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Digital map and linked data (DMap) implementation at SACLANTCEN as an aid to sea-going research

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Digital map and linked data (DMap) implementation at SACLANTCEN as an aid to sea-going research

M.D. Max, F. Spina and N. Portunato

Executive Summary: A geographical information and linked data system (DMap) is being implemented in a navigational chart format at SACLANTCEN. Although originally acquired to support experimental marine research, it has been developed to the point where it constitutes a prototype operational acoustic/environmental support system. It has proven useful at sea in support of ASW (LFAS) exercises. Because the system provides a means of sharing complex geographical information at any scale between many platforms in real time, it has the potential to enhance both ASW and MCM operations. Further development of both ASW and MCM applications are currently in progress, including consultation with naval operators, so that both scientific and operational attributes (expert system-decision aid) of the system can be enhanced.

DMaps (data maps) are computer software composed of a geographical information system (GIS) linked to digital numerical data, text, image and graphics of marine information. The commercial software operates on relatively inexpensive portable computers. The DMap can be a repository for newly input real-time experiment and sensor locations (such as DGPS position, radar) and exercise positional data (such as sonar contacts). New map overlays, for instance of bottom reverberation, may be compiled in real time as the information becomes available. DMaps provide a new basis for rapid communication. Complex geographical information such as positions, areas, clearance lanes and hazard areas, as well as numerical data related to positions, have been electronically communicated and merged with duplicate copies of the DMap on other ships operating in the same area in a joint exercise and at the Centre.

DMaps and operating software are being archived on CD-ROM, which provides a stable media for secure dissemination. A number of DMaps are currently available to support NATO naval activities and for guiding further development.

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Digital map and linked data (DMap) implementation at SACLANTCEN as an aid to sea-going research

M.D. Max, F. Spina and N. Portunato

Abstract: DMaps (data maps), consisting of a geographical information system (GIS) linked to data and information of various types are being implemented at SACLANTCEN to support marine scientific exercises and experiments, as well as for providing a stable archive for data retrieval. The DMap allows for locating of information held in a linked relational database directly from a map, and for the enlargement of the linked data sets with the acquisition of new information. The DMap is thus not only a working element of marine scientific research, but it is also a data archive, which is saved after each new work period by writing to a CD-ROM. Commercial computer software only is being used.

Keywords: geographical information system ○ GIS

Contents

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1
Introduction

The manner in which a geographical information system (GIS) and relational database software have been linked and made interactive is described. In addition to discussing current capabilities, a brief history of DMap development at SACLANTCEN is presented along with a description of enhancements in progress. A number of issues related to using the DMaps as navigational charts for naval exercises and communications are discussed. One example of DMap use for an exercise is described.

It is assumed that readers of this report interested in acquiring and implementing DMap capability will have at least a general knowledge of computer mapping and digital charting for navigational purposes.

In this memorandum, and particularly in the annex, specific computers and commercial software that have been used at SACLANTCEN are listed. This constitutes no endorsement for the particular computers or commercial software by SACLANTCEN, NATO, or any of its employees or associates. Naming the hardware and software employed has been done for information purposes only.

2
The DMap

DMaps consist of a digital map defined in a geographical information system (GIS) linked to a relational (numerical) database and other information of various types (e.g., text, graphics, images). The DMap is a true 'field information' system: an organized container for all information relevant to a particular area.

The GIS comprises a set of data layers each containing different information (Fig. 1). All layers are related to the same mapping/coordinate system. For instance, each bathymetric contour is held in a separate data layer. It may be graphically edited, this allows the line to be changed in appearance and colored. Any set of lines or areas may be copied to a new layer; this allows pattern and color-filling between selected contours. Layers may be edited, split, annotated, and added or inserted. New layers may be drawn on screen as desired. Layers may be exported to drawing and other programs.

One of the important attributes of the GIS software is that detailed maps may be set within more general maps. This allows for greater accuracy within maps of smaller areas. For instance, a general DMap is about 300 n.mi across; within the data resolution is about 20 m. Inset maps of more detailed data (which may be retrieved directly on-screen from the main map since their presence is shown by buttons) may have an resolution of less than 1 m (e.g., Fig. 2 where ripples of different scales are color-coded for analysis purposes). For smaller areas, for instance in maps of several hundreds of metres across, resolution is a few centimetres. Thus, data sets of varying detail and scale may be kept within a single digital map. This is a fundamentally different approach from a massive database composed primarily of gridded data in which all scale maps are derived from the same data set.

The front end of the DMap is the GIS navigational chart, which shows the geographical features of the area and the position of the available data. The back end is a database where all the non-geographical information is archived. The link between the map and the database allows data to be identified, retrieved and displayed directly from map; the link also allows the position of data in the database to be identified on the map. Numerical data, descriptive and instructive text, graphics, and various diagrams may all be linked with specific sites or areas within the GIS. This allows for the geographical referencing of information, and for the enlargement of the linked data sets in a real-time framework. Selected data may be made available for visualization, for instance in the case of showing a sound-velocity profile, or exported in a variety of formats for external processing.

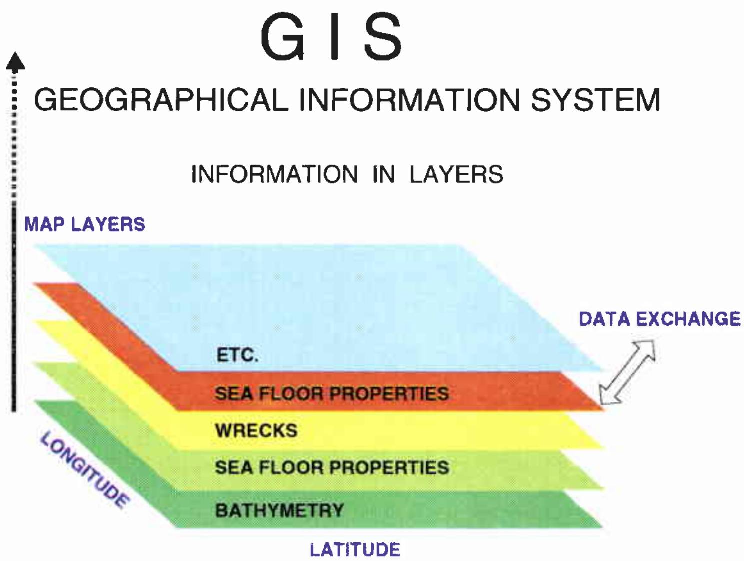

Figure 1 *Diagrammatic representation of indefinite number of geographically referenced information layers. Editing and data exchange is possible with any layer, and any layer may be deleted and new layers added as required.*

