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AUTOMATIC DATA PROCESSING LONG-RANGE PLAN REPORT

NERVA Program, Contract SNP-1

July 1970

MASTER

AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL

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Classification Category

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I. OBJECTIVES

The automatic data processing long-range planning activity was initiated by the Space Nuclear Propulsion Office, Washington, D.C., in September 1969, to evaluate the computer requirements of the NERVA Program for the time period between 1971 and 1975. The evaluation was to select the number of computer sites to best meet the NERVA Program requirements and to develop computer acquisition plans for the selected sites, making provisions for uncertainties in the requirements.

To meet these objectives, the investigation was to identify the automatic data processing requirements in support of the NERVA Program under contract SNP-1 with the principal contractor being Aerojet-General Corporation, Sacramento, and the principal subcontractors being Westinghouse Electric Company, Pittsburgh, and the NASA Nuclear Rocket Development Station, Nevada. Requirements and equipment for hybrid computers were not included.

Various configurations to meet these requirements were to be analyzed and evaluated against the requirements.

II. SUMMARY

The investigation resulted in the following recommendations:

(1) Use of decentralized computer facilities should continue. A central facility for the entire NERVA Program does not appear to be practicable; and (2) the decision relative to using the NTO as a satellite facility to Sacramento should be made at such time as to support facility activation for testing in ETS-1. Current program planning indicates that this decision should be made in the summer of 1971. This would allow two years during facility activation for use of the computer and one year for installation of communication equipment, if the decision is to combine Sacramento and NTO into an integrated computer system. The cost effectiveness of the combination would be directly affected by the capacity and utilization of the

Sacramento facility. If enough capacity exists in the Sacramento computer without expanding to handle the NTO workload, the data indicates that it is more cost effective to combine the operations. However, if a larger computer must be installed in Sacramento, cost data indicate that adding a separate system at NTO would be more cost effective. The long-term commitment of 10 years for the communication system indicates the desirability of making a final decision as late as possible while still meeting the ETS-1 activation schedule; (3) the recommendations for the Pittsburgh site are to continue use of the Telecomputing Center through CY 1972 as being the most cost effective. At that time, it should be decided whether a separate facility should be established at WANL Large or to continued use be made of the Telecomputing Center A based on cost effectiveness and more firm NERVA Program schedule and requirements. Until then, the NERVA Program has access to a large computer that is also available to other programs; (4) the Sacramento facility should proceed with the development of a formal proposal for updating the facility; (5) in the cost studies, leasing costs were used for comparison purposes. It is recognized that the lease or buy decision on any acquisition would be made under the instructions contained in NASA PR 15.205-48, NASA Handbook 2410.1 Management Procedures for ADPE and AEC Manual Chapter 1801 ADP.

III. REVIEW OF CURRENT EQUIPMENT

At the present time three principal computing centers are being used in the NERVA Program. These are located at the Aerojet Sacramento plant, the Westinghouse Telecomputing Center at Pittsburgh, and the NERVA Test Operations at Jackass Flats, Nevada.

A. SACRAMENTO

In the Sacramento computing center the principal computer is a third generation IBM 360/65 computer having binary fixed words with floating

point hardware, capable of multiprogramming. The basic binary word is a 32-bit word, and double precision is accomplished with a 64-bit word. Currently, the IBM 360/65 has been increased in capacity to a million bytes of core memory. The system contains six 9-track and two 7-track tape drives, two high-speed printers, a card reader and a card punch. On-line storage is provided by a 2314 disk system containing a total of 13 disk packs. A Conversational Remote Batch Entry (CRBE) system is used during the day shift. Six typewriter terminals and six cathode ray tube display (2260) terminals are presently utilized. The CRBE system is disconnected during the remaining two shifts to allow classified information to be processed as well as to increase the multiprogramming capability.

A Benson Lehrner 120 high-speed plotter is part of the facility. This has the capability of producing either microfilm or 10-in. wide hard-copy plots at a rate of about 30 to 60 plots per minute.

In addition to the IBM 360/65, the principal computer for engineering and scientific processing, a smaller computer, the IBM 1130, is available. This unit uses magnetic cores for data and program instruction storage. It has a 16-bit word with two additional bits for parity checking. The configuration has 16K byte of core storage and a 600 line per minute 1403 printer. It is utilized for small engineering problems and for operating a Computer Industries 30-in. width incremental drum plotter (Model 345).

In addition, time-sharing terminals to outside computer facilities are connected to GE and Univac computers. These terminals provide a time-sharing capability for performing small engineering problems and the ability to directly solve problems on programs originally programmed for this computer.

B. WESTINGHOUSE

Central Facility at Telecomputer Center

The Westinghouse Telecomputer Center is a central computing facility consisting of several independent systems that are connected via telephone lines to remote terminals at user locations. The Center is committed to provide the Corporation with a modern facility to handle consolidated needs, including projected future needs.

The systems of interest in this study are the IBM 360 and CDC 6600 system.

