations (OMAO) is currently under agreement to share the SCS software with the following organizations:

- Brookhaven National Labs – Upton, New York
  - Installed on the Japanese R/V Mirai (Japan Marine Science and Technology Center)
  - Used in CO^2 land-based experiments
- Woods Hole Oceanographic Institution – Woods Hole, Massachusetts
  - Originally examined SCS as a potential data acquisition system for submersible
- International SeaKeepers Society – Miami, Florida
  - Acquisition kernel used in systems installed on yachts
- Skidaway Institute of Oceanography – Skidaway Island, Georgia
  - Data acquired on oceanographic platforms in the Gulf of Mexico and sent back to land via microwave links
- University-National Oceanographic Laboratory System (UNOLS)
  - Installed on R/V Endeavor (NSF/URI)
  - Installed on R/V Weatherbird II (NSF/Bermuda)
- United States Coast Guard (USCG)
  - Installed on USCGC Healy
  - Installed on USCGC Polar Star
  - Installed on USCGC Polar Sea
- Canadian Coast Guard (CCG)

- Installed on CCGS Sir Wilfrid Laurier
- British Antarctic Survey
  - Installed on RSS James Clark Ross

Future Direction

The System Development branch of the Office of Marine & Aviation Operations will continue to expand and enhance the capabilities of the Scientific Computer System. A joint effort with Brookhaven Nation Laboratories has commenced to modify and deploy SCS in other land-based configurations to monitor environmental and meteorological data. Other future additions will include such aspects as Java interfaces to real-time applications, automated data sampling, "paperless" ship logs, enhanced metadata support (including video clips), and possibly voice recognition sensitive collection applications.

Also, the SCS software has been moved over to the Windows 2000 platform and tested in the lab environment. As of now, it has been installed and running on half of the NOAA fleet running SCS, with the remainder of the fleet to be outfitted with new Windows 2000 servers by February 2002.

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Scientific Computer System

SCS v3.2 for Windows NT/2000

RVTEC Presentation

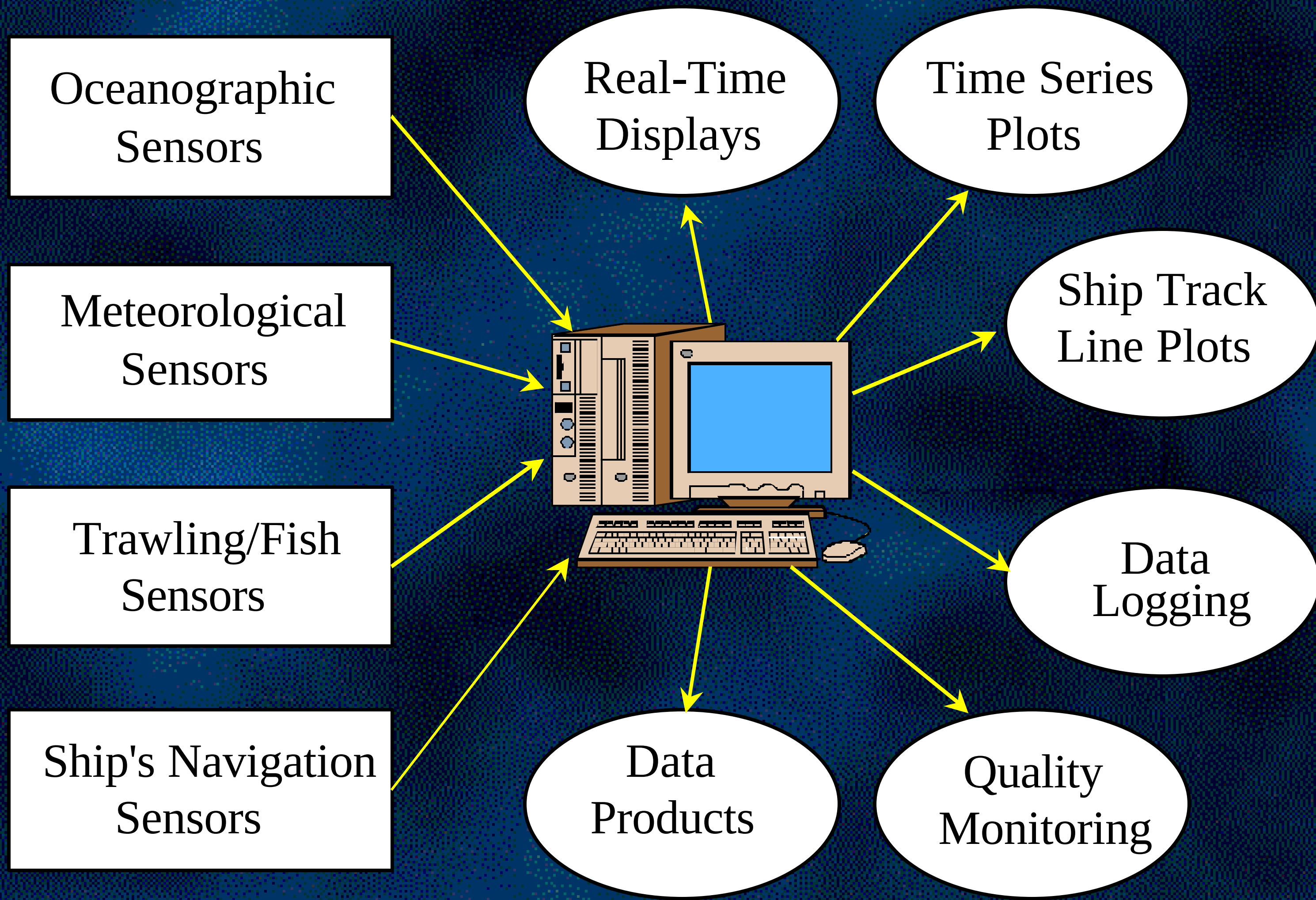
October 24, 2001

David Benigni – NOAA/OMAO

Outline

- SCS Overview
- SCS History
- System Architecture
- SCS Software/ Hardware
- Data Flow
- Primary Functions
- End-User Applications
- Advantages
- Current SCS Vessels
- Partnership Efforts
- Future Direction