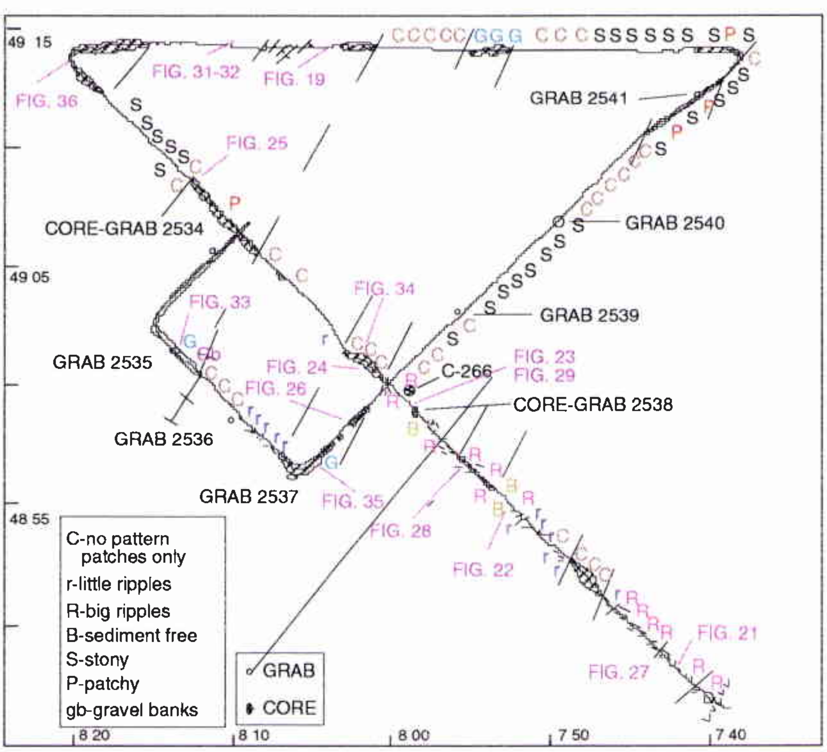

Figure 2 *Geological and surface type interpretation of a geophysical track inset into a digital map (Max et al., 1995).*

The use of DMaps falls into five basic areas:

Prepared charts DMaps are prepared for particular geographical areas and purposes. Preparing a DMap in navigational chart mode from a larger digital data set may take only a few minutes.

Editing/expansion DMaps remain editable and appendable and are thus capable of continuous refinement and data input. Prints or plotted charts at any scale or projection may be output easily. This results in what could be termed a living data map, as contrasted with paper charts which are difficult and expensive to revise.

Field operations The GIS digital map is commonly used in a navigational chart mode linked to sensors. The DMap is platform independent and may be used on ships, aircraft, or on land.

Communication The DMap itself may be used as a primary basis for communication. Electronic communication of GIS map layers and data from remote sites to SACLANTCEN has been achieved, with real-time imaging of this new information on a duplicate copy of the map.

Archival use After each stage of preparation, editing, and field use in which new information is added, the DMap comprises an up-to-date archive that allows for rapid location and export of data.

2.1. PREPARED CHARTS

A prepared map is any GIS chart for a particular area, usually one having a particular marine research requirement. Special overlays are often prepared, such as bottom reflectivity, which may be specific to the research requirement. Over time, these maps become information rich, containing more information than may be required for the specific research requirement. Only the required information need be visualized.

Simply defining a DMap area in navigational chart mode in which positions may be visualized as they become available, may be done in a few minutes, but the real value of a DMap is that it may contain large amounts of geographically referenced data. DMaps including a defined area, coastlines, bathymetry, etc., in a navigational chart mode, may be prepared in no more than a few hours, especially if the information is already in digital form. If this information exists in other DMaps, it may be compiled and assembled quickly. Preparation of more elaborate environmental information for a particular chart may take from a few hours to months. Raw digital information must often be processed before incorporation in a DMap.

Information may be entered into map layers in a number of ways:

- Digitization using the GIS.

- Direct input of existing digital data:
  - ASCII files.
  - CAD (DXF files and other formats).
  - Spreadsheets.
  - Images.
  - Graphics (as a graphic image or calculated).
- On-screen editing (line drag/redraw/draw).
- Input from external sources (real time and manually).

2.2. EDITING/EXPANSION

The DMap image is editable and appendable. DMaps may be updated as new maps and other information become available. The editing tools of the GIS, which are similar in operation to most common computer drawing programs, are used for this task; linked data may be added at the same time.

2.3. FIELD OPERATIONS

The primary purpose for which DMaps have been prepared at SACLANTCEN is to support shipboard marine scientific research and exercises of a scientific character. DMap technology allows new information to be entered into the map as a visual element with a supporting time and numerical file, together with entry into a linked spreadsheet or relational database. This allows the position of any data sample to be incorporated into the overall data set.

A number of different types of information may be accessed during field operations:

- Real-time data.
  - Navigational systems: GPS/DGPS, Loran, DECCA, Omega, etc., may all be input directly.
  - Sensors: Radar and sonar detections are currently configured for both manual and automatic entry into the DMaps, although other sensors could also be merged if required.
  - Measurement and notice positions: CTD, XBT, core and grab sample sites, camera positions, etc., may be entered as they become available.
- Map layers and data prepared on the ship or other platforms. This includes analyses of geophysical data such as high-resolution reflection seismics, side-scan sonar, video images.

- Remotely imaged data from satellites may require image processing to register them in the correct geographical frame.

2.4. COMMUNICATION

Electronic communication of small data sets between the NRV *Alliance* and SACLANTCEN and between NRV *Alliance* and other ships using SACLANTCEN as an intermediate communications node have been achieved in nearly real time (Fig. 3).

Map layers have been communicated by e-mail, taking advantage of existing communications software. File transfer protocols may be used for larger files. Linked data (tables/text/images/graphics) have also been sent in this way, which has the advantage of preserving their internal formatting. Communicating new map layers for merging in duplicate copies of prepared maps is a new way to rapidly exchange complex geographical information.

2.5. ARCHIVAL USE

Numerical data, descriptive and instructive text, graphics, and various diagrams may all be linked with specific sites or areas. After each stage of preparation, editing, and field use in which new information is added, the DMap is an archive that allows for rapid location and export of data. The DMap is thus not only a working element of marine scientific research, it also provides the framework for an archive of much of the data, which when saved in a suitable dense data form such as a CD-ROM, may provide easy access to cruise data with no post-cruise processing. As an archive, the DMap may be used for planning purposes and to locate and extract data quickly, using geographical visualization of data and information locations. Use of the DMap has dramatically cut post-cruise processing and analysis time by allowing this to be done during the cruise.

