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consists of a miniaturized Loran-C receiver, a radio telemetry link, a microwave transponder, and a renewable power source. The shipboard end of the system consists of a Loran-C receiver, the telemetry link, a microwave interrogator unit, and a computer to control the system and interpret the measurements. The differential computations could easily be handled by the ship's navigation computer but initial client preference has been to have these computations done off line by an IBM PC or PC clone. Under this scenario the position of the tailbuoy is simply handed to the main navigation system at some time-coordinated interval. Initial tests indicated that the system is capable of 15-m positioning in worst case Loran areas of the Gulf of Mexico and position accuracies of better than 10 m in the rest of the Loran coverage areas. The system is also not limited to one remote but can easily be expanded to track as many as 5 objects simultaneously. This would be crucial in multigun and multistreamer projects that are certainly a big part of the seismic industry's future.

In conclusion, a large portion of seismic exploration done today is high precision and three-dimensional in nature. This trend can only increase in the future as technology expands and profit margins decrease. To date, a stumbling block to this process was lack of knowledge of the shape and position of the recording cable. Buoytrak is a simple low-cost system that allows an operator to track, display, and know the position of the remote end of his recording cable. This system combined with compasses traditionally used in recording cables offers optimum knowledge about the positions of the hydrophones for 3-D seismic projects.

Centralized Marine Control System

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During the last few years there has been a tremendous increase in the complexity of collecting marine seismic data. Not only is this complexity evident in seismic recording systems requiring more channels, finer spatial sampling, longer streamers, etc.; but it is also seen in the shipboard navigation and control systems. Early integrated navigation systems, built around small relatively inexpensive minicomputers, slowly evolved into complex distributed processing control systems. The introduction of new low-cost, high capacity 32-bit minicomputers allows system designers the option to replace these early systems with more efficient, cost-effective centralized control systems. Due to the increased complexity of 3-D collection techniques (real time binning, multiple streamers, two-boat shooting, etc.), more emphasis is being placed on quality control and user friendliness capabilities of the system. An example of this new generation marine control system is described.

Introduction

In the early and mid-1970s, shipboard control systems were primarily integrated navigation systems with primitive capabilities for initiating source activation, for starting seismic recording, and providing relay closures. With the introduction of 3-D data collection and recent trends toward productivity improvements such as multistreamer shooting, responsibilities of the shipboard control system have expanded beyond the capabilities of these early systems. Due to these requirements the majority of the systems developed in the last 10 years were designed using distributed processing techniques. Such techniques extended the life of

some of the early systems as well as provided a means for implementing these systems with relatively low-cost hardware.

During the late 1970s and early 1980s, system designers generally had two options for implementing their systems: (1) a relatively low-cost distributed system, or (2) a centralized system designed around an expensive mainframe. The early 1980s saw the introduction of low-cost, physically compact, large capacity 32-bit minicomputers. This hardware offered system designers a third option for onboard control systems design.

Large capacity 32-bit minicomputers provide for the development of small inexpensive centralized systems eliminating many of the problems inherent with a distributed processing system. Recent advances in data collection techniques require an increase in the amount of data passed between subsystems. A centralized processing approach provides for the elimination of communication bottlenecks that can exist between processors. By having all data resident in a common "data pool," timing constraints regarding the transfer of data between systems are also eliminated. For example, gyro data is available to the navigation task at the same instant it is accessible by the streamer tracking function. There is no loss of accuracy due to a delay in transferring data between processors. Because of the complexity of new collection technologies, increased emphasis must be placed on quality control, expandability, and user friendliness aspects of the system. These characteristics are necessary to provide a system that will be operational into the 1990s. Figure 1 is a block diagram of a marine control system (MCS) designed to meet these requirements.

System hardware

There is a wide variety of hardware available for implementing a centralized control system. Hardware selection should be based on such criteria as (1) basic initial capacity and upward expandability, (2) compatibility with other marine systems, and (3) availability of external software support packages (operator interface S/W, graphics S/W, navigation S/W, etc.) MCS is controlled by a Gould 32/2705 minicomputer with 4 Mbytes of memory, a hardware floating point processor, an I/O expansion chassis, and high-speed disk and tape controllers. Data storage consists of two 340 Mbyte hard disk and two 6 250 bpi tape transports.

Specific hardware to support the extensive quality control aspects of the software includes: a Ramtek color display system with 4 color monitors, a Focus-controlled operator I/F terminal, a D-size color mapping plotter, and an A-size color printing plotter. Other significant hardware features of the system include a

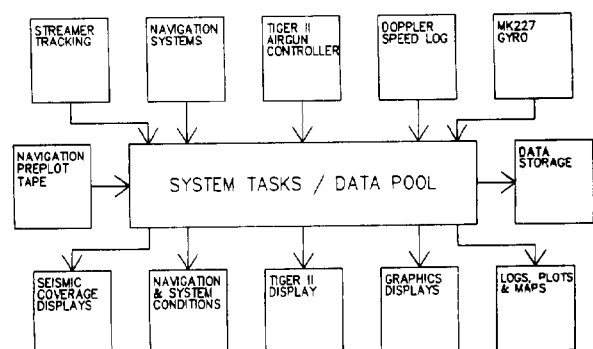


FIG. 1. MCS functional block diagram.