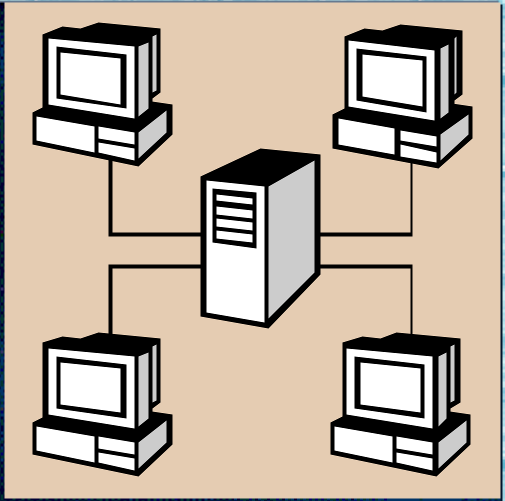
SCS Overview



SCS History

- SCS first designed in 1986
- First operational system – April 1989
  (Command-line/FORTRAN on MicroVAX II)
- GUI front end developed in 1993
  (X-Windows/MOTIF on VAXStation 4000)
- Software re-written in Windows API/MFC and C/C++ by 1997
- Windows NT version of SCS running on 10 NOAA vessels for > 4 years
- SCS now running on Windows 2000

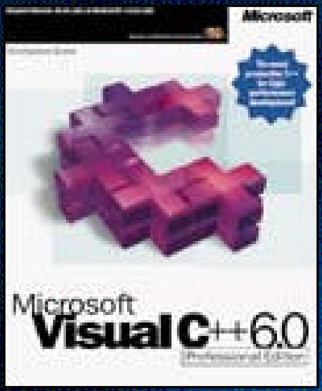
SCS System Architecture



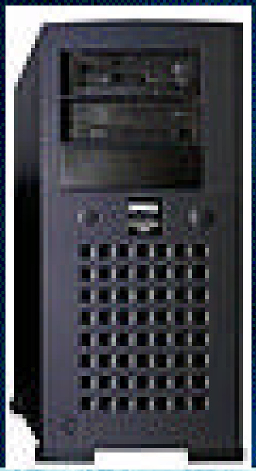
- Client/Server Architecture
- Primary apps run on the server (ACQ, Logger, Event Logger)
- User access via PCs running Windows NT 4.0/2000/98/95 with minimal setup
- Remotely-run apps use own resources (memory, CPU, etc…)

Software/OS/Hardware

- Software/OS
  - O/S => Windows NT 4.0/2000 Server/Workstation
  - GUI => Windows API, MFC
  - Code => C, C++



- Hardware
  - 1.0 GHz DELL PowerEdge 1400 Server
  - 4 18GB SCSI disk drives in RAID-5 configuration
  - 256MB RAM
  - 20/40GB 4MM DDS4 Tape Drive
  - CD-R Writer