1. IBM 360 System

In the Fall of 1969, the IBM 360 system consisted of a 360/75 as the central processing unit and a 360/50 as a support unit scheduling and processing jobs into and out of the 360/75. There were approximately 20 remote terminals being scheduled by the 360/50 computer. Each computer has a 524 K byte core. The system also contained 10 nine-track and two seven-track tape drives; 20 disc packs, two high-speed printers, and a card punch and reader.

By the end of 1969, the core of the 360/75 was doubled and the system rearranged to make the 360/75 the scheduler for terminal jobs within itself and to the 360/50. In addition, four tape drives two nine-track and two seven-track) and 12 disc packs were added.

Currently, a 360/65 has been integrated into the 360 system and four additional tape drives (nine-track) and 8 disc packs were added.

2. CDC 6600 System

The CDC 6600 system has two CDC 6600 central processing units, one with the 65K core and one with a 131K core. A CDC 6416 16K core is used as the scheduler from five remote terminals to the two central processing units. There are eight discs associated with the system, three (Model 6638) are common to both central processing units, one disc (Model 6603) each that is not common, and three discs (Model 6603) attached to the 6416 scheduler. Also, there are 16 tape drives in the system.

In 1971, the total TCC computer load on the 6600 system is expected to decrease when a CDC 7600 is installed at a present user's division facility. Therefore, additional capacity will be available for the projected NERVA load.

3. The Stromberg Digigraphics Plotter

An SD 4020 plotter is part of the Central Facility. It has the capability of producing microfilm, hard copy, or both simultaneously in either printed format or plotted format. The SD 4020 is currently used at approximately 1/4 capacity.

4. WANL Terminal

The WANL terminal is connected to the Central Facility by two 40.8 kilobits per second TELPAC "A" lines over a distance of 11 miles. An IBM 360/20 terminal is used to interface with the Central Facility 360 system. A CDC 8231 terminal is used for interfacing with the Central Facility 6600 system. All unclassified jobs are transmitted over the TELPAC line and output format is prepared at the WANL terminal. SC 4020 plotting is done at the Central Facility and transmitted by courier to WANL.

Special provisions must be made for handling CRD jobs. Less than 25 percent of the WANL computer load is CRD. The input data are prepared on magnetic tape and hand-carried four times a day by courier to the Central Facility, and the output, which is recorded on magnetic tape, is returned to WANL during the third shift; hence, normal operation results in 24 hr turn-around time or less. The output magnetic tape is processed at the WANL Terminal on the IBM 360/20 computer primarily on third shift so as not to interfere with the 360/20's use as a terminal to the Central Computer Facility during prime time operation.

To indicate overall capability of the Telecomputer Center, percent utilization, and general changes to the systems, Table 1 has been prepared. All user work loads are included.

C. NERVA TEST OPERATION

The NERVA Test operation has a second generation IBM 7094 computer as the principal machine. This includes six tape drives, card reader, and printer. There are no disk drives with the IBM 7094. The principle use of this machine is in support of the commercial work, including PERT at NTO, channel engineering for ETS-1, and data reduction for Test Cell C. In addition, an IBM 1401 is available with two tape drives, four disk packs (2 million characters), card and printer input/output drives. It is used for channel engineering for Test Cell C and to supplement the IBM 7094 in other activities. As part of the Test Cell C complex, two small computers are available to support test operations, the DDP-116 and the CDC 160A.

TABLE 1

TELECOMPUTER CENTER CAPACITY
BASED ON 6 DAYS AND 21 HOURS/DAY OPERATION

CONTRACT YEAR	AVAILABLE CAPACITY HOURS CDC 6600/IBM 360	PERCENT UTILIZATION CDC 6600/IBM 360	REMARKS
1968	7,400/5400	85/41	IBM 360/75 AND IBM 360/50. TWO CDC 6600'S W/65K AND 131 K CORE.
1969	8,500/5400	94/68	DISC ADDED TO 6600. IBM 360/50 ACTING AS PROCESSOR TO IBM 360/75.
1970	10,100/7900	95/88	DRUM ADDED TO 6600 TO INCREASE THRU PUT. IBM 360/75 CORE DOUBLED AND DOING PROCESSING TO SELF AND 50.
1971	10,250/12,000	88/86	THE CDC 6600 65K MACHINE REMOVED AND A CDC 7600 INSTALLED AT NES DIVISION. IBM 360/60 ADDED TO 75/50.
1972	7,200 ⁽¹⁾ /13,700	55/-	
1973	7,200/13,700	62/-	

(1) CDC CAPACITY WOULD BE 11,200 HOURS IF THE 6600 65K MACHINE WERE JUSTIFIED WITH ADDITIONAL WORK LOAD.

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IV. REQUIREMENTS

The requirements will be divided among the various principal user organizations, mainly Sacramento, Pittsburgh, and NERVA Test Operations requirements.

The Sacramento and Pittsburgh requirements are very similar in that these are the two major engineering centers working on SNP-1. The NERVA Test Operations requirements differ from this in that their principal function is in the real-time support of testing of various NERVA engine systems.