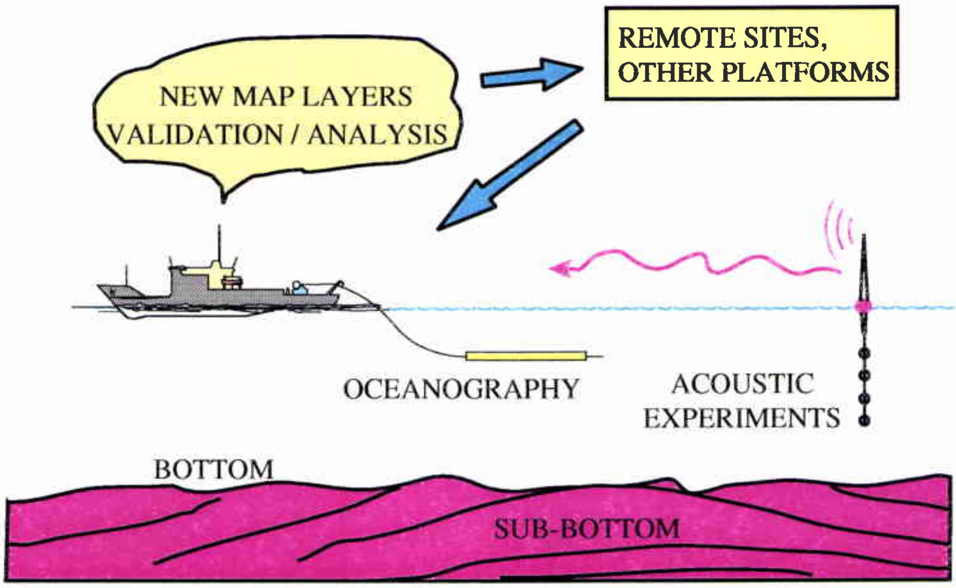

Figure 3 *Diagram of data-communication path from the ship.*

3
Relational data links: The interactive component of DMaps

Although the GIS alone provides for enhanced scientific support and research flexibility, the greatest value is gained through linking geographical positions with broader information in a DMap. Many data layers of the map itself contain elements that describe features, tracks, point locations, and areas that may be related to numerical and other data outside the map itself. The geographical elements in the DMap, such as ship's course, and points that identify bottom core, sampling and observation sites, provide the basis for locating information and accessing it. When linked, the GIS map becomes the key element in accessing a much larger data set. Each geographical entity, identified by a screen icon, is linked to its non-geographical attributes in a linked data set. These entities are defined by 'what' (a symbol centered on the position in the map layer), 'where' (latitude and longitude), and 'when' (time). The GIS supports links with both simple, internal flat-file data sets or with an external, concurrently running program.

Many standard data sets are available in digital form. For instance, the Generalized Digital Environmental Model (GDEM), part of the gridded NATO Environmental Database consisting of temperature, salinity, and sound-velocity profiles, has been related to the map. A layer on the map dedicated to GDEM, with a symbol and unique identifier at each station position (Fig. 4) is linked to the numerical data. Data access is made directly from the map screen by selecting one of the GDEM icons.

SACLANTCEN data acquired at sea and presently incorporated into DMaps are core (sound-velocity) (Fig. 5), XBT and CTD (Fig. 6), and transmission-loss data (Fig. 7), together with the positions of line segments and point locations, such as SUS (signals, underwater sound) charge drops. Other data include wreck positions, cable and pipeline courses, and drilling platform positions.

Each DMap is thus a full archive and the basis for incorporation of new information. Linked data sets may be edited and expanded by loading new data. Data selection may be both from the map and from within the relational database selection windows. The SACLANTCEN data access windows include unclassified environmental information only and environment and acoustic data which may be classified (Fig. 8).

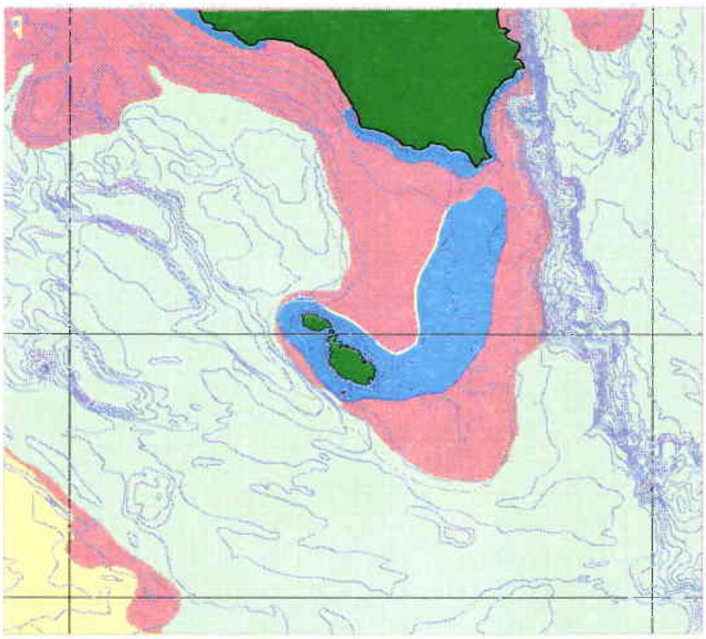

Figure 4 *Zoom of part of Sicilian–Tunisian Platform (Max and Colantoni, 1993) with the activated map layer showing GDEM positions (small diagrammatic sound-velocity profile) and wreck positions. Clicking on an icon automatically links with the data for that point.*

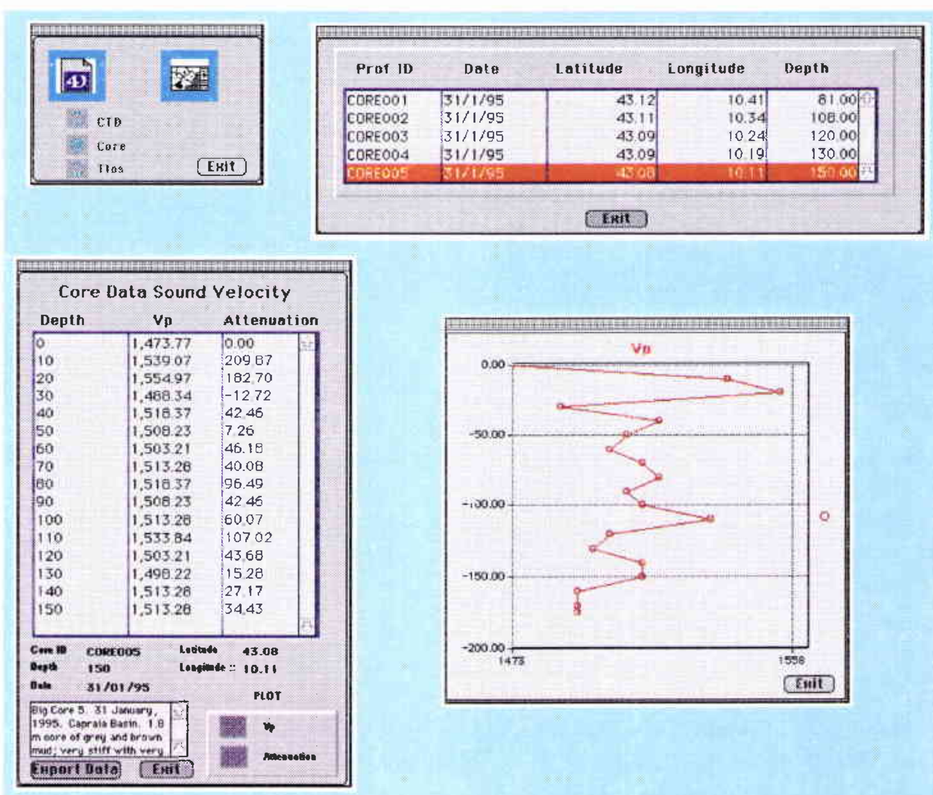

Figure 5 *Windows relating to core sound-velocity data.*

3.1. LINKING REAL-TIME DATA AND SENSORS

The DMap is used at sea for the direct input of positions. A variety of data are already configured for automatic entry simultaneously into both map and database using what is termed a 'NOW' window (Fig. 9). This allows operators with little training to input data correctly. In each case the event to be entered into the GIS is selected from a menu. When the 'NOW' button is pushed, the position is acquired from the ship's navigation system and the appropriate icon entered on the map in the correct position at the same time that a linked file is opened in the relational database. All data entries into the map are accompanied by a time and position fix to allow playback. Input of real time information from the ship's sensors (radar, GPS and other navigation systems, bathymetry, etc.) allows the DMap to act as the central repository of related time-series information.