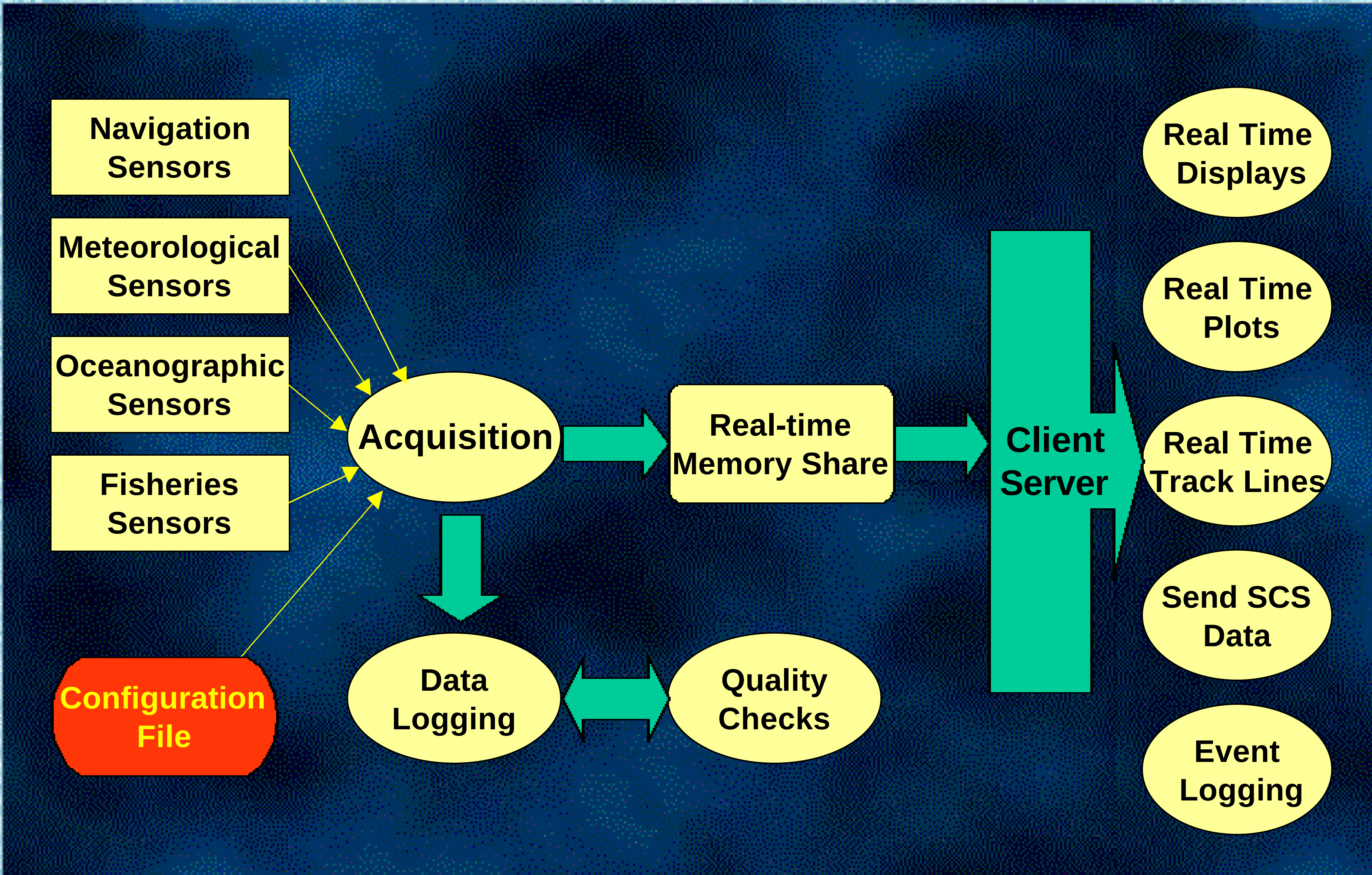


SCS Data Collection

- Digi Acceleport PCI Serial Card
  - Data collected directly into ACQ workstation
  - Expandable to 64 RJ45 ports
  - Simple to set up
  - No major failures to date

- Digi Port Servers
  - Data passed on to acquisition workstation via network
  - Can place anywhere on ship where there is a network connection available
  - 16 RJ45 ports per Server