A. SACRAMENTO

To establish the requirements for Aerojet, Sacramento operation, the various uses of computers were reviewed. The major applications of computers are in the solution of engine system, nuclear shielding, engine design, quality control and reliability, trajectory and vehicle analysis, data evaluation, data control, PERT and fiscal control problems.

1. Major Applications of Computers

a. Engine System

Models have been developed representing the performance and operational characteristics of the NERVA engine system. The function of these models is to study engine startup, full-power operation, throttling, and shutdown for the engine cycle and to provide the definition of the interaction between the various components in the engine system. The models provide a basis for the definition of the interdependency of components on each other. As such, the models are of sufficient detail for each component to adequately represent this interaction. Programs are also used to keep track of engine weights and to perform vibrations interactions throughout the engine system.

b. Nuclear Shielding

Computer codes representing the distribution of radiation around the engine system, the tank, the payload, and the crew shield are used to define the radiation levels for the engine components as well as stage and payloads. The models are in sufficient detail to provide heating rates for the components due to radiation from the engine system. Also, models are in sufficient detail to define the size and distribution for shielding requirements for the NERVA engine.

c. Engine Design

Mathematical models are used for thermal, stress, and aerodynamic computations on the various components making up the engine system. These calculations are in sufficient detail to meet the design requirements. To perform this analysis, two- and three-dimensional mathematical models are required. In addition, programs for performing controls analysis and circuitry design are utilized as part of the engine development. Thrust and specific impulse predictions are also made on the nozzle.

d. Quality Control and Reliability

Reliability mathematical models are being developed to assess achieved reliability values for components/systems and to predict the projected capability of the components/systems to satisfy the reliability requirements. These models will be programmed for computer solution. In addition, a number of computer programs are being developed for specialized statistical/reliability analyses, including:

- (1) Statistical analysis of test data, including materials data analysis, analysis of component test data, etc.
- (2) Monte Carlo solutions of stress equations and stress-strength analyses.

- (3) Instrumentation and controls system reliability analyses.
- (4) Reliability apportionments
- (5) Trend data analyses

The manufacturing history of the component is maintained and data are stored as a basis for quality control.

e. Trajectory and Vehicle Analysis

Mathematical models of vehicle and trajectory and associated computer codes provide data placing the engine, the engine system, and considerations such as shielding and reliability in appropriate mission context. The major task here is trajectory simulation, reflecting engine characteristics, probable characteristics of a nuclear orbit-to-orbit shuttle (OOS) and many factors of natural environment. Auxiliary program structures deal with cost effectiveness of the OOS under varied ground rules, payload sensitivities to engine and OOS parameters, OOS tank pressurization, OOS mass properties, and OOS attitude control.

f. Data Evaluation

The computer is used to accept data from tests, convert it into engineering units, and translate it into a format that is desired for data evaluation and analysis. This includes evaluation of data from both component and systems tests. Among the functions to be performed are calibration, listing, plotting, conversion to engineering units, engineering calculations on the data, frequency and vibration analysis, mechanical impedance, averaging filtering, curve-fitting, best estimates, etc.

g. Data Control

Programs are required for parts listing, technical documentation index, specification index, drawing lists, functional responsibility

matrix, and material properties. A system is being developed to provide information retrievability and traceability throughout the NERVA Program.

h. PERT and Fiscal Control

PERT reports are prepared as a means of defining and evaluating progress towards the successful completion of the NERVA Program goals. In addition, special cost reports are prepared for cost control; proposals are prepared; and budget and SNPO fiscal reports are prepared.

2. Exclusions

The central accounting functions, the test facility simulators and any special digital process computers were not included in this study. A preliminary description of the digital controls system requirements is presented in Appendix C-2, but these were excluded from the requirements placed on the data processing systems considered in this report.

To establish quantitative numbers on these requirements, data from the eight-year SNP-1 plan, issued in December 1960, was used (Ref. 1). In this plan each project under SNP-1 forecasted their computer requirements. As part of this, a review was made of the reasons why each project anticipated a change in the level of their activities.

The major causes of increased projected computer use were: (1) requirements for more detailed cycle analysis of engine systems; the added complexities of a twin-turbopump system; support of shorter testing turn-around times; and the added requirements of close tolerances specified throughout the engine system; (2) increased emphasis on nuclear shielding due to the importance of man-rated systems requiring the use of sophisticated computer codes such as Monte Carlo; (3) emphasis on detailed stress and thermal

Reference 1: RN-DR-0188, Long Range Program Plan for Full-Flow Engine, December 1969

analysis in engine design over all parts of the operating map under all operating conditions; and (4) emphasis by reliability personnel on designing. In addition, data control and traceability are becoming increasingly important uses of the computer to provide rapid data retrieval and management.

The budget forecasted under SNP-1 is shown for the December Long-Range Plan and a projected Agency Annual Budget for April 1970 (Table 2). As these figures indicate, the long-range plan projections and the guidelines are different. The guidelines are less than forecasted in the long-range plan. For this study, the December guidelines were used as the base for maximum projections required on the computer, and the April guidelines were used to define the minimum requirements. The difference in the two sets of plans results in a projected schedule slip for a first test on the reactor test system from December 1972 to a test in 1974, and delay of the first test on the engine test system in ETS-1 from June 1974 to the end of 1975.

