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Sandia Laboratories Technical Capabilities

COMPUTATION SYSTEMS

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SANDIA LABORATORIES TECHNICAL CAPABILITIES

COMPUTATION SYSTEMS

ABSTRACT

This report characterizes the computation systems capabilities at Sandia Laboratories. Selected applications of these capabilities are presented to illustrate the extent to which they can be applied in research and development programs.

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FOREWORD

Sandia Laboratories, a multiprogram laboratory of the Department of Energy, is located in Albuquerque, New Mexico, and Livermore, California, with a remote testing facility at Tonopah, Nevada. In fulfilling its responsibilities in the fields of national security and energy, and in other programs, Sandia has acquired extensive capabilities in research, development, testing, and evaluation, and has made numerous contributions in scientific and engineering fields. These capabilities—the basic tools used in research and development—are the subjects of this series of reports. Each of these capabilities is described in a separate report, as listed below. In each report supporting information is provided to show applications of the capabilities.

All the capabilities are in current use. It is intended that their descriptions will allow planners to directly associate them with the technical requirements of studies being considered, and that they will also be sources of technical information for other laboratories, federal agencies, universities, and the Sandia staff.

For those interested in the overall capabilities of the Laboratories, all the reports are compiled in a single publication bearing its own number.

C. Donald Lundergan, Technical Editor
P. L. Mead, Publication Editor

TECHNICAL CAPABILITIES OF SANDIA LABORATORIES

Summary (SAND77-0651)

Aerosciences	SAND74-0075	Instrumentation and Data Systems	SAND74-0083
Applied Mathematics	SAND74-0079	Materials and Processes	SAND77-0002A
Biosciences	SAND74-0076	Measurement Standards	SAND74-0077
Computation Systems	SAND77-0767	Physical Sciences	SAND74-0074
Design Definition and Fabrication	SAND76-0413	Quality Assurance	SAND77-0652
Earth Sciences	SAND74-0085	Safety and Reliability Assurance	SAND74-0090
Electronics	SAND74-0086	Systems Analysis	SAND74-0089
Engineering Analysis	SAND74-0087	Testing	SAND74-0088
Explosives, Electrochemistry, and Electromechanisms	SAND74-0081	Auxiliary Capabilities	SAND74-0082
		Environmental Health	
		Information Sciences	

Compilation of
Sandia Laboratories Technical Capabilities
(SAND74-0092)

COMPUTATION SYSTEMS*

The computing centers and their technical support organizations at Sandia Albuquerque and Sandia Livermore are responsible for planning, adapting, and operating large-scale digital computer facilities in support of the scientific and engineering community of the Laboratories. Such modern, large-scale computers are essential to the solution of such problems as component design and development, modeling of complex systems, and detailed simulation of physical phenomena. A growing number of smaller digital computers are being integrated into facilities dedicated to the support of specific areas of research and development such as experiment control, data acquisition, and test monitoring. A few main-line computers are also devoted to management information and business data processing, but as these are nontechnical functions, they are not covered in detail in this report. The major example is the dual-processor Univac 1108 system, which is primarily devoted to administrative computing, although about 25% of its time is used for engineering support in such areas as quality control; engineering information, and product inventory.

The central computing facilities are based on Control Data Corporation scientific computer systems. The Albuquerque facility contains three CDC-6600's and a CYBER-172 which share a common mass-storage subsystem as well as extended core storage. The latter computer functions as a front-end controller in support of the largest computer in the complex, a CDC-7600. The Livermore facility contains two CDC-6600's, also with a common mass storage capability and a shared extended core. Remote job entry and interactive computation are increasingly emphasized. Time-sharing is accommodated at both centers. At Albuquerque, one of the CDC-6600's is devoted exclusively to the support of time-sharing activities during the normal workday.

A. R. Iacoletti
Technical Coordinator

Computation Systems Professional Staff and Investment in Equipment

	<u>Professional Staff</u>	<u>Investment in Equipment (in \$1000)</u>
Central Computer Systems and Associated Technical Support	143	33,500
Computer Center Support Staffs	86	
Corresponding Line Support Staffs	57	
Major Computer-Based Special-Purpose Systems and Support	44	6,000

*Compiled November 1977

SYSTEM PLANNING, DEVELOPMENT, AND SUPPORT

These services are provided (1) to perform the long-range planning required for future computing systems, (2) to assemble and adapt computer facilities for the needs of the Laboratories, and (3) to determine and promulgate ways to use existing facilities most effectively. These activities encompass the evaluation of computer technology and its projection in the context of the evolving needs of the Laboratories, the adaptation and development of software for operating systems, the construction of software for specific applications, computer hardware specification and selection, mathematical services, communications, and consultation.

