HARDWARE/SOFTWARE CONSIDERATIONS FOR OPTIMIZING CARTOGRAPHIC SYSTEM DESIGN

P. D. Bell and J. A. Kearney
Synectics Corporation
310 E. Chestnut Street
Rome, NY 13440

BIOGRAPHICAL SKETCH

Paul D. Bell received a B.S. degree in Applied Statistics and Computer Science from Utah State University, Logan, Utah in 1967. He is currently serving as project director of the Advanced Cartographic Data Digitizing System (ACDDS) project, sponsored by the Defense Mapping Agency Hydrographic Topographic Center (DMAHTC). Mr. Bell has been involved with automated cartography in many aspects for over ten years, which include digitizing system design, implementation and support, as well as functional processing of cartographic line center and raster information. Previous experience includes systems programming and implementation for real-time data acquisition systems.

John A. Kearney received a B.A. degree in Computer Science from the State University of New York, Oswego, New York in 1978. He is currently serving as projector director of the SIGINT Support Facility/ Advanced Sensor Exploitation (SSF/ASE) Interface project sponsored by Rome Air Development Center (RADC). Mr. Kearney has previous software experience with automated cartography, interactive graphics, interactive and batch word processing, and Digital Landmass Simulation (DLMS) data.

ABSTRACT

An important goal in configuring and designing a hardware/software system is to attain a final product which utilizes, to the fullest extent possible, the baseline hardware and system software available to the developer. The Advanced Cartographic Data Digitizing System (ACDDS) has attained this goal while exhibiting an extensive range of interactive and batch cartographic data handling software functions. The ACDDS is a user-oriented system featuring: state-of-the-art hardware, reliability and maintainability, expandability, and future adaptability.

The design taken by Synectics Corporation to develop an advanced cartographic system for production use at the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) was to configure a cost-effective distributive computer network with a minicomputer host and satellite microprocessor based digitizing work stations.

TYPICAL REQUIREMENTS OF CARTOGRAPHIC SYSTEMS

The most important discipline of cartographic system design is understanding the user's requirements. By utilizing the technique of structured analysis, the user's requirements are defined and documented. As we all know, this is certainly easily stated, but rarely performed without some fuzzy requirement(s) surfacing. This fuzziness must be taken into consideration within the hardware/software design of your system. The typical requirements of cartographic systems that follow are founded upon the Advanced Cartographic Data Digitizing System (ACDDS) currently undergoing Operational Test and Evaluation (OTE) at DMAHTC.

Functional Requirements

The ACDDS design is based upon a subsystem concept. This allows for the optimized utilization of both human and machine resources. One subsystem (work station) supports acquisition/editing of cartographic data in an interactive graphic real-time environment, while the second (host) manipulates the collected data in a batch environment.

Work Station Functional Requirements

(a) Sign-On - provides the user with easy operational access to work station functions.
(b) Session Start/Station Initialization - provides the operator with easy entry of job chart parameter control information.
(c) Registration Function - correlates a chart on the digitizing surface to its actual position on the earth's surface.
(d) Header Build - generates a set of cartographic header description codes that are applied to digitized features.
(e) Executive Mode - operator controlled process scheduler and controller of the interactive real-time functional work station tasks.
(f) Trace Mode - records trace features (vector) by accepting X,Y coordinate pairs derived by the digitizing table and stores pairs into a feature data set.
(g) Depth Entry Mode - records bathymetric depth sounding feature data (X,Y depth) via keyboard or voice éntry terminal.
(h) Discrete Point Mode - records single point feature information such as spot elevations, buoys, etc.
(i) Review Mode - graphically examines all features (trace, depth, and discrete point) collected within a job.
(j) Auxiliary Mode - changes parameter information used within a job such as display scale, graphic remarks, header build data, return to registration, etc.
(k) Edit Mode - allows the user to select a feature and affect some change. Edits include: file header update, feature header update, locate feature (X,Y; feature I.D.; geographic coordinate), feature reorder, trace feature edit, depth/point data edit, delete feature, and edit utilities.
(l) Help Mode - allows the operator to select "HELP" at any point during work station functions and explains select functions.
(m) Kill Function - allows the operator to escape from the present function and return control to previous mode of operation.
(n) Remote Job Entry (RJE) - makes available to the work station operator a means by which batch processing tasks may be submitted to the host processor.