During the December study, each Project figured its workload using current computer dollars as a base and assuming the same computer and the same costing system. As such, the ratios of the workload change compared with the 1970 base can be fairly well established. However, the actual base is not as well established, since in making the basis of the projections was billable dollars, with billable dollars being a function of the central processor time, the number of disc files used, the number of tapes utilized, input/output requests, etc. Depending on the size and type of programs being used, the amount of resources to do a particular job varied greatly from program to program. To establish computer hours in terms of the IBM 360/65, a base of 4500 hr was used. This 4500 hr is the number of Central Processing Unit (CPU) hours that are being projected for use during the current fiscal year. With this base, the increased ratios from 1970 to 1975 were projected, which shows an increase of CPU hours from the base of 4500 to 12,200 equivalent IBM 360/65 hours. With the April Agency Budget, the data was ratioed down based on the difference in dollar amounts. However, it did not appear

TABLE 2
ANSC FUNDING PROJECTIONS

DECEMBER 1969 NERVA LONG RANGE
PROGRAM PLAN FUNDING PROJECTIONS **

<u>CONTRACT</u> <u>YEAR</u>	<u>\$ IN MILLIONS</u> <u>W/O FEE</u>
1970	22.6 ***
1971	33.8
1972	76.5
1973	80.1
1974	83.6
1975	74.2

SNPO-C AGENCY ANNUAL BUDGET
FUNDING GUIDELINES *

<u>CONTRACT</u> <u>YEAR</u>	<u>\$ IN MILLIONS</u> <u>W/O FEE</u>
1970	22.5 ***
1971	24.3
1972	50.3
1973	50.7
1974	36.9
1975	36.9

* R-1/E-1 IN TEST CELL "C" IN 1974
R-2 IN TEST CELL "C" IN 1975
E-1 IN ETS-1 IN 1975

** R-1 TEST DECEMBER 1972; E-1 TEST JUNE 1974

*** PLUS SRT

reasonable to expect a drop-off in the 1974-75 period when testing operations would be starting on the NERVA Program, so it was assumed that the workload would level off with test support replacing engine design activities. This data is presented in Table 3.

The need during 1971 was projected slightly higher with the Agency Budget and with the NERVA Long-Range Plan, based on the experience obtained between December and May on computer utilization and the fact that the 1971 original budget was intended to be maintained at approximately the same level as 1970, because of anticipated funding constraints.

A more detailed project-by-project projection in May of the requirements shows an anticipated increase in computer requirements of 43% in 1971 and 75% increase in 1972.

The workload projections were based on the direct charges to the SNP-1 contract. Certain items were excluded from the study. These included accounting, since during the study this effort was being performed on a separate IBM 360/65 as part of a central accounting function; the digital control system; the test facility simulators, or any special digital process computers. The digital control system is considered part of the flight hardware and must be qualified for flight use. Computer requirements are defined in Appendix C. Early prototype of the system will use some general-purpose type of digital computers. The requirements are for a number of small processing units with perhaps 16K memory with each processor. The large central facility does not appear to offer a reasonable facsimile for a prototype digital controller. Therefore, though the large central facility can be used to develop certain routines, it was not considered technically sound to attempt to make the central facility handle this activity. Part of the activity is developing a special software monitoring system that would interfere with the central general-purpose facility operations. Also, the test facility simulator was excluded. At the present time, a hybrid system has been recommended. The real-time requirements and high usage rate appear to limit the use of the central facility for handling this application.

TABLE 3

SACRAMENTO WORKLOAD PROJECTIONS

	DECEMBER 1969 NERVA LONG RANGE PLAN		APRIL 1970 SNPO-C AGENCY BUDGET	
	<u>THOUSAND HOURS</u>	<u>INCREASE RATIO</u>	<u>THOUSAND HOURS</u>	<u>INCREASE RATIO</u>
1970	* 4.5 (Base)	--	--	--
1971	5.5	1.2	6.0	1.3
1972	11.3	2.5	7.0	1.6
1973	12.4	2.7	8.0	1.8
1974	12.1	2.7	8.0	1.8
1975	12.2	2.7	8.0	1.8

* Based on IBM 360/65 with 756K core

2. Type of Requirements

Having determined the magnitude of the computer batch load, there are various other types of requirements to consider.

a. Batch Processing

Batch processing is designed to handle the long-running routine large input/output work on which most of the historical data is based. This becomes the basis for sizing the computer and is actually the type of work that has been discussed above. In addition to batch processing, there are certain other requirements that greatly increase the engineering efficiency in using computers. These include:

(1) Remote Batch Terminals

These are terminals in the engineering area that can provide a capability for inputting and outputting the batch work directly from these areas. Sacramento has two major engineering areas; therefore a requirement for two of these is projected.