Computer System Support

Activities are directed toward the development and adaptation of computer facilities to meet evolving computing needs in the scientific and engineering areas. Recent emphasis has been in interactive computation, multi-computer networking, and remote entry. Specific developments have included the design and implementation of software systems permitting concurrent, multimachine access to a common, on-line mass-storage facility. Development of the existing Sandia Interactive Graphics System (SIGS) is another example. (Items 1-3*)

Current Activities

- Multicomputer network design and development
- Computer configuration structuring and selection
- System development for special-application computers
- Computer interface hardware design
- Front-end processor for remote job entry
- File management software development
- Operating systems and compiler support
- Simulation of computer systems
- Remote plotting network development

Mathematical Computing Support Services

Activities include mathematical modeling, numerical analysis and code construction relative to specific research and development problems or problem classes, as well as the development of generalized mathematical subroutines for broad use in numerous application codes. These subroutines collectively constitute the Sandia Mathematical Program Library. (Items 4-9)

*See Highlights, below.

Current Activities

- Applied mathematics and numerical analysis support services
- Mathematical program subroutine library development and updating
- Numerical analysis research
- Aerodynamic/ablation codes
- Fluid mechanics and heat-transfer analysis
- Generalized mesh generation for structural analysis computations
- Statistical signal-processing studies
- Field-test analysis support
- Computer benchmarking studies (test codes for evaluating new equipment)
- Nuclear waste disposal
- Combustion research

Consultation Support

These efforts include the collection and distribution of information bearing on effective use of computing facilities. In addition, a continuing program of technical training and consultation is conducted for the user community.

Current Activities

- Computing course development
- User consultation services
- Programming manual preparation
- Video taping of computer courses and symposia
- Computing newsletters
- Computer-operator training
- Corporate contact for inter-laboratory code distribution
- Maintenance of general-use program abstracts and computing library
- Code-improvement assistance

Communication Development and Support

Activities include the development of communication links to support distributed processors, remote job entry terminals, and interactive user terminals, which are located throughout the Laboratories. These efforts provide the user with faster and easier access to the central computing facility.

SYSTEM PLANNING, DEVELOPMENT, AND SUPPORT

Current Activities

- Development of comprehensive laboratory communication plan
- Minicomputer network development
- Hardware design for computer complex
- Maintenance and expansion of existing communication system
- TV computer status system
- Link to Sandia Livermore
- Link to Los Alamos Scientific Laboratory
- Link to other DOE laboratories

* * * * * HIGHLIGHTS * * * * *

Item 1. *Scientific Computer Network at Albuquerque (Figure 1)*

Operating system software has been developed to allow the sharing of mass storage by three CDC-6600's and a CDC CYBER-172. Sharing permits more effective use of computer resources and provides better service. It eliminates redundant copies of program and data files, significantly reduces the use of magnetic tapes, and provides fast access to files.

Common input/output queue software further extends the utility of the network. Common-queue software allows a job submitted to a remote entry station to be executed on whichever machine has the greatest facility for timely turnaround of that job. The common-queue package has sufficient safeguards to preserve queued files during virtually any type of system interruption.

Interactive graphics software permits simultaneous access to the network for up to 8 high-precision stations, each of which is connected to the central facility via a 40.8 kilobit-per-second link.

Item 2. *Dual CDC-6600 Complex at Livermore (Figure 2)*

The dual CDC-6600 complex at Livermore provides access to a common mass-storage subsystem for both

interactive and batch programs. For large codes, users may view input and output data interactively whereas the program itself is run in the batch mode, thus suiting the mode of operation to the application.

Item 3. *Further Development at Albuquerque*

The integrated computational network is being expanded. One phase of this expansion is full integration of the CDC-7600 computer into the network. This will permit more efficient transfer of jobs into the computer and the use by those jobs of a shared catalogued file base. The file base will also be shared between the time-sharing node and the remainder of the network. This sharing will permit the construction and submittal of large batch jobs from a time-sharing terminal; the output of these jobs may later be scanned in an interactive mode. The remote job entry facility is also being expanded. Replacement of the present hardwired multiplexer will permit expansion of batch terminals from the present mix of 4 high-speed and 7 low-speed terminals to 8 high-speed and 20 low-speed terminals. The first phase of the expansion also calls for the implementation of electrostatic plotters at high-speed terminals.

Item 4. *Research in Numerical Analysis*

A major emphasis in numerical analysis research has been in the area of numerical solutions of initial-value and boundary-value problems for ordinary differential equations. As part of this effort, a state-of-the-art Runge-Kutta-Fehlberg code was developed for the initial-value problem. A code, SUPORT, using superposition and orthonormalization, was developed for the linear two-point problem. For nonlinear problems, the method of quasilinearization is combined with the SUPORT code to form a new code called SUPORQ. A suite of codes has also been developed to solve boundary-value problems via "shooting" (trial and error) techniques. In the area of partial differential equations, a method-of-lines approach using a B-spline collocation technique is being employed to solve time-dependent problems arising in combustion and heat-transfer studies. In the area of linear equations, a code has been developed that uses incomplete factorization and the generalized method of conjugate gradients to solve large sparse positive definite matrices that arise from finite-element models.