3.2. MANUAL INPUT OF DATA

Manually input positions may be used to mark samples, line segments, and other locations, e.g., SUS charge shot points (Fig. 10). This is done by activating the relevant data layer overlay and defining a new icon at a particular point on the map, using either a numeric data entry or the longitude–latitude read-out from the cursor position. There is also a capability to place operator-selected sonar contacts, and finally there is an interactive routine that allows the grouping of contacts for purposes of classification. The GIS software allows on-screen editing (color, line width, patterns, etc.) and definition of new icons as desired.

Numerical data such as sound velocity and attenuation of cores, which are normally measured onboard immediately after recovery, and CTD and XBT data, as well as any other data derived onboard, also may be input and edited.

3.3. OPERATIONAL ADVANTAGES OF DMAP IMPLEMENTATION

Screen summaries of SUS charge points, CTDs, etc., may be printed at any time and lists of all data can be shown as a function of time. These images may also be electronically communicated.

Being able to log all positions automatically removes the requirement for the bridge or a special watch officer to note everything, change navigation screens, etc., which often was the controlling factor on the ship's speed for a SUS transmission loss experimental line. It was found during the course of the experimental series that it was possible to safely increase the speed of runs from 6 kn to 10 kn. Introduction of the DMap has thus had a direct impact on experiment productivity by shortening the time required for individual experiments by about one-quarter.

Control of other activities, such as setting depth ranges for the swath multibeam bathymetric mapping system, finding approximate depths at positions prior to arrival, etc., were all facilitated by having information in the DMap that could be easily accessed.

Designing experiments with a complex geometry is also facilitated. Line lengths, ranges, bearings, etc., may also be quickly found from the DMap directly, greatly improving the speed of planning and operations. Features may be 'interrogated'; on a complex image with many layers open, selection of any object element can indicate its layer or data type.