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high speed 32-bit wide data bus (Selbus) with a maximum bandwidth of 26.7 Mbytes/s. The speed of the CPU is enhanced by memory interleaving and a hardware floating point processor. All interfaces to the Selbus are microprocessor-controlled and have direct memory access capability. These H/W features along with the "data pool" concept virtually eliminate any problems with data I/O or data transfer between subsystems.

System software

Some very good software subsystems are currently available commercially. Properly integrated with operator interface and geophysical software these packages form the basis for a new system. The software purchased for MCS includes the Gould MPX operating system, an advanced integrated navigation package, a graphics software package, system diagnostics, and a navigation mapping package. Primary new software development for this new generation of integrated MCS included system integration, operator interface software design, quality assurance software design, and applications control software design requiring geophysical exploration expertise (real-time binning, streamer positioning, source control, etc.) Figure 2 is a block diagram of the MCS software task structure.

The integrated navigation system (INS) allows for interfacing up to 8 separate radio navigation systems, a satellite navigation system, a ground speed log, gyro compass and streamer data acquisition systems to provide navigation, auto vessel steering, and line control. A stand-alone external hardware simulator allows the operator to create simulated data (including random noise) for a variety of navigation devices. Extensive S/W effort was expended to develop a comprehensive operator interface and quality assurance package. The quality assurance software provides real-time binning on a shotpoint level, prospect level fold coverage, end of line summary plot/reports, raw data checks, multiple source and streamer positioning, source tuning and status and navigation geometry checking. The MCS generates a quality index for each subsystem at the shotpoint, line, and prospect level by comparing client specifications to the data being collected.

Each time a new prospect is to be started, a tape from the navigation department is received and loaded into the computer. This tape contains a preplot file which consists of all the pertinent information for the entire prospect including: line end coordinates, navigation base station data and spheroid data. MCS will automatically transfer the base station data from this file into the common "data pool" to be used by the navigation task when the operator selects the line to shoot. MCS retrieves the line end coordinates, the shot interval, first shotpoint number, etc. from the preplot file. Prior to shooting the first line of the prospect, a

preplot map is generated to verify the integrity of the data stored in the data pool.

The primary real-time QA data structure supported by MCS is called a history file. This file maintains prospect status on a prospect level. Included in this file is a summary of all data collected on a shotpoint basis such as raw navigation data, streamer and source positioning data, source array definition and fault status, seismic recording record and reel numbers, operator comments, etc. During the course of collecting a seismic line seven main QA/QC functions are executed.

- 1) The history file is updated at each shotpoint for the line being collected. Data for the entire prospect are kept in this data base, allowing prospect-to-date reports to be generated at any time.
- 2) A continuously running alarm reporting task receives low-level alarm reports (such as detection of invalid data) from other tasks via QAQC data pool entries. The alarm reporting task is also responsible for recording all hardware problems. Operator comments are solicited by the system when appropriate to further document alarms.
- 3) A QAQC intertask routine is executed to examine specifically data transferred between tasks to detect inconsistencies.
- 4) As noted above, the QAQC function calculates overall quality indices based on client specifications for each major MCS function. Statistics are kept for each designated parameter within a function. Reasonableness checks are made and any exceptions to the prospect specifications noted and reported.
- 5) At the end of each line, the QAQC function determines the overall quality of the line and creates plots and displays.
- 6) At the completion of the prospect the QAQC routine is responsible for generation of a comprehensive report on the quality of the prospect. This report includes configuration diagrams, operator comments and prospect level quality plots summarizing data from line plots.
- 7) Also, at the completion of the prospect the QAQC routine automatically generates a standard formatted seismic observer's log. This function eliminates hand written logs.

MCS also has the ability to produce D-size navigation QC maps from the data contained in the prospect file on command by the operator. The operator interface software was designed using a commercially available screen formatting and user input package called Focus. An extensive HELP file is accessible from any menu the operator may be viewing at the time. This file contains information which leads the user through correct operation of the system. Focus does not concern the operator with unnecessary information and only displays that portion of the file which deals with the menu currently active.

Summary

Marine control systems are becoming more complex as a result of advances in seismic processing technology and efforts to improve data collection productivity (multistreamer and multisource configurations.) The high complexity of these new systems and increased accuracy required by new processing technologies cause more emphasis to be placed on quality control and operator-friendliness aspects of these systems. Traditional methods of enhancing data collection capabilities by distributed processing can be replaced by centralized control systems which eliminate data transfer problems between subsystems. This new direction toward centralized processing was made possible due to the introduction in the early 1980s of small, low-cost, high performance 32-bit minicomputers.

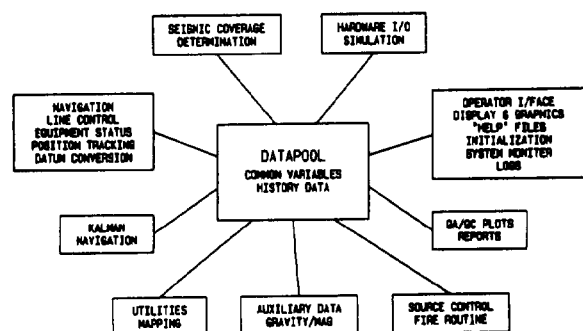


FIG. 2. MCS software task structure.