Item 5. *Applied Mathematics and Numerical Analysis Support*

Consultation and analysis are provided in numerous areas of applied mathematics and numerical analysis as they relate to a wide spectrum of engineering and physics problems. In support of other efforts within the Laboratories, the mathematical computing staff has recently developed (1) an interactive code, IUNFLD, to solve integral equations of the first or second kind and to use splines or polynomials for constrained curve fitting, (2) a

mathematical model for the deep sea disposal of nuclear waste, (3) a computer code for use in analysis of the design of neutron generator tubes, (4) a mathematical model for the production of pure homogeneous ingots using a vacuum arc remelt technique, (5) a computer code to numerically solve the nonlinear stability problem that arises at the gas/slag interface in magnetohydrodynamics channels, (6) a code to optimize various input-output configurations for solar and wind energy storage devices, and (7) a mathematical model for time-dependent, one-dimensional premixed laminar flames.

Item 6. *Ion-Beam Accelerator*

The computer has been used to simulate ion-beam devices. Such devices involve the solution of ion trajectories together with the electrostatic field which accelerates the ions. Since the field which influences the ion trajectories is itself determined by the ion flow in the region, an iteration procedure must be used to find the configuration in which the ion flow and field are given self-consistently. Of particular significance is the shape of the plasma surface from which the ions emerge. This too is obtained from the self-consistent solution. Such codes are extremely useful in the design of ion-beam devices by revealing the effects of changes in parameters or geometry without resorting to expensive and time-consuming experimentation. They also provide insight into the interpretation of experimental data. Figure 3 illustrates contours of constant ion density obtained by using the code.

Figure 3. Contours of equal ion density

SYSTEM PLANNING, DEVELOPMENT, AND SUPPORT

Item 7. *Mathematical Modeling of Alloy Solidification*

Alloy solidification studies related to the Sandia vacuum consumable arc remelt facility are being supported through development of a mathematical model of the molten-metal flow in the solidifying ingot. This model is now being used to develop a numerical simulation of the flow, incorporating phase changes, nonlinear material properties, and combined electromagnetic and buoyant body forces. The resulting code requires several novel features, including arbitrarily strained orthogonal coordinates and special operator splitting, so that the discrete equations will conserve energy, mass, and vorticity on grids of manageable size.

Item 8. *Solar Plant Simulation*

Evaluation of the costs and performance of solar and energy storage systems requires detailed computational

simulations. One current program simulates the operation of solar electric plants in a utility network. Since solar energy may be collected at times when its use would not be optimal for the network, the simulation dispatches the solar units in a way that maximizes their value. The optimization involves such factors as minimizing the cost of fuel required to run conventional plants required as backup to insure that the network can reliably meet demand.

A Monte Carlo computer program (MIRVAL) simulating the sun-heliostat receiver interaction is used to generate power-versus-time input data for the dispatching-optimization computation. Figure 4 shows the severe shadowing that would occur if a mirror field were used early in the morning.

Figure 4. Mirror deployment and receiver tower for the solar test facility at Sandia Albuquerque, as viewed from the direction of the sun

Item 9. Combustion Modeling

The modeling of multicomponent, chemically reacting fluid flows -- e.g., the description of physical phenomena involving combustion processes -- depends on the use of high-speed computers because of the complexity of the governing conservation equations. Presently, useful results are being obtained with both one-dimensional, time-dependent and two-dimensional, time-independent numerical models. Figure 5, an example of current work in the combustion

field, shows the temperature and velocity contours for a steady-state hydrogen-air laminar jet diffusion flame. Other work in progress includes the numerical modeling of shielded diffusion flames, the prediction of specie and temperature histories of premixed laminar flames, computer simulation of chemically reacting fluid flows in porous media (weapon applications), and the development of detailed models for the study of engine cylinder flow fields.

Figure 5. Isotherms and constant-velocity contours for a 6 m/s H_2 -air laminar jet diffusion flame

CENTRAL COMPUTING

The central computing facilities at both the Albuquerque and Livermore locations of Sandia Laboratories are designed to accommodate the concurrent processing of a number of individual programs. Economies of scale are thus achieved by the effective sharing of high-performance central processors and centralized mass-storage file subsystems. Both batch and interactive modes of computation are supported. The bulk of the general-purpose computing load is handled by these main-line systems. This includes applications in the system studies area, as well as fundamental research, weapon design, reactor studies and nuclear safety, component development, effects modeling, and test-data reduction. The main-line systems at the centers are approved for the simultaneous processing of both unclassified and classified information, through Secret.

Equipment

Sandia's scientific computer systems are built around CDC-6600 and CDC-7600 computers designed for high-speed extended precision calculations. The Albuquerque center contains three CDC-6600's and a CDC-7600 as worker computers, all sharing a common mass-storage subsystem. In addition, the three CDC-6600's share an extended core storage device (bulk core). These systems are accessed via a mixture of high and low-speed terminals. Interactive graphics applications are serviced by a network of six Digital Equipment Corporation computers (PDP-9's and a PDP-15) remotely linked to one of the CDC-6600's. A pair of Tektronix 4081 graphics stations and a large number of Tektronix 4014 and Tektronix 4010 storage tube terminals are also supported via the Time-Sharing System.