(2) Interactive Terminals

These are teletype or alphanumeric CRTs, low-speed input/output, used for writing programs, solving small problems, and for information retrieval. In future engineering operations this is likely to be one terminal for each group of four people. A current review of requirements indicates that this number may be cost-effective for programmers who are directly related to writing the software, but engineering groups would require one terminal for every 10 people. As such, the initial projection is for 12 terminals in 1971 with a growth to 36 by 1975.

(3) Interactive Graphics

Interactive graphics provide a capability of interfacing the engineering with the computer, using pictorial displays of the data under investigation. This makes it possible for engineering decisions to be made with the computer providing rapid data recall and manipulation. The advantages of the display unit become apparent when one considers that with such a terminal during analysis of data one can select channels as required, expand the abscissa or ordinate scale, manipulate channels together, offset them, and compare data directly against predictions. In addition, it is possible by use of the terminals to program the dimensions of various components and therefore manipulate them for analysis of maintainability and rapid changing of engine layouts. Engineers setting up complex heat-transfer or nuclear problems can graphically review the input to quickly determine inconsistencies in the information before running the problem, thus reducing computing time and increasing engineering productivity.

3. Computer Memory Requirements

Figure 1 provides a distribution of the computer memory requirements versus the percentage of computer hours. As the figure indicates, ANSC uses large computer requirements over 60% of the time. The configuration that was being run at the time did not permit use of the core above the 400 thousand bytes. A machine that would provide a larger core would probably show a distribution up to 700 thousand bytes, thus reducing the peak.

4. Representative Workload for Sacramento

To establish a workload mix representative of Sacramento, 46 operational programs were analyzed for the months of October and November, 1969. This was used as a typical base for the number of times programs were run, Central Processor Unit (CPU), time, elapsed time, core required,

PERCENT OF CENTRAL PROCESSOR TIME
vs
PROGRAM CORE REQUIREMENTS
ALL NRO PROGRAMS FOR PERIOD DEC. 1968 THRU AUGUST 1969

Figure 1

and input/out used. This data became the basis for a typical one-day workload. At this time period studies were going on for XE data analysis and on NERVA engineering. As such, it is probably a reasonable representation of future computer requirements. This one-day workload was then expanded to account for changing workloads during the evaluation of the computing systems. The evaluation of the requirements is based on the schedule shown in Table 4. It indicates that the major activities to be supported in Test Cell C by Sacramento in 1973 and an R-1 test and an E1-test in ETS-1 in 1975. Support must be provided for facility activation starting in 1973.

B. WESTINGHOUSE

The basis for the WANL general-purpose computing requirements over the next eleven years (CY 1970 through 1980) is the "NERVA Long Term Program Plan and ROM Cost Estimate," submitted to SNPO by WANL in December 1969. This program called for testing five reactors and six engines with an R-1 test date of December 1972 and the last engine test in mid-1977 to complete the development program. One modification has been made to this plan, based on the stretched-out funding situation that developed since the ROM cost estimate was furnished. This modification involves an assumption that the R-1 test date is more reasonably December 1973, with completion of the development testing in mid-1980. That is a 1-year slip in the start of the test program, and a 3-year slip in the completion of the test program was assumed for this study. The results of this assumption are shown in Table 5 where the computing load in elapsed computing hours and total computing dollars are shown against the contract year for both the long range program plan as submitted and the modified program plan. Table 5 is based on the following assumptions:

1. The Westinghouse Telecomputer Center's IBM 360/75 ASP system and the CDC 6600 system would be used for the computing.
2. Only the direct computing work load is considered.

TABLE 4
NERVA TEST OPERATIONS
SUPPORT TEST CELL "C" , ETS-1, E/STS-2
PROJECTED SCHEDULE ASSUMED

<u>YEAR</u>	<u>TEST CELL "C"</u>	<u>ETS-1</u>	<u>E/STS-2</u>
1971	PEWEE I TURBOPUMPS NUCLEAR FURNACE		
1972	PEWEE II		
1973	R-1	FACILITY CHECKOUT	
1974	R-2	FACILITY CHECKOUT	FACILITY CHECKOUT
1975		E-1	FACILITY CHECKOUT

TABLE 5

PROJECTED NERVA COMPUTING LOAD FOR WANL

CONTRACT YEAR	PROGRAM PLAN AS SUBMITTED		PROGRAM PLAN AS MODIFIED		
	ELAPSED COMPUTER TIME	COST	ELAPSED COMPUTER TIME		COST
	HR/YR	MILLION \$	HR/YR	HR/MO	MILLION \$
1970	2100	1.22	2000	166	1.22
1971	2800	1.62	2000	166	1.22
1972	3360	1.95	2630	219	1.54
1973	3920	2.28	3180	265	1.86
1974	4000	2.32	3580	298	2.09
1975	3180	1.84	3580	298	2.09
1976	2440	1.41	3420	285	1.97
1977	1730	1.01	2850	235	1.65
1978	-	-	2190	182	1.30
1979	-	-	1790	149	1.10
1980	-	-	1070	89	.75

NOTE: BASED ON CY 1969 STATISTICS:

- A. THE ELAPSED COMPUTER HRS/YR ARE A COMBINATION OF CDC 6600 AND IBM 360 HOURS WHERE 85% OF THE TOTAL HOURS ARE CDC 6600.
- B. THE CPU HOURS ARE 55% OF THE ELAPSED HOURS.
- C. THE COMPOSITE COST IS APPROXIMATELY \$580/HR WHICH INCLUDES THE MAIN FRAME COSTS FOR THE IBM AND CDC AT \$400/HR.