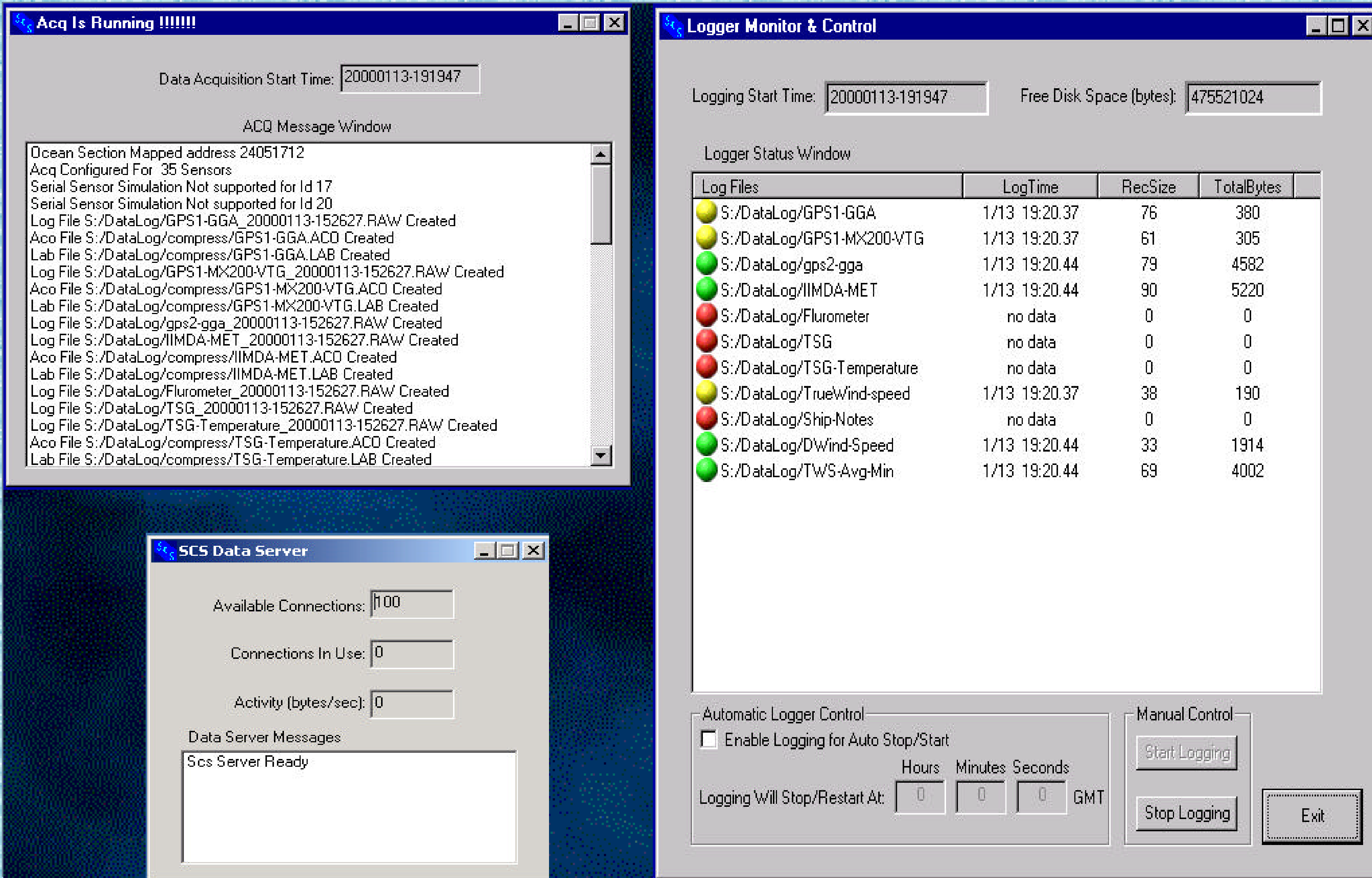
SCS Data Flow



SCS Primary Functions

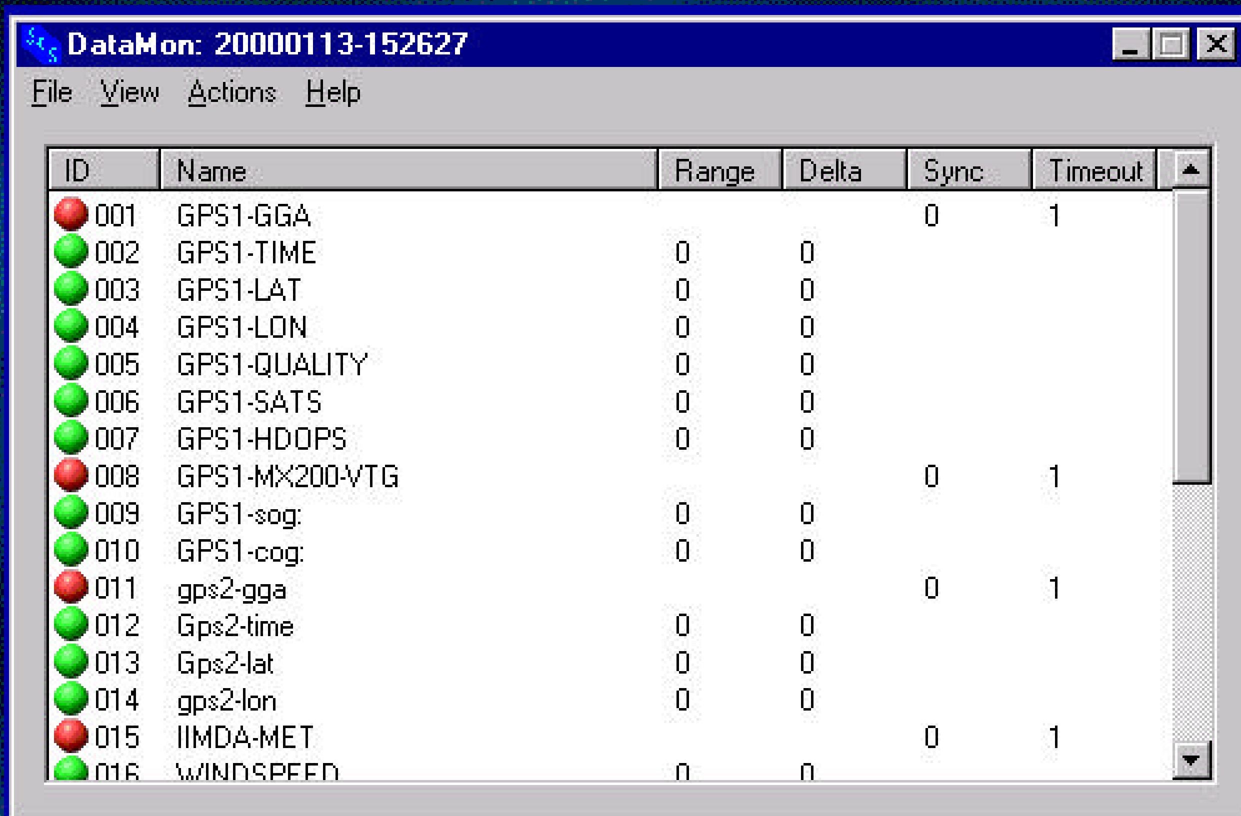
- Acquire real time sensor data
- Log raw data to disk
- Monitor incoming data for errors
- Display real time data in text and graphical formats
- User-configurable Event Logs
- Serial data output to remote PCs
- QA Post Processing of ASCII data set
- End of cruise data products