The Livermore computing center contains two CDC-6600's sharing a common mass-storage subsystem. Extended core storage is also apportioned between the two machines. Also provided is a wide range of interactive graphics capabilities including (1) the CDC-777 Cybergraphics system, which consists of a CDC System 17 minicomputer controlling two high-capacity, high-precision graphics consoles remotely connected to one of the CDC-6600's; (2) a Tektronix 4081 graphics system which provides both refreshed and storage graphics and the ability to operate either as a stand-alone system or as an intelligent graphics terminal to a CDC-6600, and (3) a network of 10 Tektronix 4014 and 4010 graphics terminals for general time-sharing and graphics applications which do not require refresh capabilities.

Servicing the total scientific computing complex is an off-line computer output microfilm subsystem in the Albuquerque center consisting of a Datagraphix Model 4460 and a Model 4020. These devices can portray graphical information on 16 mm/35 mm film and microfiche. Computer-generated motion pictures, in color or

black-and-white, can be produced to represent time-dependent physical processes:

Expansion of the computer output microfilm facility in Albuquerque is scheduled for the near future. This will include a microfilm recorder for reports and other tabular data, a graphical recorder with sufficient precision to accommodate the transcription of computer-generated E-size engineering drawings onto microfilm, and a graphical recorder for improved color film generation.

The Livermore center has installed an APPLICON AP-75 high-precision system to service the computer output microfilm requirements of that facility, including the generation of 16 and 35-mm film and microfiche.

Current Major Equipment (Albuquerque)

Computer Model or Feature	Number of Capacity
CDC-7600	1 unit
Small core memory	65,000 words*
Large core memory	512,000 words*
CDC-6600	3 units
Main memory size (each)	131,000 words*
Extended core storage (shared)	1,500,000 words*
Shared mass storage	367 million words*
Nonshared mass storage	259 million words*
High-speed batch terminals	3 units
Low-speed batch terminals	7 units
High-performance graphics stations	6 units

*Word size is 60 bits.

Current Major Equipment (Livermore)

<u>Computer Model or Feature</u>	<u>Number or Capacity</u>
CDC-6600	2
Main memory size (each)	131,000 words*
Peripheral processors (each)	10
Extended core storage	500,000 words*
Shared mass storage	216 million words*
Nonshared mass storage	24 million words*
Graphics computer station	2
Interactive terminals	19

*Word size is 60 bits.

Programming Languages and Special Processors

The central scientific computing facilities were acquired for the solution of problems in the research, design, development, and testing areas. Therefore, the programming languages, as well as the general-application software packages provided, are oriented toward this objective. FORTRAN is the primary language, although symbol manipulation, graphical plotting, simulation languages, and specialized higher-level software processors are also furnished. In contrast to the Laboratories' business data processing system (a dual processor UNIVAC-1108), the emphasis has not been toward special languages for data-base management applications or other nonscientific activities.

Currently Supported Languages and Nationally Known Software Processors

Assemblers and compilers
 COMPASS
 FORTRAN extended
 FORTRAN (FUN)
 SNOBOL
 PASCAL
 ALGOL-60
 Graphical plotting
 DISSPLA
 GCS
 SCORS
 IGS/4460
 SLPLOT
 Maintenance Packages
 UPDATE
 MODIFY

Mathematical libraries
 Sandia mathematical program
 IMSL
 Continuous system simulation languages
 CSSL
 MIMIC
 Electronic circuit analysis
 ITRAC
 ECAP
 SCEPTRE
 NET
 SPICE
 SALOGS
 Heat transfer
 CINDA
 Structural analysis
 NASTRAN
 Spectral analysis
 MACRAN

Mathematical Program Library

The Sandia Mathematical Program Library consists of a number of FORTRAN-callable, high-quality, general-purpose mathematical subroutines. These, in turn, are incorporated in numerous individual computer programs that require the particular mathematical computations provided. Extensive validation testing, a standardized software approach, user-oriented documentation, and backup consultative support typify this capability. Numerical analysis research is carried out in conjunction with this effort. As numerical techniques evolve, state-of-the-art improvements and/or replacements are made in the collection. This Library, although first implemented on the CDC-6600's, has been developed with the objective of achieving a high degree of code portability.

Current Routine Subcategories

Linear algebraic equations
 Numerical quadrature
 Ordinary differential equations
 Data fitting and smoothing
 Eigenvalues and Eigenvectors of matrices
 Fourier transforms
 Zeros of functions and optimization
 Zeros of polynomials
 Special functions

TIME-SHARING SYSTEM

A CDC-6600 computer at the Albuquerque computing center and another at the Livermore center support Sandia's time-sharing requirements. Time-sharing is the nearly simultaneous servicing of many users interacting with the computer via keyboard and/or display-tube terminals. This mode of computation aids scientists and engineers in program design, information retrieval, and general problem-solving activities requiring rapid computer response and interactive control. Problems requiring long periods of computer time are executed on the batch computers (the CDC-7600 and the CDC-6600's): In Albuquerque the time-sharing system may be used to build and submit these longer-running jobs to the batch machines. Access to the system is via dial-up lines. Because these lines tie into the commercial telephone network, the time-sharing system is restricted to unclassified jobs. Access is controlled through user identifiers and passwords. Over 80 terminal users can be serviced concurrently. The Livermore center provides a comparable capability, but classified information can be handled there because the computer lines are hardwired.