(o) Send File to Host - transmits a work station data file to the host system.

(p) Work Station Diagnostic - allows the user the means of verifying that the work station hardware (graphic CRT, alphanumeric CRT, and digitizing table) are in operational order.

Host Functional Requirements.

(a) Magnetic Tape Input/Output - enables the transfer of geographic and table data to/from magnetic tape.

(b) Filter Data - filters a data file (geographic or table) to produce residual files containing accepted and rejected features.

(c) Merge - combines two disk feature data files (geographic or table) to form a third disk file.

(d) Format Conversion - converts Bathymetric Data Reduction System (BDRS), Lineal Input System (LIS), and ACDDS data (table or geographic) to any other system format.

(e) Unit Conversion - changes the units in which sounding depth data are stored to either feet, meters, or fathoms.

(f) Projection Transformation - converts table data to geographic data and geographic data to table data by utilizing the following projections: Mercator, Transverse Mercator, Lambert Conformal, Polyconic, Polar Stereographic, Albers Equal Area Conic, and Gnomonic.

(g) Sectioning - segments a geographic or table file.

(h) Paneling - butt joins two feature files which share a common boundary and creates a single disk file.

(i) Symbolization - symbolizes lineal and point features in accordance with symbology specifications defined by DMA.

(j) Plot - produces an accurate proof plot or symbolized plot on a Xynetics or Calcomp plotting system.

(k) Table File Update - generates all required files necessary for work station functionality from an input data file.

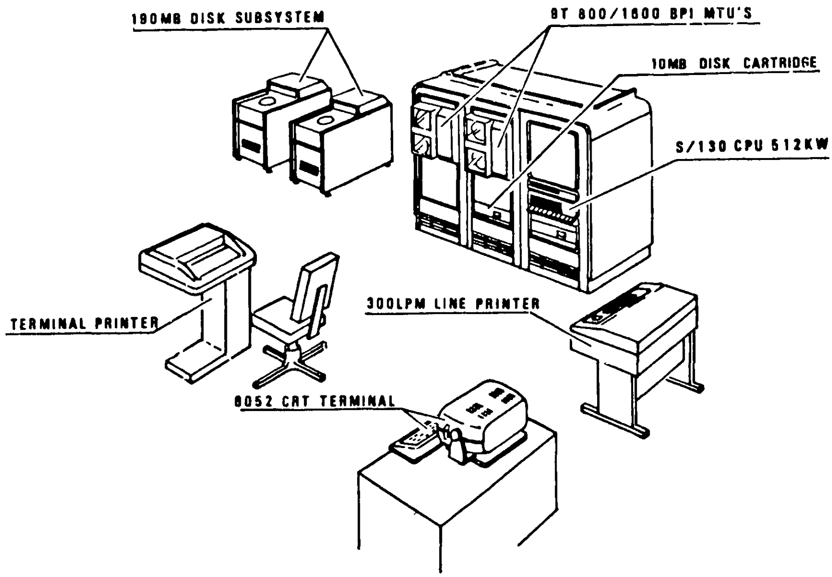
(l) Checkpoint/Restart - stops and restarts a batch function in the middle of an execution.

(m) Host Utilities - prints ACDDS table or geographic files, builds/prints - filter files, symbolization specification files, etc.

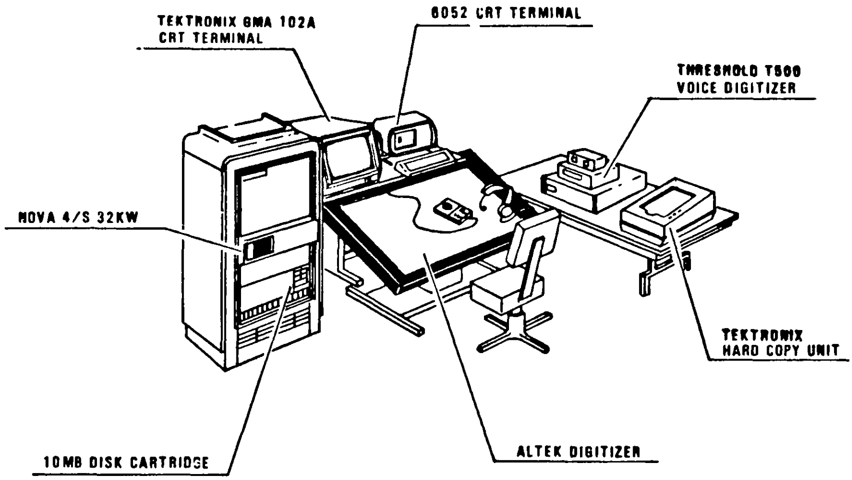
Hardware Requirements.