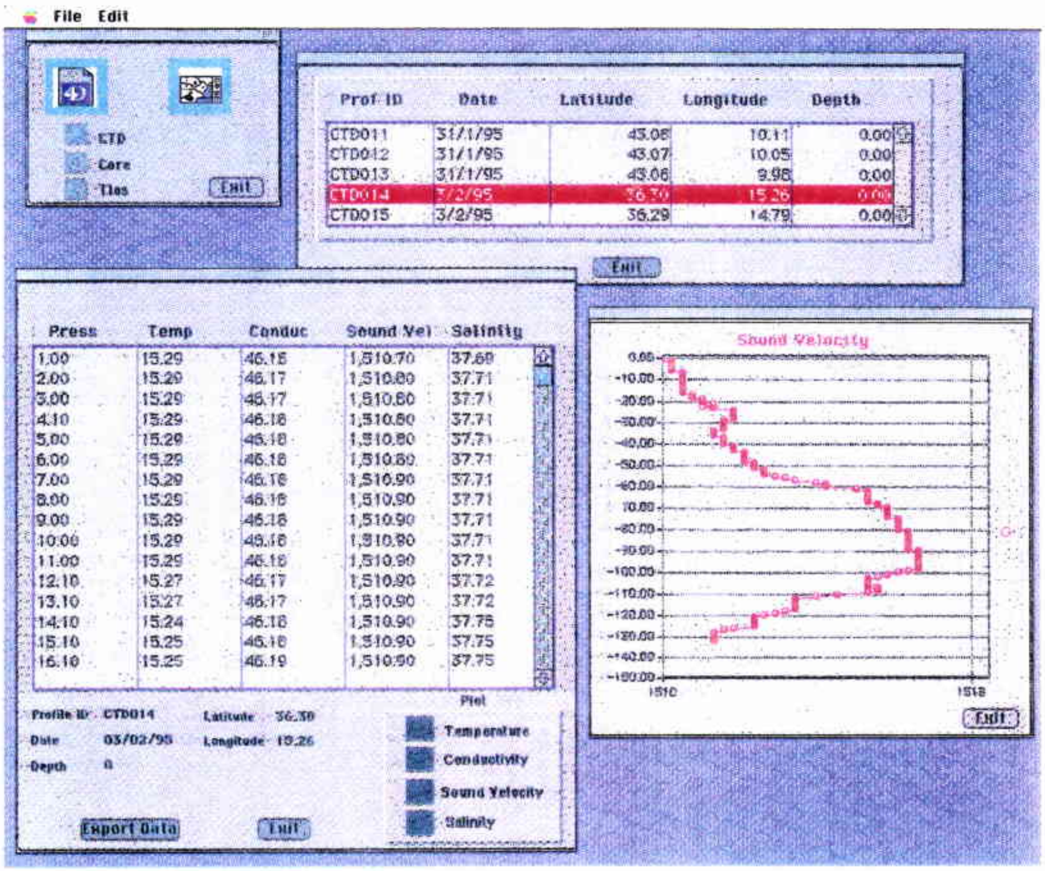

Figure 6 *Windows relating to water property and sound-velocity data.*

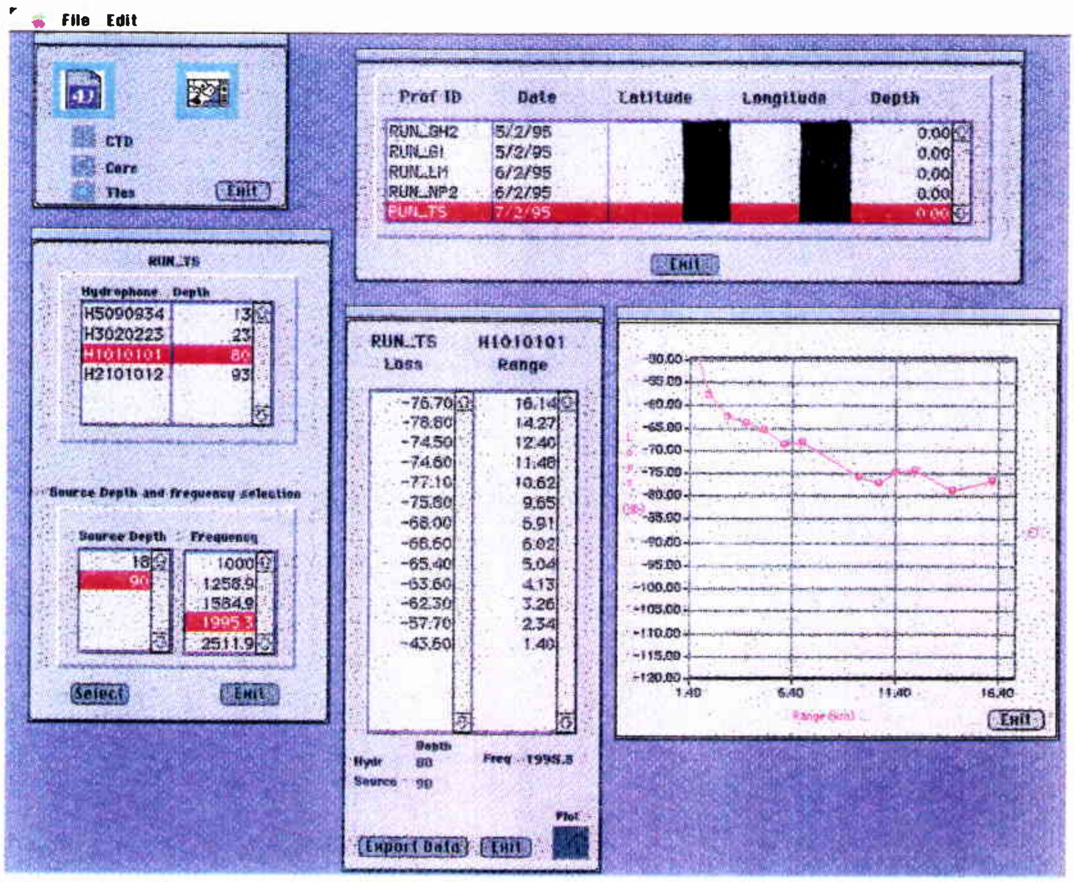

Figure 7 *Windows relating to transmission-loss data.*

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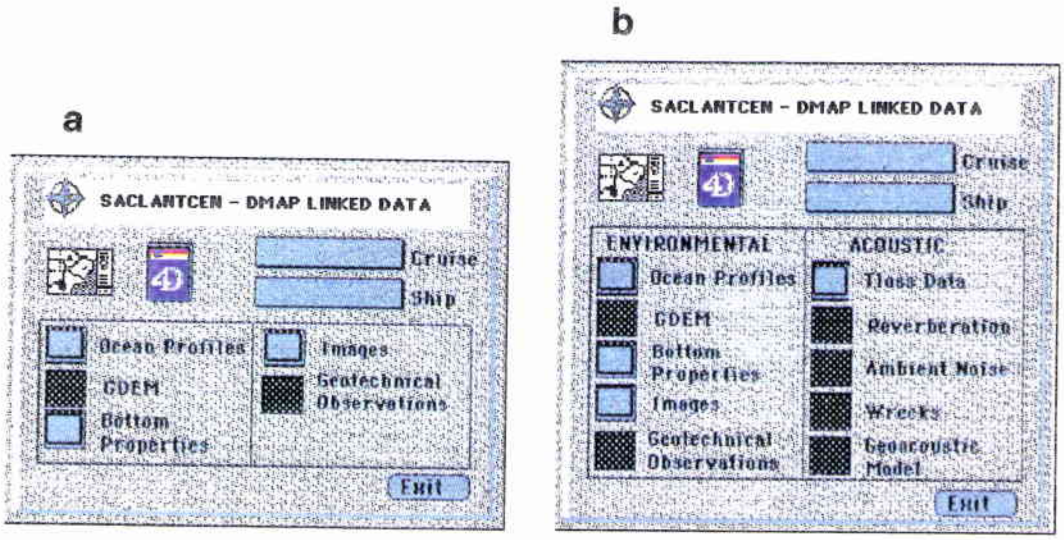

Figure 8 *(a) Linked data of an environmental character only. (b) Linked data of an environmental and acoustic character.*

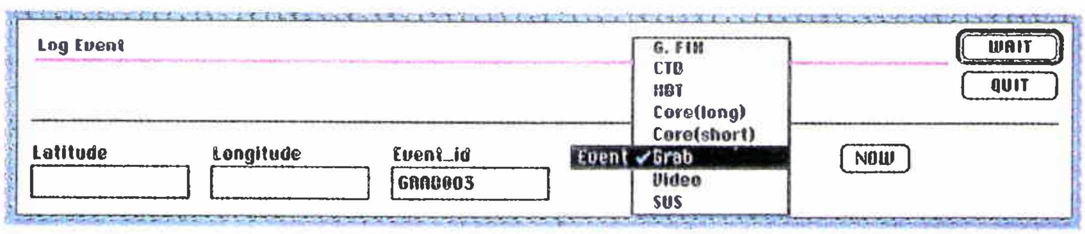

Figure 9 *Window for selecting the type of information to be recorded. Pushing the* 'NOW' *button places the position icon on the map and opens a linked data file automatically.*

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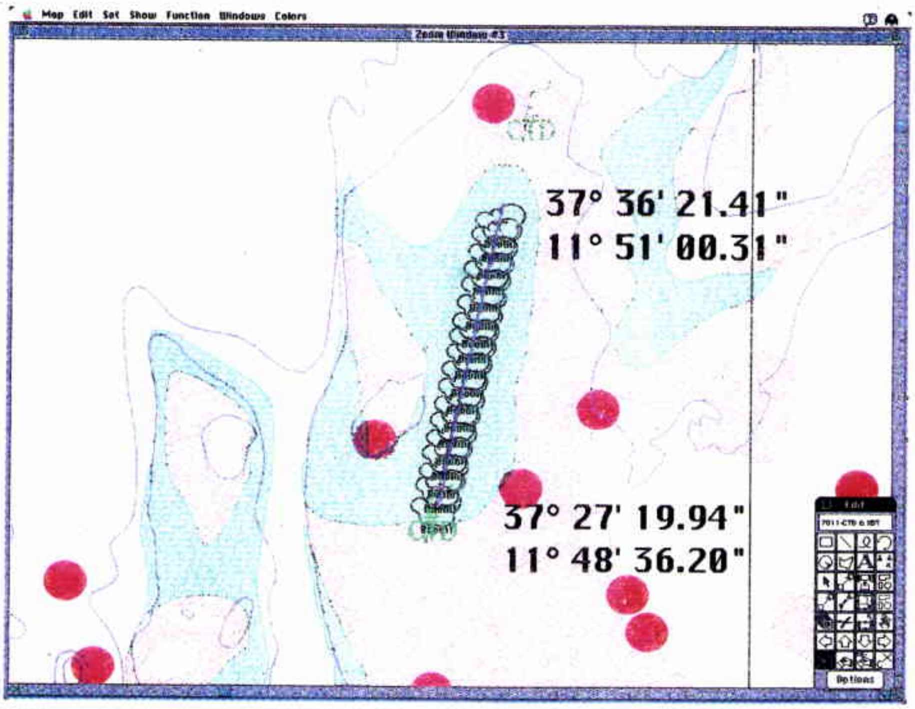

Figure 10 *Example of a SUS charge shot point record (not associated with Fig. 12), bottom types, CTD positions, and core locations in a zoom working window.*

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4

At-sea Low Frequency Active Sonar (LFAS) exercise use of the DMap

The exercise itself was carried out using the DMap linked to the exercise sonar computers. The DMap displays were set in a central position with the map monitor in the lower position and the linked data monitor above (Fig. 11). To either side in the equipment rack were the Unix workstations, on which special acoustic monitoring programs were running.

New map layers designed to optimize operation during the exercise (Annex A) were developed. A number of different features of the bottom were characterized by their morphological and physical properties and their anticipated acoustic response. The acoustic frequency range to be used during the trial was taken into consideration, as were other attributes of the sonar system, its processing capabilities, and operator practices. Features on the bottom likely to be imaged fall into two categories: artifacts and naturally occurring features.

Artifacts, such as wrecks (see, e.g., Fig. 4), well-heads, constructions, and dumps, are part of the historical record and may be located and acquired with varying degrees of difficulty. A list of wrecks was obtained from the Defense Mapping Agency of the United States; using a prepared Excel file, these positions were converted to the GISmap format and inserted. Dumps were noted in a separate layer.