Equipment

The CDC-6600 time-sharing facility in Albuquerque is configured to provide optimal service for its highly interactive load. Interactive use of the system involves such things as the editing of information, short program execution, and graphic data display. In this type of problem solving, the user expects prompt response from the computer. To provide adequate concurrent service, the system must have well-structured memory resources. The storage hierarchy in the CDC-6600 system consists of a main memory, a high-speed extended core storage, and random-access magnetic-disk storage.

Another factor in satisfactory terminal response is the communications element. A MODCOMP minicomputer interfaces the CDC-6600 with over 80 dial-up lines. Data rates of 10, 30, and 120 characters per second are provided. The time-sharing facility has capacity for more lines and higher data rates as the need arises.

terminals are all located within the security area and may be used for classified processing. Over 20 terminals are currently available, with a maximum capacity of 32 low-speed (4800 baud) and four high-speed (40.8 kilobaud) ports. Terminal users have access to most of the same processors and system utilities as batch users, in addition to services necessary for support of interactive terminals.

Programming Languages and Special Processors

The languages, special processors, and utilities supported on these time-sharing facilities reflect the breadth of applications amenable to interactive computation. Only a small subset of the software tools available is noted here. Typically, time-sharing systems are rich in supporting software. This is necessary because of the high degree of man-machine interaction involved. Thus, emphasis is placed on testing aids, editors, file manipulation and retrieval capabilities, etc.

Current Equipment

<u>Computer Model or Feature</u>	<u>Number or Capacity</u>
CDC-6600	1
Main memory	131,000 words*
Swapping storage	750,000 words*
Disk storage	60 million words*
Remote terminal lines	64

*Word size is 60 bits.

At Livermore, time-sharing access to one of the CDC-6600's is provided by a network of graphic and alphanumeric terminals connected via hardwired lines. The

Currently Supported Languages and Nationally Known Software Processors

Assemblers and compilers
 COMPASS
 BASIC
 FORTRAN extended
 COBOL
 APL
 SYMPL
 PASCAL
 SNOBOL
 Miscellaneous cross assemblers, compilers,
 and simulators for minicomputers.

COMPUTATION SYSTEMS

Testing tools, editors, and maintenance packages

XEDIT
TECO
UPDATE
MODIFY
TIDY

Mathematical libraries

Sandia mathematical program library
IMSL

Electronic circuit analysis

ITRAC
ECAP

Document preparation

RUNOFF

Graphical Plotting

DISSPLA
PLOT-10
SCORS
GCS

Applications

The time-sharing systems service a large number of users, including those only occasionally or minimally involved in computation per se. The spectrum of applica-

TIME-SHARING SYSTEM

tions is quite broad, ranging from theoretical modeling to engineering applications to test operation scheduling and quality control. Excluded are large-scale computation-bound codes. This restriction ensures adequate system response for jobs that are appropriate for a time-sharing environment. In any case, the systems are used primarily for scientific and engineering applications requiring rapid turnaround and direct interactive control. Some of these applications are of a one-time nature. The time-sharing computer in such instances represents an extension of the engineer's standard calculating tools. Other applications require the continued use of codes and the maintenance of data bases over extended periods of time.

A brief summary of application areas is as follows:

Engineering and scientific calculations
Cross compiling of codes for various
dedicated minicomputers

Simulation of continuous systems
Closed-form equation solution; i.e.,
symbol manipulation

Technical document preparation and updating
File maintenance and inquiry applications; i.e.,
test operation center scheduling, measure-
ment standards files, etc.

INTERACTIVE GRAPHICS FACILITIES

Interactive graphics is a computational capability provided for applications requiring on-line decision-making based on a dynamic, visual depiction of the processes under consideration. Typical applications include network design, circuit layout, trajectory analysis, system simulations, and data fitting. The Laboratories' primary emphasis in the interactive graphics area is directed toward high-performance systems that provide a variety of graphical input and display devices, and afford maximum flexibility in interactive control. Satellite computer/controllers manage these interactive, refresh-scope-based facilities and provide the necessary interface to the larger centralized systems (CDC-6600's). Primary computation is done in the latter systems, and the results (display files, data arrays) are transmitted to the graphics satellites. Complementing the high-performance systems is an increasing number of storage-tube graphics terminals linked directly to the central facilities in Livermore or Albuquerque. In Albuquerque these terminals are supported on the time-sharing system via dial-up access.