ACQ/Logger/SCS Data Server



Data Monitoring/QA

- Range Checks
- Delta Checks
- Synch Checks
- Sensor Timeouts



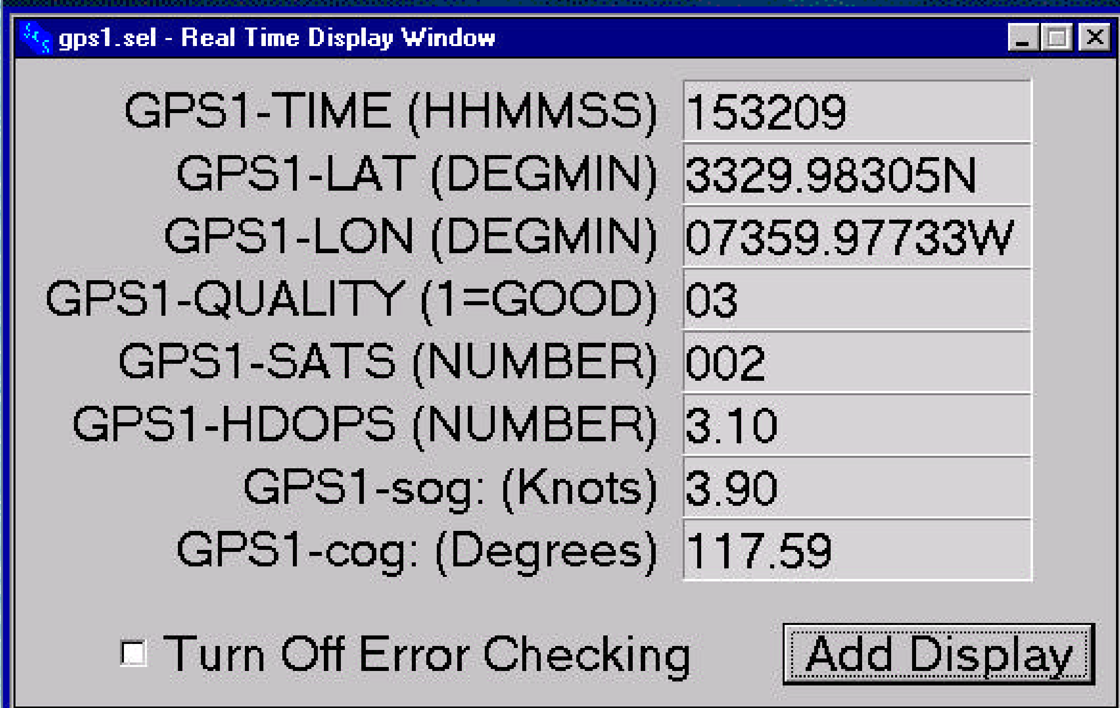
ID	Name	Range	Delta	Sync	Timeout
001	GPS1-GGA			0	1
002	GPS1-TIME	0	0		
003	GPS1-LAT	0	0		
004	GPS1-LON	0	0		
005	GPS1-QUALITY	0	0		
006	GPS1-SATS	0	0		
007	GPS1-HDOPS	0	0		
008	GPS1-MX200-VTG			0	1
009	GPS1-sog:	0	0		
010	GPS1-cog:	0	0		
011	gps2-gga			0	1
012	Gps2-time	0	0		
013	Gps2-lat	0	0		
014	gps2-lon	0	0		
015	IIMDA-MET			0	1
016	WINDSPEED	0	0		

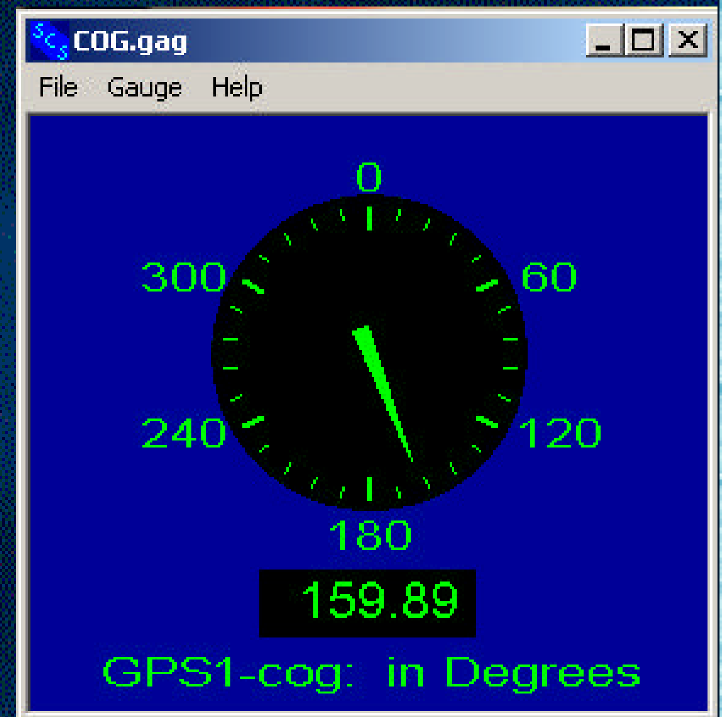
Primary End-User Apps

- Real Time Text Displays
- Real Time Graphical Plots
  - Time Series
  - Track Line
  - XY
- Event Logger
- Send SCS Message
  - Updated
  - Polled
  - TCP/IP Socket