It should be noted, that without clear limits and priorities on size, performance, price, and functional requirements, unnecessary enhancements creep into the cartographic hardware design. After several iterations of "creeping elegance" the hardware no longer meets the original design objective. On the other hand, contingency plans should be designed into the system that encompass the "fuzzy set" and growth requirements. Following is a brief overview of typical hardware requirements for workstation and host cartographic subsystems, as depicted in Figure 1.

Cartographic Work Station Hardware Requirements. Common to cartographic work stations is a hardware configuration similar to the ACDDS which consists of: Data General NOVA 4/S Computer with 32K 16-bit words of memory, Floating Point Processor, 10MB Disk (5MB fixed - 5MB removable), Universal Line Multiplexor - Communication, Data General 6052 Video Display Terminal with keyboard, Altek Corporation DATATAB back lite digitizer, Tektronix GMA 102A 19 inch Graphic CRT and



ACDDS HOST HARDWARE CONFIGURATION



ACDDS WORK STATION HARDWARE CONFIGURATION

Figure 1.

controller, and Voice data entry terminal (Threshold Technology T500).

Cartographic Host Hardware Requirements. The ACDDS host hardware, typical of most cartographic systems, is comprised of: Data General ECLIPSE S/130 computer with 512K of MOS memory (16-bit word), Floating Point firmware, I/O Expansion chassis, 60 CPU Terminal Printer, Data General 6052 Video Display Terminal, Magnetic Tape Units (two 800/1600 BPI), 190MB Disk Unit (two), 10MB Disk (5MB fixed - 5MB removable), Data General 300 LPM Printer and Communication Chassis.

System Software Requirements

One might ask, what are some general requirements of system software that cartographic systems must have? These requirements are addressed in two areas, work station and host.

Work Station System Software. The system software running on the ACDDS work station is Data General's Real Time Disk Operating System (RDOS). The features of this operating system easily accommodate cartographic work station system design. They are as follows: supports real-time operation, easy system generation and tailoring with system tuning capability, easy interfacing of foreign peripherals, dynamic system buffer input/output, multitasking, intertask communications, program segmentation, device interrupt service capability, high level language processors with optimized code generation, provides communications for RJE, and system utilities.

Host System Software. The host system supports batch processing functional requirements. Within the ACDDS, the host system utilizes Data General's Advanced Operating System (AOS) which supports batch and real-time processing demands of cartographic systems. AOS capabilities include multiple batch job stream concurrent with real-time operation, multiprogramming processes, multitasking within each process, intertask and interprocess communication, easy system generation and tailoring, communication for RJE, high level language processor with optimized code generation, and system utilities.

Throughput Requirements

Now let us discuss the requirement of work station and host system throughput. Many times this requirement is fuzzy, implied, or not stated causing problems of acceptance of a system. For an optimized design of a cartographic system, this requirement must be clearly defined and understood. Typical throughput requirements similar to the ACDDS are discussed below (reference Figure 2).

Work Station Throughput. Session Initialization, consisting of chart and parameter control information data entry, header build, and registration data entry, should be achieved in less than five minutes as demonstrated on the ACDDS. A manual lineal data capture rate of 100 lineal inches/hour, with a target of up to 500 lineal inches/hour, was an ACDDS requirement. A capture rate of 491 lineal inches/hour was achieved. Computer-assisted (voice data entry terminal) depth data capture of 500 depths/hour was also an ACDDS requirement. The achieved rate of 949 depths/hour was demonstrated. The ACDDS also demonstrated a depth data capture rate of 1147 depths/hour via manual entry, against a requirement of 200 depths/hour.