Sea-bottom provincing for geoacoustic response (Fig. 4), areas of steep slopes, and slumped zones were among the natural bottom attributes thought to be likely to be important during the exercise.

- The most likely sources of reflection were areas of rocky bottoms, shoals, emergent rocks, and a number of pinnacle-like volcanic edifices that are common in this region.
- More widespread areas of steep slopes having exposed rocks and indurated sediments that contain large faceted areas have been formed by slumping and landslide, initiated by earthquakes and oceanographic effects associated with sea level rise and fall. These usually have sharp slope breaks (Max et al., 1993) whose position is often not directly reflected in the available bathymetric data sets.
- Rough slumped deposits at the base of the steep slopes and in slump runs that continue for considerable distances from the base of the slopes are common in the area (Max et al., 1995). The acoustic response of these areas is expected

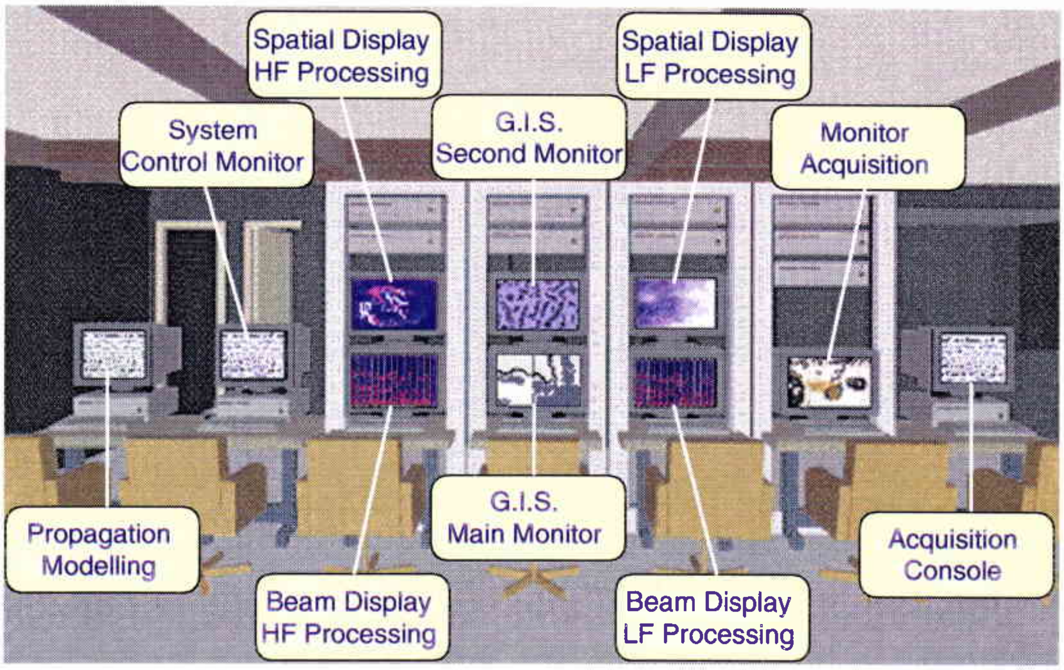

Figure 11 *View of the DMap and sonar monitors and overhead computers on the NRV Alliance. Spatial displays relate the instantaneous sonar situation at any particular time with the ship's position. HF – high frequency; GIS – geographical information system; LF – low frequency; MF – beam-by-beam sonar displays.*

to differ considerably from the hard, dense faceted slopes because they are composed of irregularly disposed landslide material. The bottom is hummocky and often blocky and sediment is intermingled with slump blocks.

4.1. REAL-TIME IDENTIFICATION AND CLASSIFICATION

The main aim of the exercise was to locate all sources of acoustic reflection in the study area and to separate naturally occurring and artifact responses from those generated by test vessels. This was greatly facilitated by the time-series memory of the GIS and the linked and created real-time data sets. The acoustic detections were imaged on the GIS, which fixed the position of all platforms and acoustic responses in a single geographical reference. This allowed images of response positions to be built up as a composite, independent of the raw beam and spatial displays of the sonar system, which identified acoustic response by reference to the ship's position. The geographical position of the ship was automatically logged on the active layer and the linked data file every 5 min.

The GIS was interfaced with the Unix workstations where the acoustic echoes were displayed on the basis of range and relative bearing (MF display). The contacts found on the MF display, on a ping-by-ping basis, were manually selected by the chief sonar operator, often in consultation with other operators and supervisory staff. After having been identified, the contacts were transformed into absolute geographical coordinates. These were transferred and altered into the geographical datum of the GIS using interface software, and were then sent over the Ethernet to an active layer in the GIS. In the sonar spatial display, the basic element is always the ship's position, whereas in the GIS all positions are fixed in absolute geographical locations (Fig. 12). Because the GIS has the ability to allow a variety of symbols to be chosen by the operator, on-screen classification was made using icons representing ships and other objects.

At the end of each run, as well as prior to, during, and after formal exercise phases, a basic acoustic reflection map was produced, with respect to *Alliance*'s general position during the course of the exercise. The union of all the layers of bottom acoustic response data allowed the creation of a general bottom-acoustic chart (Fig. 13). It must be noted that this chart, and the chart of non-bottom echo responses (Fig. 14), representing the position of a underwater object with time, were both produced in real time, being finished within minutes of the close of the exercise. Real positions of detections could be compared with proposed courses, where known.

Particular attention was paid to developing a methodology for contact classification and the detection of wrecks and bottom artifacts which could have had a response similar to that of a target. Because the known wrecks in the area were linked to descriptions, possible detections could be compared immediately with the wreck position and other information such as wreck size, height, orientation, attitude, tonnage, sinking year, vessel type, etc. The wreck icons were of two types depending on the accuracy grade of the localization. Using operator-designed icons, which can be placed on the map, further wreck classification can be done. Alternatively, the selection of a particular wreck from the text database, could automatically highlight the corresponding icon on the map. In addition, echoes could be associated with individual wrecks and the position of certain wrecks searched for on the map.

Most importantly, however, is the ease with which both port–starboard contacts may be plotted as an aid to resolving left–right ambiguity (Fig. 14). Before implementation of the GIS/DMap, reconstruction of an exercise was a laborious procedure.