In addition to the central facility-supported systems, several essentially autonomous interactive units are in operation. These include three APPLICON-875's used for machine-aided design definition. In addition, Sandia's CDC-6400 data-reduction computer (discussed in a following section) supports two high-precision CDC-777 graphics terminals.

Graphics Satellite Stations

The Livermore facility contains two high-performance CDC-777 graphics stations. These consoles are controlled by a CDC System 17 minicomputer which, in turn, is connected to the Livermore time-sharing CDC-6600 over a hardwired high-speed (40.8 kilobaud) communications link. These stations provide a refresh-type scope display and interactive control that functions under a standard CDC operating system. In addition, the central facility supports a medium-scale Tektronix-4081 graphics station with a limited refresh mode capability, and a number of direct-view storage tube (DVST) terminals. The Albuquerque center also supports a host of DVST terminals and two Tektronix-4081's.

The high-performance graphics complex in Albuquerque is collectively known as the SIGS (Sandia Interactive Graphics System). SIGS consists of six satellite computers (five PDP-9's and one PDP-15), each with a Vector General interactive display. One of these satellites supports a COMTAL 8300 image processor unit for generating continuous-tone graphics. The satellite computers, in turn, are connected to a single CDC-6600

computer via a high-speed synchronous communication link. These links are controlled by a MODCOMP II computer. The software for this communication subsystem, designed at Sandia, permits the concurrent servicing of each remote station. Each satellite is capable of stand-alone operation with its full complement of local peripherals (disk storage, printer, card reader, tapes, etc.). Most computations, however, are accomplished in the host CDC-6600 system. A typical application would require programming at both the CDC-6600 and satellite ends. This Sandia-developed interactive graphics system is unique, both in hardware and software; therefore, it is not compatible with similar subsystems developed by Control Data Corporation. (Item 1)*

*See Highlights, below.

INTERACTIVE GRAPHICS FACILITIES

*Standard Equipment on Each of the Six
Satellite Graphics Computers (Albuquerque)*

<u>Component or Feature</u>	<u>Number or Capacity</u>
Main memory size	24,000 words*
Disk storage	524,000 words*
DEC tape transports	2
Electrostatic printer/plotter	1
Card reader	1
Teletype console	1
Direct view storage tube	1
Vector General display console	1
Graphics input devices:	
Keyboard	1
Light pen	1
Data tablet	1
Control dials	10
Features:	
21-inch refresh scope	
Hardware rotation	
Three-dimensional Vector representation	
Depth cueing	
Hardware scissoring	
Display subroutines	

*Word size is 18 bits.

Applications

Applications in which the existing interactive graphics facilities are used vary considerably and represent a growing spectrum of activities. The common thread, however, is the need to incorporate the human decision-making element into the computation process in an iterative manner. The best applications are those in which graphical portrayal of the problem plays an essential role in its solution.

Current Applications

Printed circuit board layout
 Circuit design and analysis
 Integrated circuit mask generation
 Aircraft/store-separation analysis
 Source/sink aerodynamic model calculations
 Stability analysis of linear systems
 Post-processing graphical analysis of
 hydrocode calculations
 Generalized curve fitting
 Data reduction
 Mesh generation for large Lagrangian codes
 Digital logic simulation
 Material-strength modeling
 Topographical analysis for guidance system
 design
 Solar collector simulation

* * * * * HIGHLIGHTS * * * * *

Item 1. Interactive Graphics Codes

Of the various interactive graphics codes developed, two deserve special mention for their extent of application and their relative impact. DAVINCI is an interactive program that allows the layout and updating of printed circuit boards. Basic DAVINCI options selected by a lightpen allow the user to display various combinations of circuit layers. The pictures can be enlarged by a software window option to permit examination of areas in closer

detail. Clearance for electrical standoff is an important design parameter. The system provides visual and analytical checking methods. Manipulation capabilities allow parts to be added, deleted, revised, or duplicated. The final results are outputted in a manner suitable for generating artwork masters on automatic drafting machines, or alternatively for driving numerical-control machines.

INTERACTIVE GRAPHICS FACILITIES

The second code, GAIN, provides an interactive capability for defining network topologies in schematic form. The circuit descriptions, in turn, are transferred to an interactive version of SCEPTRE which computes and displays the response characteristics of the circuits so defined. This combination provides the designer with an iterative, human-oriented computational capability that expedites the design process.

Both GAIN/SCEPTRE and DAVINCI were developed for use on the SIGS graphics system. Figure 1 demonstrates the use of the latter code.

Figure 1. The DAVINCI code being used on the Sandia Interactive Graphics System

COMPUTER-BASED SPECIAL-PURPOSE SYSTEMS AND SUPPORT

Computers are being used increasingly to control laboratory equipment, to assist in on-line experimentation, and to acquire data. Following are examples of some of our major computer-based special-purpose systems. In each case a computer is integrated into a larger system and provides the critical control and processing required. Such computers, although usually general-purpose in nature, are thus essentially dedicated to the specific applications for which the system as a whole is designed.