Host Throughput. The number of functions executing simultaneously for a typical host system are two or more. The ACDDS can handle up to 20 functions simultaneously. The throughput requirements of

FUNCTIONS EXECUTED:

- PROJECTION TRANSFORMATION
- UNIT CONVERSION
- FORMAT CONVERSION
- SYMBOLIZATION
- SECTION
- PANEL
- TAPE I/O
- PLOT
- MERGE
- SORT

	TIME	FILE SIZE	NUMBER OF FUNCTIONS EXECUTING SIMULTANEOUSLY
THROUGHPUT REQUIREMENTS	1 HOUR	2400 LINEAL INCHES	MINIMUM OF 2
DEMONSTRATED CAPABILITY	55.3 MINUTES	2410 LINEAL INCHES	4

ACDDS HOST THROUGHPUT

FUNCTION	REQUIRED THROUGHPUT	DEMONSTRATED CAPABILITY	ACHIEVEMENT BEYOND REQUIREMENT
MANUAL LINEAL TRACE	100 INCHES/HOUR	491 INCHES/HOUR	391 INCHES/HOUR
COMPUTER-ASSISTED POINT ENTRY	500 POINTS/HOUR	949 POINTS/HOUR	449 POINTS/HOUR
MANUAL POINT ENTRY	200 POINTS/HOUR	1147 POINTS/HOUR	947 POINTS/HOUR

ACDDS WORK STATION THROUGHPUT

Figure 2.

processing one run of each host function against 2400 lineal inches of data within an hour time frame was the requirement for the ACDDS. The demonstrated throughput was performed against 2410 lineal inches of data within a 55 minute time frame.

SOFTWARE REQUIREMENT CONSIDERATIONS

Previous sections have already discussed hardware and system software requirements common to cartographic systems. It is of paramount importance that these requirements be analytical while giving special consideration to the application software design and development needed to meet the functional requirements. Thus, the expenditures allocated to the areas of hardware, system software, and application software must be properly balanced to provide a cost-effective means of meeting the requirements of the end user. The ACDDS exemplifies a system which was designed and implemented along these guidelines.

Work Station Software

To provide cartographic functionality, an efficient, yet relatively inexpensive work station hardware configuration should be selected. For program execution, the ACDDS work station processor features a total of 32K words of unmapped memory. The operating system that was tailored for this configuration occupies approximately 11K words of memory. Therefore, about 21K words of memory were available for application programs.

At first look, it appears that the work station hardware configuration may be insufficient to handle the extensive array of software functions discussed earlier. In fact, collectively, the work station real-time application programs require slightly over 100K words of memory in which to execute. But the work station functions possess two qualities which make various means of program segmentation quite feasible: work station functions are extremely interactive in nature, that is, they don't require the rapid speed of number crunching batch processes; work station functions are logically independent, the only link that these functions have to each other is that they often require access to common job files on disk.

The application software exploits, to a great extent, the capabilities of the operating system to permit such techniques as multitasking and program segmentation. A multiple task environment is one in which logically distinct tasks compete simultaneously for use of system resources. Multitasking is particularly useful in an interactive environment to effectively permit several functions to operate concurrently. This technique, along with three methods of structured program segmentation discussed in the following paragraphs, provides the tools required to execute the work station software functions in approximately 21K words of physical address space.

Chaining allows the programmer to write a large program in a sequence of executable segments where the end of each segment invokes the beginning of a subsequent segment. Chaining operates at only one level and RDOS does not save a core image before bringing a new program into memory and executing it.

When a program swap occurs, the operating system saves a core image of the current program on disk and then brings a new program into memory for execution. The new program may then swap to a lower level or simply exit to allow the calling program to be restored from disk and resume execution. RDOS permits program swaps to occur in up to five levels.

The work station application software also makes use of a more common form of program segmentation called overlaying. Overlaying is used to further segment programs which are still too large for the 21K physical address space.

Host Software

The host hardware, typical of cartographic systems, is configured with large amounts of memory and peripheral storage. Also present is a sophisticated operating system with both multitasking and multiprocessing capabilities. By exploiting these features, the ACDDS host application software makes it possible to manage many complex processes simultaneously. A 'front-end' process constantly monitors all job request communications from both the work stations and the host. At the same time, an 'executive' process manages and controls the host batch environment by executing cartographic functions as requested by the user. Since these functions are logically independent of each other, they can be performed concurrently. With the present ACDDS memory configuration, five batch jobs can execute in main memory at one time. If more are added, some become blocked or swapped out of memory.