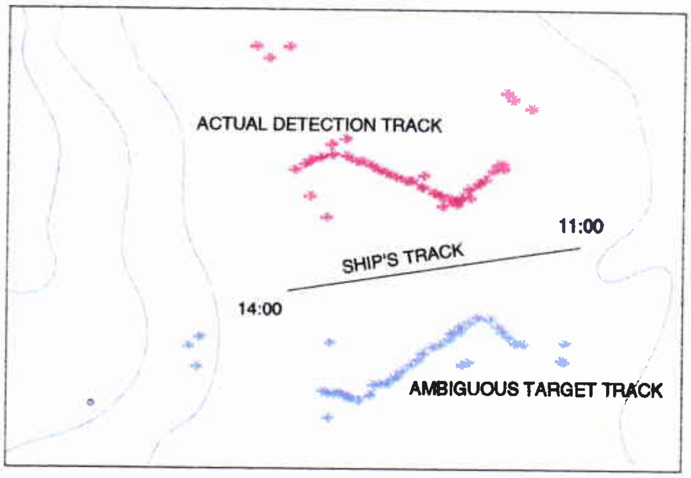

Figure 12 *Diagram of all significant (manually selected) acoustic detections over a 3 h period during the trial.*

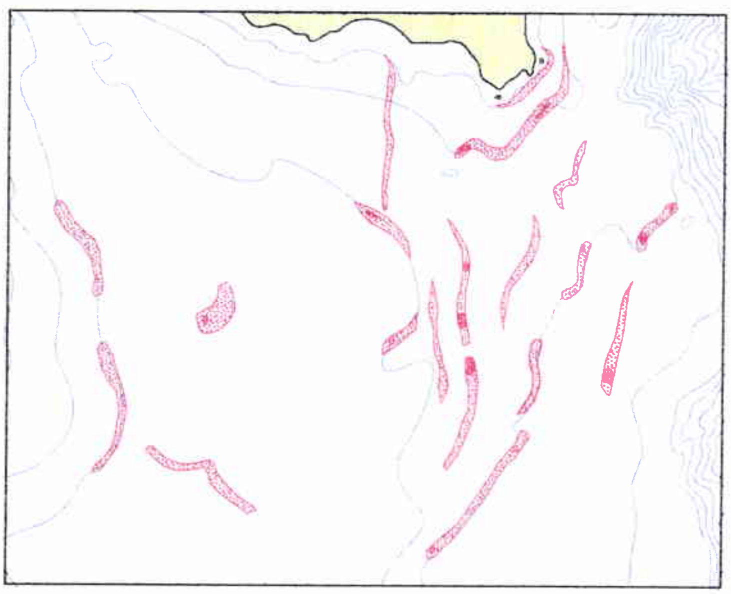

Figure 13 *Diagram of an acoustic chart showing principal sites of bottom-acoustic reflection. Solid red, very strong returns; stippled red, persistent returns.*

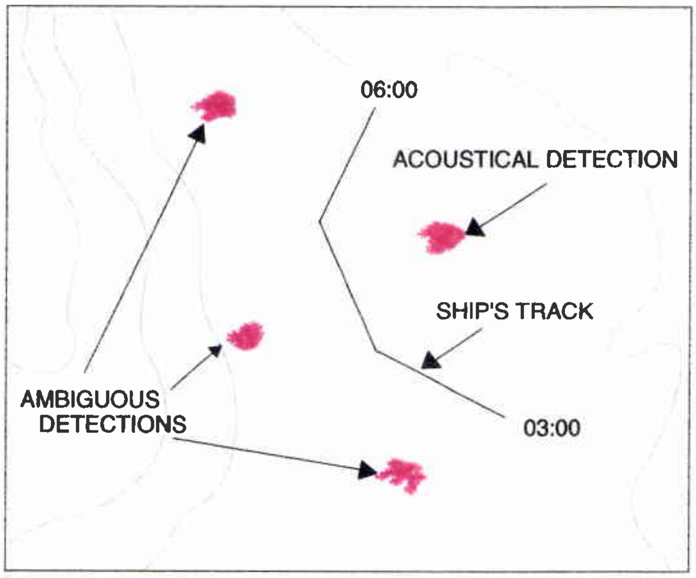

Figure 14 *Diagram of an acoustic detection chart demonstrating results similar to a real 3 h run. Note that the acoustic detection remains fixed while the ambiguous detections swing to remain in-line with the ship's course and the acoustic detection.*

5
DMap products

There are two versions of the basic DMap with different capabilities. The more limited-capability 'run-time' version uses built-in software and lacks the capability for its structure to be modified. A defined data structure is linked to a GIS map through location numbering, but data cannot be sourced directly from the map. New map layers cannot be created. New information, however, can be put into the existing linked dataset, whose individual data types can be enlarged with new data. This version could be considered as a standard working DMap for new data input, and can be used in the navigational chart mode. It is operated without the hardware key of the GIS (which is a plug-in electronic hardware switch that insures that only one user at a time can access the full functionality of the GIS software). The run-time version is suitable for much marine work and in a somewhat modified form may be suitable for particular exercises or military applications.

The more complete 'development' version allows for all visualization and operations of map layers, including creation and deletion of layers and a number of map layer output functions such as plotting. This version can be linked directly with the relational data set and the map itself used for location and extraction of linked data. The development version allows not only for expansion of data within the defined data structure, but for modification of that data structure, for instance to incorporate a new type of data. This version requires a hardware key for the GIS, which in effect is its operating licence and other software licences, for software being used with the DMap. It is envisaged that development DMaps will have different configurations depending on the type of experiment or use to which they will be put, as contrasted with the run-time DMaps, which are likely to have a more common and more simple, environment-based content.

Both the run-time and development versions of the DMap are available in two forms. One version is a limited presentation of unclassified, largely environmental information (Fig. 8a), and the other is the complete dataset that contains environmental and other information, presently largely of acoustic data and related information (Fig. 8b), which may be classified if certain data are present. An environmental DMap subset can be produced in a short time from a complete DMap, with the limited data selection window pasted over the relational data set from which unwanted information has been deleted.

All versions of the DMaps have a multi-platform and multi-cruise (data input periods) capability. The development versions have the capability for indefinite expansion and modification while the run-time versions all have the capability to absorb more data into the relational data set, but the new data and chart information need to be recycled through a development version for a fully updated run-time version to be created. It is envisaged that the most common use of the DMap technology will be using a linked development version of the GIS linked to a run-time version of the relational data set, which will allow for continuous expansion of an established data structure and updating of the GIS chart.

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Annex A
DMap system description, data links, and presentation

In this DMap approach to displaying complex geographical information, relatively low density data for the large-scale maps and high density data for the small scale maps result in relatively low data storage requirements, a less powerful computing requirement, and data of appropriate density/detail. It has been possible to utilize very powerful commercial software that is relatively inexpensive and structures data in a similar manner so that it may be used by more than one program. It is possible to link the DMap software with other processing and visualization software, running on the same or other computers.

A general guideline followed during implementation of the SACLANTCEN DMap was to minimize the software development, that is to avoid programming or writing application software. Existing commercial software was used. In addition to map management and display, provided from within the MapGrafix GIS, there was a need for database and data display software. The relational database software chosen was 4th Dimension, which has both a lower level database and a higher level version for application generation, and is provided with a large set of 'extensions' to meet specific requirements, such as passing selected data to other programs, obtaining the results, and displaying them. Excel was initially chosen for data display, but has now been replaced by graphics running entirely within the relational database. Text was processed using MS Word.

This software was installed on a Macintosh computer (Quadra 650, 700, etc.). A digitizer (Océ G6835) and plotter (HP DraftPro EXL) provided the basis for map input and compilation. A CD-ROM reader (Apple) provided additional flexibility for accessing databases such as the GEBCO Digital Atlas (Jones et al., 1994) (an early version of which was available on 9-track tape) and an HP 550C draft color printer was used for printing good quality color images rapidly. Additional RAM (48 Mb) was installed, as was a removable 88 Mb hard drive (Optima DisKovery 88R). A high-end Macintosh and Power PCs now form the core of the system, to which two 21 in monitors, CD, SoftWindows, and removable hard drive have been installed.