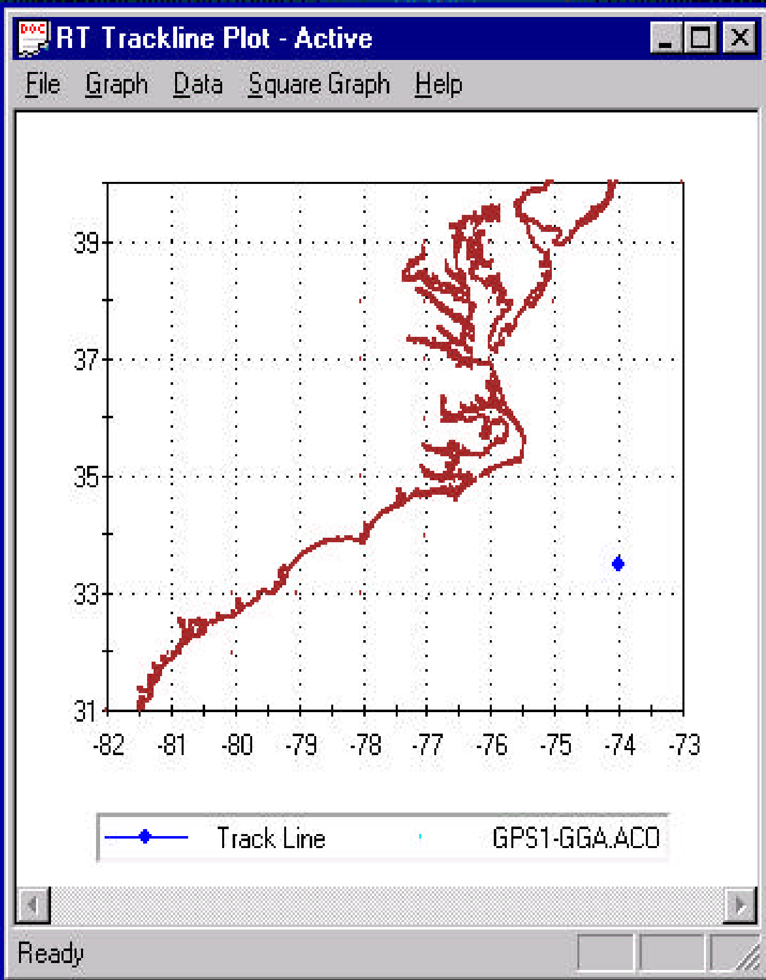
Real Time Displays/Gauges

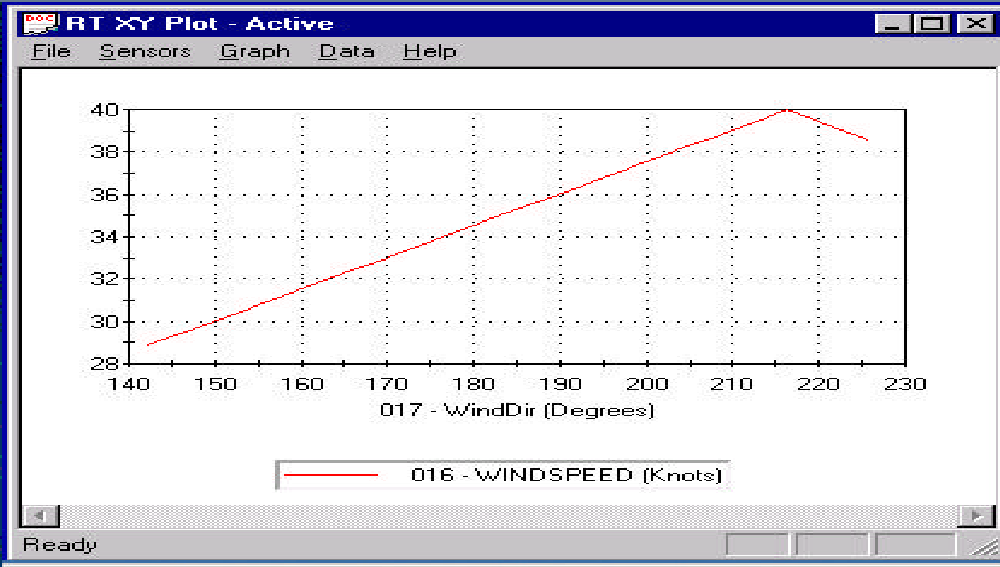
- Provides basic visualization of real-time data
- Displays are user-configurable
- Visual indication when data fails to update