3. The mix of computing programs and, therefore, profile is considered constant over the time period.
4. The CY 1969 statistics noted on the table are constant over the time period.
5. No consideration is given to additional computing hours that would be required to reflect support of stage development and flight programs.
6. Special purpose computing requirements and equipment such as for digital controls have been excluded from the requirements.
7. Analog and hybrid requirements are excluded as special purpose.

1. Simulation for SCERT

To obtain a reasonable simulation of the WANL work load for simulation in the SCERT Program, an initial assessment was made from the computing statistics for contract year 1969. Approximately 85% of the work load was done on the CDC 6600 system, therefore, those programs that use the CDC 6600 were screened for simulation. Seventeen programs were selected from approximately the 150 programs available. These 17 programs represent approximately 40% of the total NERVA computing hours, and they represent a fair mix between computer bound programs and input-output bound programs. The programs selected and the information pertinent to these programs is given in Table 6.

After selecting the programs to be simulated, data were gathered from the cognizant programmers via a form developed with COMRESS to obtain average program information such as run time, run frequency, files used in the program, print files, and internal activity per file. These data were given to COMRESS for simulation, and the results of their simulation for average run time and core storage was compared with average performance of the programs in actual experience. For the most part, the simulation was reasonably accurate; however, several programs were resimulated to get the simulation data within 4.5 percent of the actual statistics. Having done this, it was assumed that the simulation was satisfactory and that the programs could be scaled proportionately to match the computer load specified. That is, the same mix and relative frequency of running the programs were assumed.

TABLE 6

WANL CDC 6600 PROGRAMS SIMULATED IN SCERT

PROGRAM	TECHNICAL AREA	CORE STORAGE (DECI. CHAR.)	RUN TIME (MIN)	CPU TIME (MIN)	FREQ. RUNS PER MONTH PLANNED	PER MONTH ACTUAL
DOT-A	NUCLEAR & RADIATION	116K	60	50.8	22	22
DOT-B	"	84K	120	110.0	20	22
DOT-C	"	52K	90	85.8	11	22
ANISN-A	"	116K	5	4.4	1/2	2
ANISN-B	"	52K	5	4.7	14	17
ANISN-C	"	64K	8	7.5	9	6
PERT-2D	NUCLEAR	64K	19	4.8	1/2	6
PERT-1D	"	52K	3	2.9	2	3
EXTERMINATOR	"	96K	90	66.9	57	107
APPROPOS/POINT	RADIATION	52K	2	1.5	4	7
MAP-II	"	52K	8	7.3	1/2	6
NAGS	"	84K	6	1.9	14	26
KAP V	"	52K	10	9.9	15	16
TRACK 200	THERMAL	106K	10	6.2	36	37
TAP	"	500K	0.9	0.8	4	14
FEATS	STRESS	40K	2.5	0.7	265	266
TNT-II	SYSTEMS	1000K	2	1.9	26	26

* FOR PEAK YEARS - 1974/1975

INFORMATION CATEGORY

Unclassified

AUTHORIZED CLASSIFIER

AUTHORIZED CLASSIFIER

DATE

REQUESTED BY:

APPROVED BY:

CHARGE NO.

The peak computing requirements were matched with the SCERT simulation to obtain the WANL input for use in a combined computer facility study to accomplish the total NERVA computing requirements and also to study the local Pittsburgh area facilities to accomplish the NERVA computer requirements required by WANL. Specifically, the peak load in CY 1974 and 1975 of 3600 hours elapsed time (2000 hours CPU time) were used and considered as equivalent CDC 6600 hours even though 15 percent of the time is allocated to IBM 360/75 equivalent hours.

C. NERVA TEST OPERATIONS REQUIREMENTS

The requirements for the NERVA Test Operations are tied directly to the facility activation and test schedule. Current estimates for testing are shown in Table 4, with the possibility of earlier testing in ETS-1 in 1974. The amount of time between tests is fundamental in sizing a computer facility for NTO. The requirements for turn-around time of two days were identified in the draft of the F-004 document dated 15 January 1970. E-1 will have turn-around times similar to XE-Prime (two weeks between Experimental Plans). The procedures used for XE-Prime data processing are described in Appendix A. It is assumed that the basic software and hardware capabilities should be demonstrated during E-1 for future reduced times between tests of two days to one week in a period beyond 1975, while minimizing the size of the computer facilities that would be required in the period up to 1975. The following requirements are therefore being used as a basis for the study.