Other facilities of the operating system utilized by host application software include shared memory pages. The capability of reading a common or 'shared' memory location makes it possible to effectively checkpoint an executing batch job. Upon user request, this job can be swapped back into memory and restarted from its breakpoint.

The point to be made within the software requirement area, is that an extravagent hardware configuration is generally not required for systems such as the ACDDS. A modest amount of software effort to exploit the available hardware and system software resources should be invested to avoid overscoping the hardware requirements.

HARDWARE/SOFTWARE EXPANDABILITY CONSIDERATION

As stated earlier in this paper, contingency plans should be designed into the cartographic system for expandability. By making the expandability feature a priority item within the initial design of the system, the hardware and application software areas become somewhat protected from short and medium term obsolescence.

Hardware Expandability

Each component within the hardware design phase should be looked at for expandability and each area documented. Within the ACDDS hardware design, the following expandability contingency considerations are available.

Work Station. Hardware expansion on the work station can include: upgrade of the Data General NOVA 4/S computer to a NOVA 4/X supporting 128K words of MOS memory, expansion of the 10M byte disk subsystem to include three additional drives, addition of a magnetic tape subsystem if future requirements dictate, and addition of a voice entry terminal to the work station CPU with no internal hardware modifications.

Host. Upgrade of the ACDDS host system could consist of: enhancing the host Data General ECLIPSE S/130 to a Data General ECLIPSE S/140 or S/250 CPU, expanding the 190M byte disk subsystem from two to four disk drives, expanding the magnetic tape subsystem from two to eight tape units, expanding the synchronous communications to provide a high performance interface to the work station communications and expanding the 10M byte disk subsystem from one to four disk drives.

Application Software Expandability

Early on, within the ACDDS functional design phase, the "hooks and handles" for functional expandability were made available by utilizing the structured approach to cartographic design. This approach dictated modular software that could easily be used between work station and host functions. These common modules include: file input/output routines, data pack and unpack routines, parameter naming conventions, etc. It should also be noted that by utilizing this approach, software corrective and adaptive maintenance efforts are minimized.

Work Station. By utilizing the RDOS operating system's features and the work station's module applications software design, additional functions may be added in an easy manner. RDOS swaps, chains, and overlays can be efficiently used to add additional capabilities with virtually no software modifications. Each program swap, chain, or overlay was designed as an independent functional module with new modules being developed with this same criteria.

Host. The strong features of the host's ECLIPSE S/130 Advanced Operating System (AOS) makes available an intelligent multiprogramming system. This, combined with the modular host system control and applications software ensures for an early expandible software system. To add a new application, one must only modify the remote job entry module and a single routine within the control software.

CONCLUSIONS

The intent of this paper was not to teach you how to optimize cartographic system designs, but rather to demonstrate that there is no magic related to this process. The designer must be aware of the global design requirements of the system within the hardware, system software, and application functional software areas. He must know the limits and capabilities of his selected hardware, be extremely knowledgeable of the system software and its' usage, and of course, know his cartographic applications. Thus, he must know his cartographic design requirements, for a brilliant solution to the wrong problem will not do any system designer much good.

ACKNOWLEDGMENTS

The ACDDS project was sponsored by the Rome Air Development Center under contract F30602-79-C-0261, Griffiss Air Force Base, New York, and the Defense Mapping Agency Hydrographic Topographic Center, Washington, D.C. Special thanks to Mr. T. Hallinan and Mr. J. Palermo of RADC, Mr. J. Ruys of DMAHTC, and Ms. J. R. Terenzetti of Synectics Corporation for their support and effort within this project.

REFERENCES

Data General Corporation. 1979, Real Time Disk Operating System (RDOS) Reference Manual.

Data General Corporation. 1979, Introduction to the Advanced Operating System (AOS).

Monmonier, M. S. 1982, Computer Assisted Cartography Principles and Prospects: Englewood Cliffs, N.J., Prentice Hall, Inc.

Synectics Corporation. 1980, Final Design Plan for Advanced Cartographic Data Digitizing System.

Synectics Corporation. 1981, Advanced Cartographic Data Digitizing System Program Maintenance Manual, Volumes I and II.

Yourden, E. 1982, Managing the System Life Cycle: New York, New York, Yourden Press.