Instrumentation and Data Systems

Four major computer systems are included in this category. Most final reduction of data from the various test sites is done on the CDC-6400 computer in Albuquerque. Telemetry, optical, radar, and various instrumentation data are processed by that facility. Playback is by an off-line CDC-3100 computer. Other facilities include an automatic data-processing system based on an XDS Sigma-5 computer, which is located in the environmental test area in Albuquerque. This system is used for on-line control of vibration testing and for post-test digitizing and analysis of data. Following preliminary analysis and validity testing, the results are often transmitted to the CDC-6400 for final processing.

The same relationship with respect to the CDC-6400 holds for the DITAC system at the Tonopah Test Range. DITAC is an advanced real-time digital acquisition and plotting system engineered around a pair of Honeywell DDP-124 computers. In addition to its data-gathering function, DITAC controls the automatic positioning of cinetheodolites, tracking telescopes, and radar instrumentation. DITAC also handles the automatic focusing of optical instrumentation, and provides real-time target trajectory data to digital plotting boards and visual displays.

A data playback and digitizing system, built around an XDS-930 computer, also exists at Livermore. (Item 1*)

Current Activities

- Development of user-oriented data-reduction system
- Development of time-sharing technique for managing telemetry data base

Flight-Simulation Facilities

Analog and hybrid computer equipment is used to perform real-time flight simulations. In some instances,

actual guidance-and-control hardware is incorporated into the data loop for more realistic simulation. These facilities play an important role in the development of stand-off missiles, reentry vehicles, shells, and rockets. The four facilities dedicated to flight simulation work include three AD/FIVE's interfaced to a PDP-11/45; an EAI-7800 interfaced to an EAI-PACER; an EAI-580 and TR-48 interfaced to a NOVA-800; and an EAI-680. Each of the first two facilities includes a Carco three-axis angular-motion simulator interfaced to the hybrid computer equipment. Hardware may be mounted on the Carco device and subjected to the angular velocities and accelerations actually experienced in full-scale flight. (Item 2)

Current Activities

- Guidance and control-system development
- Six-degree-of-freedom flight simulations
 - Modified Euler approach
 - Method of quaternions
- Tricyclic angular motion studies
- Point-mass trajectory calculations
- Rocket staging
- Wind effects
- Aerodynamic heating investigations

Microelectronics Laboratory System

A dedicated computer system is used to control laboratory experiments involving semiconductor devices, and to perform high-speed data-acquisition and reduction on a real-time basis. The central computer is presently a Varian 72 with 144,000 words (16 bits each) of core memory, 36 million words of disk storage, and various peripheral devices. Linked remotely to this computer are a number of Hewlett Packard minicomputers which in turn control semiconductor device testers and equipment in the Semiconductor Development Laboratory. Data from the testers are processed, and summary information is plotted on graphics display stations in remote laboratories. The automated station provides the design engineer and the laboratory experimenter with processed experimental information on a real-time basis. (Item 3)

*See Highlights, below.

COMPUTER-BASED SPECIAL-PURPOSE SYSTEMS AND SUPPORT

Current Activities

- Testing of device characteristics
 - Current versus applied voltage
 - Capacitance-voltage characteristics
 - Time-dependent effects
 - Microwave transistor S-parameters
- Measuring wafer characteristics
 - Circuit characteristics
 - Sheet resistivity
 - Impurity concentrations
 - Lifetime values
- Evaluation of fabrication processes
 - Automatic equipment control
 - Accurate device/wafer records

Numerical Control Facility

A PDP-15 computer generates machine-tool programming instructions used to control machinery in the fabrication shops. Direct data transfer from computer to machine reduces lead time and practically eliminates wait time for program changes and program optimization. A link from the PDP-15 to the UNIVAC-1108 at the central computing facility permits the processing of computing jobs that exceed the capacity of the PDP-15.

Current Activities

- Real-time system programming
- Numerical-control part programming
- Tool application programming
- Computer interface design

Electron-Beam Fusion Data Acquisition Facility

A MODCOMP II/25 computer system is used to acquire and process data from the e-beam fusion research accelerators Hydra, Proto I, and Proto II. The central processing unit contains 65,000 16-bit words of core memory plus hardware floating point. Peripherals include two cartridge moving-head disks, two 7-track tap drives, two Tektronix 4010-1 computer display terminals, and a hard-copy unit. The real-time multi-task capabilities of the Max III operating system are used extensively.

Data are acquired on-line via 15 Tektronix 7912 transient digitizers. The computer performs a diagnostic check for each 7912 before each shot. It then arms the digitizers and acquires data after the shot. Input signals are automatically routed from the accelerator in use to the 7912's via a computer-controlled coaxial switching matrix. All data are displayed in graphic form on the 4010 terminals. The software is written to allow two independent users to operate simultaneously, one on each terminal.

Data are also acquired off-line via conventional oscilloscope photography. The photographs are then digitized by a Colorado Video 270 digitizer incorporated into a closed-circuit television system and interfaced to the computer. Data produced by the video digitizer are handled in the computer in the same way as data produced by the 7912's.