1. Bases for Study

a. Real-time processing of all channels to engineering units, using data compaction techniques to minimize further processing of tapes. Approximately 300 channels (more or less, but compatible with the main core availability) would be sorted by channel, with the remaining 700 channels sorted by time to minimize requirements on core storage. Large high-speed random-access disc would not be required.

- b. Record all data in raw form on tapes.
- c. Provide three to four (allowing some flexibility for optimization of the particular computer configuration) interactive graphic-type console displays. These displays would be distributed among the Control Room operators and the Test Diagnostic Center (TDC) personnel. The SPEAR team would utilize the same CRTs as provided for TDC.
- d. Post-test analysis would require the sorting of all measurement channels from time to channel.
- e. Alphanumeric CRTs would be provided for data display to eliminate the need for data listings for use by the SPEAR team. Quantities of plots for SPEAR and off-site data review would be provided by Sacramento.
- f. A computer program would be developed to generate test chronology.
- g. Computer-sequenced operations, test limit monitoring, automatic test/facility checkout will be performed with the programming staff available and the capabilities of the machine as defined by other requirements.
- h. Channel engineering will be automated with immediate acquisition on disc of current data and historical data being stored on slower access units. Three to four low-speed alphanumeric CRTs will be distributed throughout the Test Stand for accessing the computer.
- i. Data calibration will be performed by the computer in conjunction with meeting the real-time processing requirements.
- j. Multipurpose Room displays in the A&E Building will be provided.

The frequency of tests should be similar to the technology program. Table 7 shows 43 facility tests, five tests on XECF, and 17 tests on XE-Prime over a 3-year period. This averages out to roughly a test every two weeks, with over one test per month during facility activation.

The foregoing items would be used to demonstrate the automatic data processing requirements from the F-004 document. The requirements from the F-004 are presented in more detail below.

2. Automatic Data Processing Requirements from F-004 Department

The ADP system for ETS-1 consists of the following major items of equipment (ADPE):

- a. Digital computer central processing unit
- b. Peripheral input/output equipment
- c. Core (memory storage)
- d. Out-of-core storage
- e. Transmission equipment
- f. Display equipment

The primary purpose of the ADP system is to make the engine system and facility data available for interpretation and evaluation by human observers; consequently, presentation of information processed by the ADP system shall be presented in the most digested or readily understandable form possible, normally in real time and utilizing cathode ray tube (CRT) displays.

The data processed by the ADP system shall be made available in the Control Room as a direct source of information for the Test Director and the operating crew.

TABLE 7

MAJOR TEST SUMMARY

FEP-1

FEP-1	28 September 1966
FEP-1A	4 October 1966
FEP-1B	26 October 1966
FEP-1C	9 November 1966

FEP-II

FEP-II	20 October 1966
FEP-IIA	26 October 1966
FEP-IIB	9 November 1966

FEP-III

FEP-III Phase 1 (V5002)	17 January 1967
FEP-III Phase 2 (V5001)	24 March 1967

FEP-IV

FEP-IV	24 February 1967
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ETC

Shield Water Tests	28 March 1967
Shield Reliability Tests (Series 1)	31 March 1967
ETC Makeup & Mechanical Seal Tests	22 April 1967
ETC Leak Tests	24 April 1967
ETC Off-Normal Tests	28 April 1967
ETC Purge Tests	11 May 1967
Shield C/O	8-17 October 1968
Shield Remote Demo.	19 October 1968

STEAM LINE

Separator Test I	3 October 1968
Separator Tests II, III	9 October 1968
Steam Line System Test	6 December 1968

NES

NEP-III	1 February 1967
NEP-IV	7 February 1967
NEPN-1	13 June 1967
NEP-HE-1	3 March 1968
NEP-HE-II	8 March 1968

XECF

Vibration Test #1	11 December 1967
Vibration Test #2	18 December 1967
Vibration Test #3	20 January 1968
EP-I	2 April 1968
EP-II	11 April 1968

TABLE 7 (cont.)

FEP-V

FEP-V EP-1	31 July 1968
FEP-V EP-1A	1 August 1968
FEP-V EP-1B	8 August 1968
FEP-V EP-2	22 August 1968
FEP-V EP-2A	23 August 1968
FEP-V EP-2B	5 September 1968

CV

CV EP-1	12 September 1968
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SGS GEP

GEP-VIII	2 November 1966
GEP-IX EP-1	15 December 1966
GEP-IX EP-2	26 January 1967
GEP-IX EP-3	1 February 1967

NES

Duct Water Flow Test	7 December 1966
ENP-1	19 January 1967

ETS-1 FACILITY

Data System Test	5 February 1969
Final Facility C/O	12 February 1969

XE-PRIME

EP-1 (Crit. Test)	4 December 1968
EP-1A (Crit. Test)	20 February 1969
EP-1B (SGS & RX at 10 kw)	27 February 1969
EP-2 (terminated due to wind & SGS)	13 March 1969
EP-2A (SGS & Bootstrap)	20 March 1969
EP-3 (aborted due to TBV)	3 April 1969
EP-3 (scrubbed due to wind direction)	16 April 1969
EP-3 (Intermediate Power & Restart)	17 April 1969
EP-5A (aborted due to TPA)	15 May 1969
EP-5B (aborted due to TPA)	16 May 1969
EP-5C (Full Power)	11 June 1969
EP-4A (Startup)	26 June 1969
EP-6A (Startup)	10 July 1969
EP-7A (Startup)	24 July 1969
EP-8A (Physics and Startup)	13 August 1969
EP-9A (High Specific Impulse)	8 August 1969
EP-10A (Post Test Critical and Laminar Flow Instability)	11 September 1969