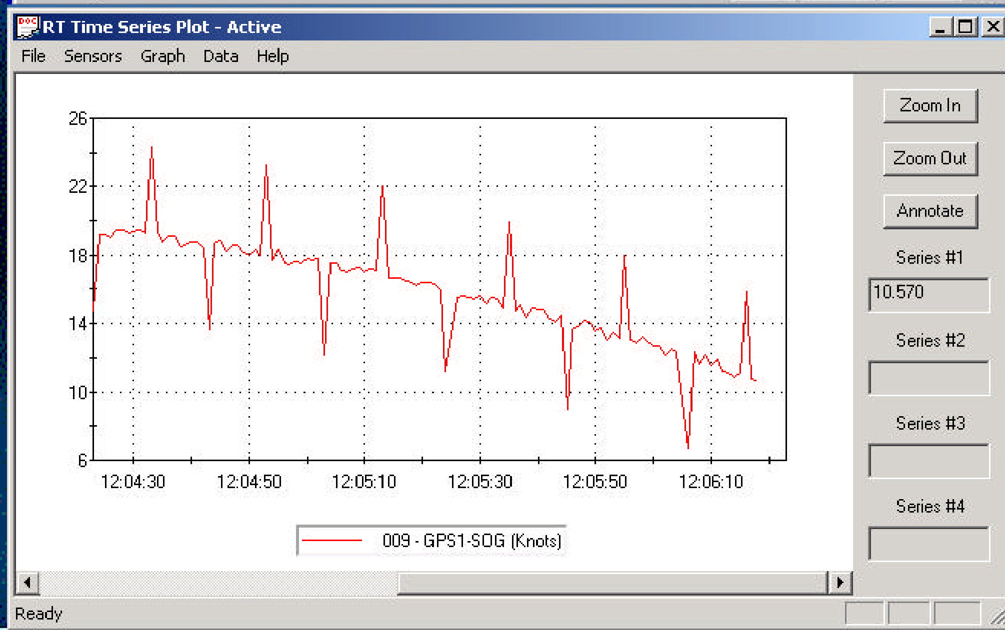




Real Time Graphical Displays

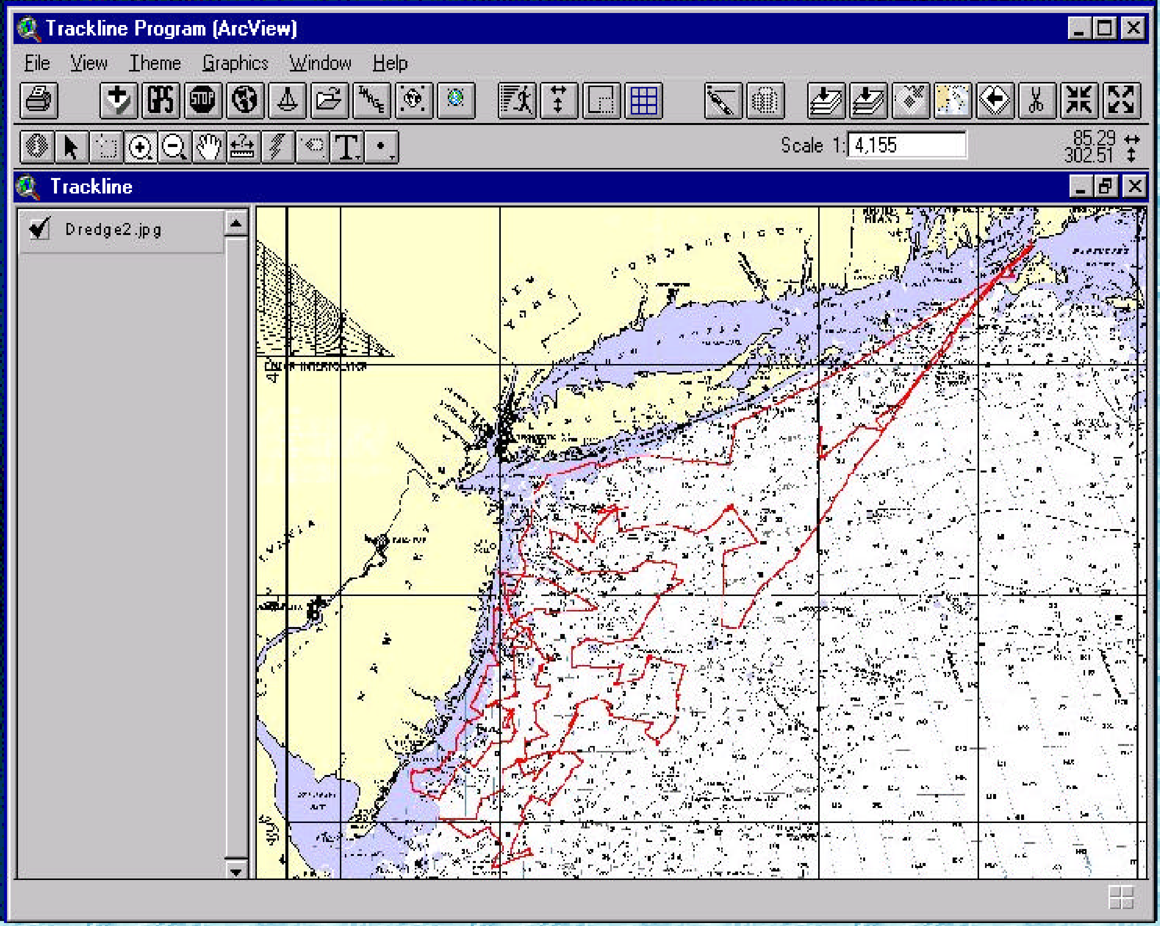






GIS Functionality

- Ship's Track Line
- Coastlines (Digital Chart of the World)
- NOAA Nautical Charts
- Satellite Images
- Contour Data
- Stations/ Waypoints