Current Activities

- Monitoring accelerator diode voltage [V, (dV/dt)] and current [I, (dI/dt)] waveforms for all three machines.
- Computing diode impedance, power, and energy from voltage and current inputs.
- Monitoring diode x-ray output with pin diode detectors.
- Monitoring neutron output on target shots.
- Deconvolving out cable high-frequency rolloff effects from all input signals.

Five-Megawatt Solar Thermal Test Facility

A network of 9 minicomputers is used to control a field of approximately 78 sun-tracking mirrors (heliostats). The primary computer-controlled functions are control of the steam and heat rejection subsystems, data gathering, and control of the experiments under test. Five MODCOMP II 25's are used for mirror control: Hewlett Packard 21 MX's are used for weather data, experiment data, solar flux calibration, and the supervisory functions of operator interface, real-time data presentation, and network management. Experimental steam boilers for electric power generation are tested at the facility, as well as other sun-powered devices. In addition, experiments are conducted which facilitate the investigation of photovoltaic devices and high-temperature metallurgy research. A dual-monitor color graphic console is incorporated into the controls, eliminating the large control boards usually required in a generating plant, and allowing real-time data display and operator modification of the test.

Current Activities

- Heliostat testing
- Development of reflected energy data-calibration techniques
- Development of human-engineered, operator-oriented control methods
- Investigation of safety problems in using reflected solar energy
- Development of real-time data analysis and display techniques.

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HIGHLIGHTS

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Item 1. User-Oriented Data-Reduction Facility

A major new data-playback/data-reduction system has been funded and is under development. The facility will consist of a state-of-the-art automated telemetry "front-end" coupled to the CDC-6400 mentioned earlier. With the addition of a major on-line graphics capability, the system will permit users to "interact" with their data and control the reduction process via CRT consoles. Turn-around time for field-test data reduction is expected to be substantially improved. Figure 1 is a schematic of the playback/data-reduction facility.

Item 2. Rocket Stability Analysis

The AD/FIVE-PDP 11/45 hybrid computer shown in Figure 2 was used in the flight-stability analysis of the Nike-Malemute sounding-rocket system. Causes of excessive angular motion observed in the flight of the second-stage Malemute were traced to certain high-order aerodynamic forces and moments acting normal to the plane of incidence. The analysis indicated the type of configurational changes required to obtain satisfactory flight characteristics.

Figure 1. Central computer user-oriented data reduction system

COMPUTER-BASED SPECIAL-PURPOSE SYSTEMS AND SUPPORT

Figure 2. The AD/FIVE-PDP 11/45 hybrid computer

Item 3. *Microelectronics Laboratory
Computer Development*

A new microelectronics laboratory has been constructed that is capable of producing silicon semiconductor devices ranging from discrete devices to medium and large-scale integrated circuits containing thousands of transistors. To support this effort, a program has been implemented for the computer-aided design of circuit masks. In addition, computer codes are being used for circuit analysis and simulation studies bearing on the design of complex integrated circuits.

A sixth SIGS graphics station has been installed to support the growing computational load in this area. Moreover, the previously described microelectronics computer facility provides additional services such as monitoring and control of diffusion furnaces, ion implantation and wafer probing equipment, and radiation-effects testing. This data-acquisition and laboratory control computer is depicted schematically in Figure 3.

COMPUTER-BASED SPECIAL-PURPOSE SYSTEMS AND SUPPORT

Figure 3. Microelectronics data acquisition system

SUMMARY OF MAJOR COMPUTATION SYSTEM FACILITIES

SCIENTIFIC COMPUTERS. Networks of large-scale computers at Albuquerque and at Livermore are used for solving problems in the areas of weapon design, component development, energy research, reactor and nuclear safety, effects modeling, and test-data reduction. These centralized facilities presently include a CDC-7600, five CDC-6600's, and a CYBER-172.

MASS STORAGE. Both centers support large-capacity magnetic-disk subsystems for the storage of data and program files. These are backed up by an extensive magnetic tape library.

REMOTE TERMINALS. Within the various facilities, remote batch terminals provide a direct link to central computers. In addition, a large number of teletype-like portable terminals permit access to the respective computer centers via dial-up or hardwired lines. A growing number of medium-scale and high-performance graphics stations provide interactive graphics capability for on-line design.

COMPUTER OUTPUT MICROFILM FACILITIES. An important capacity exists for placing computer-generated graphical and tabular information onto microfilm (16mm, 35mm, microfiche). Savings accrue in both media and storage costs. Moreover, particularly in complex simulations of time-dependent physical processes, the cinema-graphical depiction of results is the optimal approach to understanding the phenomena involved. Both black/white and color film are generated.

INPUT/OUTPUT PERIPHERALS. Printers, card readers, tape drives, and other input/output devices provide a fundamental capability to the computing networks, both on-site and at remote entry terminals.

COMPUTATION SYSTEMS

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