The Macintosh operating system and Apple Events, an internal high-level programming language, are the standard means of communication between applications and the operating system itself. Data were originally linked to MapGrafix via Hypercard. Now these resources are provided by the Macintosh system 7.5. For example, an application may launch another application, and/or open a document and then close it after use to regain RAM. Applications may both act as clients able to issue requests, or as servers being able to receive and reply to requests. Apple Events has been used to communicate between application software packages.

A rich and complex programming environment that characterizes relational database programs allows sophisticated data integration (Onder and Sullivan, 1994). Programming tasks are carried out using embedded sub-program compilers that are part of the software itself, without a new programming requirement.

Adobe Illustrator, usually used at the SACLANTCEN to produce the graphics for reports, may import files from the GIS after slight modification of element and object descriptions. Once the map layers with the desired information are selected, existing patterns and colors eliminated and the resulting image saved, the file is processed using Acrobat Distiller to create a vectorized image compatible with Adobe Illustrator.

A.1. DMAP IMPLEMENTATION AT SACLANTCEN

One of the primary areas where improvement in performance through the introduction of new technologies and practices is possible is in the acquisition and relational archiving of marine data in such a way that post-cruise processing is minimized by carrying more work out at sea, during the course of the experiments and also during transits.

SACLANTCEN GIS was begun early in 1993 when the software, digitizer, and plotter were installed to support a shallow-water seafloor characterization project. A great deal of existing information had to be converted to digital form so that it could be edited and compiled. The GIS was selected mainly because its digitizing and map drawing capabilities included computer-aided design (CAD)-style active screen image digitizing and editing.

With experience it became clear that as well as inputting, editing, and compiling various charts of the sea bottom, the software could be adapted to support much broader elements of the SACLANTCEN research program. DMaps now have been used for exercises and experiments by a number of other SACLANTCEN projects.

A.2. EXAMPLES OF GIS/DMAP DEVELOPMENT AT SACLANTCEN

1 – SWAP In addition to providing useful experience and practice in learning the software, this map was used to provide a digital environmental chart for a low frequency active sonar (LFAS) exercise in the southwestern approaches to the British Isles in October, 1993. The prepared map contained 67 layers of information, including several designed specifically for individual technical operators. Run-throughs of different screens before handing over the prepared map resulted in the preparation of several special screen views of the data more suited to the operational requirements of the exercise.

Supporting descriptive texts at an elementary level and at a more complete, referenced scientific level, in addition to a thorough description of the GIS layer directory, were included as background for the exercise personnel.

During this exercise, sonar reflectors and false targets associated with bottom features were classified and archived.

2 – Elba (South) This involved a smaller data set for an acoustic experiment south of the island of Elba (in Italian waters) during August–September, 1994.

As before, the aim was to provide a detailed bathymetric chart by digitizing, but without any supporting environmental information other than local bottom roughness. Digitized SACLANTCEN high-resolution bathymetry was inset into the combined digitized and imported digital general area bathymetry. The detailed areas could be opened directly from the general map.

Automatic real-time insertion of the ship's position and an early version of the linked relational database was achieved during this cruise.

3 – Sicilian–Tunisian Platform This map in the south-central Mediterranean (Fig. 5) was used for a multi-nation LFAS exercise during October–November, 1994. This DMap is very data rich, also being the area of an ongoing geoacoustic terrane analysis. Over 180 layers of information were available, but only a small number of these were used during the course of the experiment.

Bathymetric data were derived from the GEBCO/UNESCO digital atlas (Jones et al., 1994), with modifications made by digitizing more detailed information from large-scale charts of shallow-water areas. This newer, better-controlled bathymetry was merged with the originally bathymetry. 1:100,000 detailed bathymetric maps of the Italian coastal area, which had been digitized by ENEA (Italian environmental research agency), were loaded into the DMap as insets. Compiled and digitized environmental information from many sources (Max and Colantoni, 1993) were also incorporated.

In addition, the positions and characteristics of wrecks in the areas, extracted from a tape database of the Non-Submarine Contact List, supplied by the Defense Mapping Agency of the United States, were placed on two map layers. A map layer showing positions of statistical water column acoustic-velocity profiles (GDEM) was linked with a relational database from which the numerical data could be accessed, extracted, and viewed as a 2-D graph.

4 – Elba (North) This is a map of a small area used for an experiment during part the 'Winter Sun' cruise in January–February, 1995. This map lay entirely within an existing digital 1:100,000 scale bathymetric chart, which was clipped to show only the experiment area. A more detailed Italian Hydrographic Office bathymetric survey was supplied as position and depth along track. It was hand-contoured at SACLANTCEN at 25 m contour intervals, digitized, and incorporated into the existing bathymetric data set. Geophysical tracks and core locations from the area were also digitized and merged. The DMap, along with existing reflection seismics, side-scan images, and core data, were used to design a high resolution backscatter experiment.

5 – Otranto Gap A detailed map of the southern Adriatic and its approaches was made for a joint oceanographic/bottom study/acoustic cruise that took place in May–June 1995. High-resolution bathymetry and a more accurate shoreline for the Albanian Shelf were input to the map, as were all the positions, tracks, and other data. Immediately following the cruise images of teh geophysics were linked with the map and geographically registered side-scan images were inset as detailed maps set within the main map and opened and closed using the button functions.

6 – Work in preparation Maps are currently in preparation of selected areas of the Black Sea, the Spanish Mediterranean coast, the inshore shelf near La Spezia, and elsewhere. In addition, sea areas for which DMaps have been made are being revisited for new experiments, with consequent updating of the DMaps.

A.3. DEVELOPMENTS FOR NEAR-TERM DMAP USE

Other software designed to operate in the Macintosh DMap environment that has Navy or marine science applications needs to be assessed both by Centre and NATO activities. For instance, a tactical exercise information system using the same software as the SACLANTCEN DMap has been acquired from the US Navy missile test range in California. Other software is available and is being acquired for assessment.

In a major innovation, all new data incorporated into the DMap, including CTD, core, ship's position, and other information may be captured on a CD-ROM in both demonstration and active DMap versions. This will allow widespread and rapid dissemination and production of multi-session CD-ROMs of GIS-integrated map and acquired data in a very secure form as a cruise archive and as a basic DMap for any other cruise to the same area.

The DMap system is currently being transitioned from the Macintosh Quadra to PowerPC systems. This will result in increased capability and speed and maintains the concept of using relatively inexpensive computers as the basis of the GIS. Use of the PowerPC has also allowed DOS/Windows CD-ROM data (Jones et al., 1994) to be accessed through SoftWindows, and soon through a PowerPC native operating system such as Windows NT.

Work is proceeding to merge PC data and the Macintosh DMap so that the user will have access to all data and software without regard as to the operating system. Implementation of the Unix operating system on the PowerPC platform offers further scope for expansion of capabilities.

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Title

Digital map and linked data (DMap) implementation at SACLANTCEN as an aid to sea-going research

Abstract

DMaps (data maps), consisting of a geographical information system (GIS) linked to data and information of various types are being implemented at SACLANTCEN to support marine scientific exercises and experiments, as well as for providing a stable archive for data retrieval. The DMap allows for locating of information held in a linked relational database directly from a map, and for the enlargement of the linked data sets with the acquisition of new information. The DMap is thus not only a working element of marine scientific research, but it is also a data archive, which is saved after each new work period by writing to a CD-ROM. Commercial computer software only is being used.

Keywords

geographical information system, GIS

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