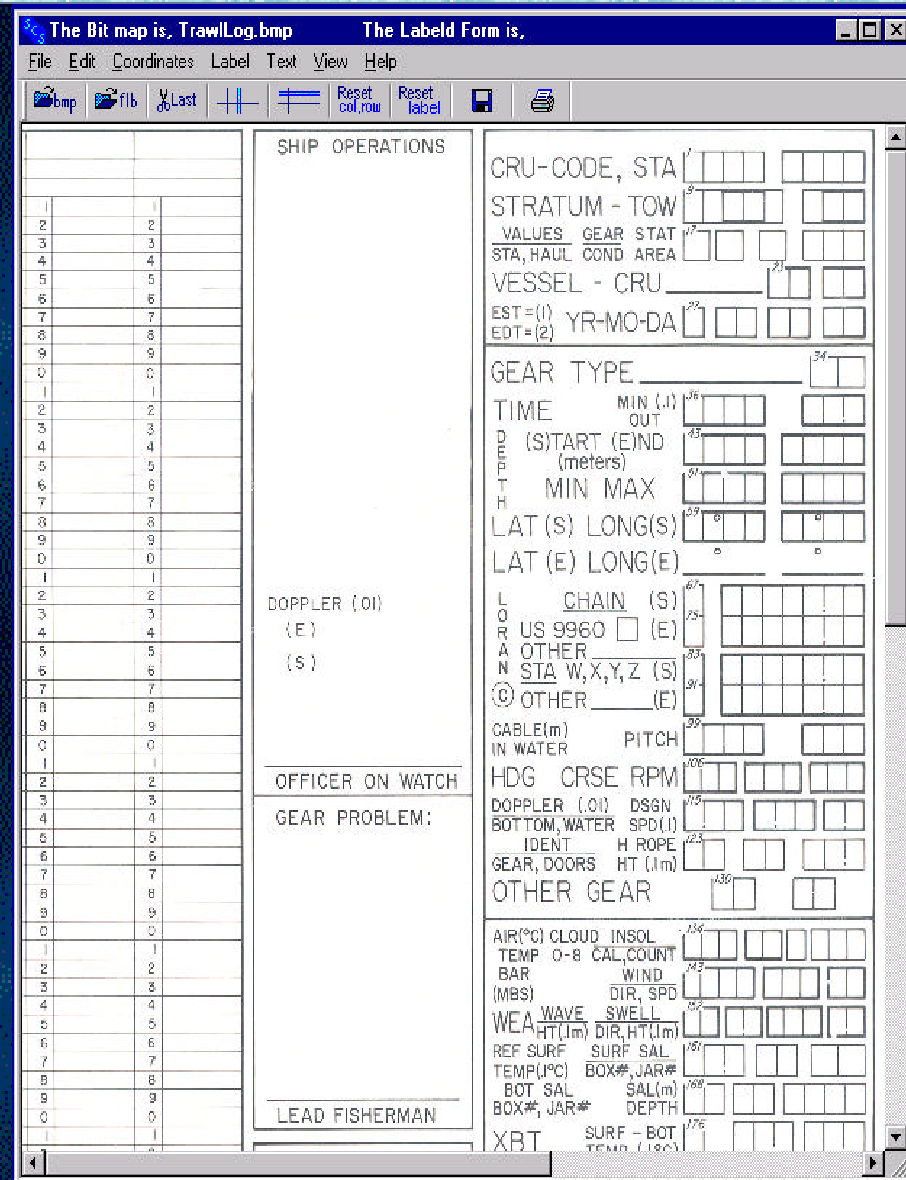


Event Logger

- Provides scientists with personalized/ customized data logging
- Allows metadata to be associated with each event (i.e. vessel, cruise#, etc…)
- Event buttons provide for annotation while the event is running
- Several events can be run simultaneously
- Events can be configured to start automatically (i.e. at a specific time or when at or around a lat/long waypoint)

Event Reports/Automated Logs

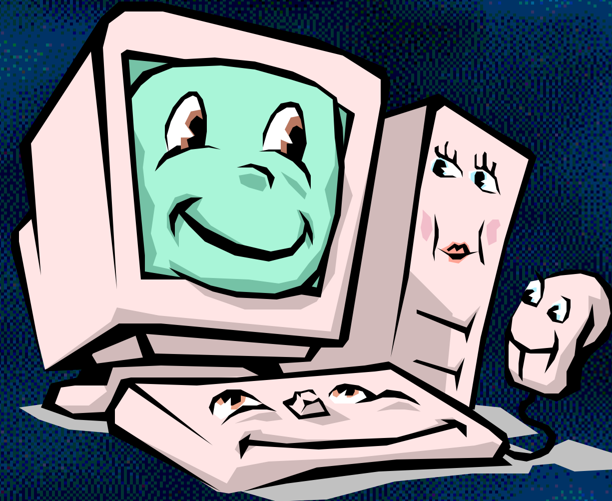
- Scan in paper forms; create digital forms
- Associate event sensor data and metadata with digital form
- Print out filled-in form at end of event



SCS Messages

- Provides customized data strings through standard RS-232 serial connections
- Feeds data collected by SCS into scientists' own acquisition programs
- Polled capability – data sent only after request received from external source
- New TCP/IP Socket capability – data stream provided via the network

Overall SCS Advantages



- Simple to use
- Easy to manage
- Fast and easy to configure
- Stability (in use for > 4 yrs)
- Easy user-access to data
- Standard data end products (i.e. CD-ROM, floppy, ZIP, JAZ, etc…)
- Can be configured to use on any vessel without the need for new software modules

NOAA Vessels with SCS

MILLER FREEMAN	Fisheries (NE Pacific/Alaska)
DAVID STAR JORDAN	Fisheries and Oceanography (West Coast / Tropical Pacific)
TOWNSEND CROMWELL	Fisheries Mid-Pacific (Hawaiian Chain)
MCARTHUR	Fisheries and Oceanography (West Coast, U.S.)
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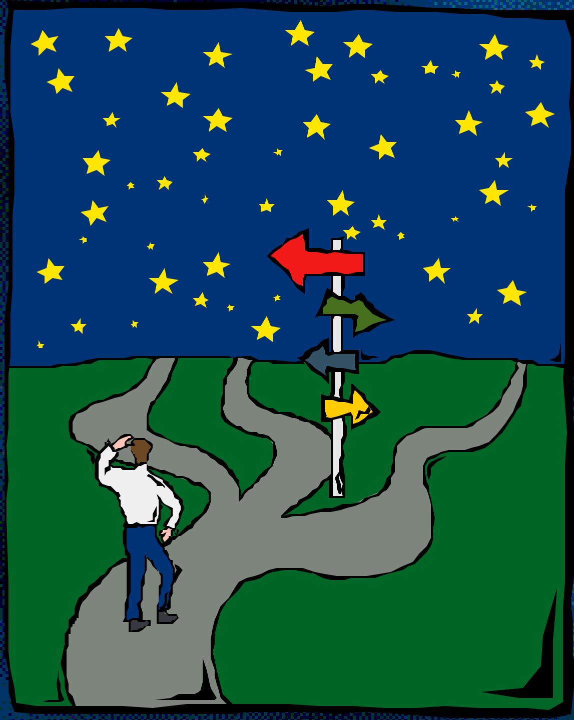
OREGON II	Fisheries (Gulf of Mexico/SE U.S)
GORDON GUNTER	Fisheries (Gulf of Mexico/SE U.S.)

- SCS is also installed in a van for rapid deployment on a charter vessel. Currently on R/V YUZHMORGEOLOGIYA (Antarctic)

Partnership Efforts

- Brookhaven National Labs
  - Japanese R/V Mirai
  - CO2 land-based experiments
- Woods Hole Oceanographic
- International SeaKeepers Society
- Skidaway Institute of Oceanography
- British Antarctic Survey
- UNOLS
- US Coast Guard
- Canadian Coast Guard
- National Oceanographic Data Center (NODC)

Future SCS Developments



- JAVA display applications
- WWW-based documentation
- Technical support via WWW
- Enhanced GIS capabilities
- Improved sensor history and metadata tracking
- .NET/C# development