A Test Diagnostic Center (TDC) shall be provided close to the Control Room in which processed engine or facility data are displayed, so as to permit the evaluation of performance by properly trained and experienced personnel. Capability shall be provided to permit presentation of processed data on-line (that is, in real time) and off-line (that is, by recall from recorded data):

Since the testing schedule requires a 48-hour turn-around, the post-test evaluation of performance must be accomplished during and immediately after the test operations are completed, with recommendations no later than 16 hours after the un. To accommodate this requirement, the immediate replay and capability for random access and display of the processed test data shall be provided.

The ADP system shall interface with the Instrumentation and Controls system so that all ETS-1 I&C channels can be accepted, processed, and displayed in real time as required by the specific test in progress.

The ADP system and the I&C system shall be independent (buffered) so that failure of any component in one system will not impede the proper functioning of the other system.

Accomplishment of all data-processing activities that are routine is to be undertaken by the ADP system insofar as practicable.

The ADP system shall be installed on a schedule and in such a manner that support of the activation evaluation, checkout and acceptance testing of the facility shall be provided.

a. Hardware and Software Necessary for Functional & Display Requirements

The ADP system shall consist of the hardware and software necessary to accommodate the following functional and display requirements:

(1) Real-Time Engineering Analysis

All data produced by the test article and the facility shall be delivered to the computer in real time. These data include the output of the narrow-band digital data system (1700 channels), the wide-band system (130 channels), and the events (channels). Capability to convert this raw data to engineering units in real time and capability for making engineering calculations using the engineering unit data as necessary shall be provided. It is expected that these engineering calculations will be performed by a library of up to one hundred FORTRAN subroutines and that the actual set of calculations performed for any one test will be variable.

(2) Data Recording

Provisions shall be included to record all data in raw form prior to delivery to the computer. Provision to recall the raw data by replay into the data system and thereby simulate the I&C system at the ADP interface shall be provided. In addition, the computer-processed data-engineering unit data, as well as calculated data, shall be recorded in rapid access device that shall be of sufficient size to permit the collection of all test data during 1 hour of operation. Data compression techniques may be used, provided the quality of stored data is not degraded. Evaluation of XE test data indicates that the test data can be compressed to 10% of its original volume without degradation of quality. Accessibility in real time of all data in the rapid access devices shall be provided.

(3) Post-Test Analysis Support

Accessibility of all data from the rapid access devices during the periods between tests shall be provided. Availability of the processed and stored information shall be in the same forms or modes that were available during the tests and this availability shall be accomplished by time sharing or in a manner such that significant interference with computer usage in support of preparation for subsequent tests shall not occur.

(4) Console Displays

All data processed by the computer shall be available for graphic display in real time. In addition, the data routed in the rapid access devices shall be available for graphic display in the Test Diagnostic Center (TDC) and for graphic, digital or analog display in the Control Room. Six CRT display units with full graphic capability are required in the Test Diagnostic Center, six units are required in the ETS-1 Control Room, and five additional units are required in the E/STS-2 Control Room. Also, units are required in the Test Cell "C" TMR and units are required in the Test Cell C Control Room. Further, units shall be installed in the A&E Building.

In addition, (3)* graphic units shall be installed at Sacramento, (3)* units at Pittsburgh, one at Cleveland and one at Washington, D. C., shall be provided. All graphic units (CRTs) at NTO shall have access to the test data as it is processed in real time and to the data recorded in the rapid access devices. Accessibility of these data to the units in Sacramento, Pittsburgh, Cleveland and Washington may be limited to the extent necessary to permit transmission of data by high-grade leased telephone lines.

*Not in F-004 draft.

(5) Test Limits Monitoring

Capability for the identification of up to 200 channels of engineering unit or calculated parameters for comparison with predetermined limits shall be provided. Approach to the limit and the reaching of or exceeding of the limit shall be signaled and presented automatically on one or several of the graphic display units. In addition, provision to introduce an audible signal into the communication net, for example, a recorded voice warning of the approach to the test limit, shall be provided.

(6) Multi-Purpose Room Display

Graphic, digital and/or analog display of all data collected, processed or stored by the computer in the rapid access devices shall be available in the Multi-Purpose Room (MPR) of the A&E Building.

(7) Demand Profile Generation

Provision to generate demand profile signals for facility functions shall be made.

(8) Computer-Supervised Demand Trim

The capability to determine the difference between actual and nominal performance shall be provided in a manner similar to the engineering calculations. These difference signals shall be made available to the engine and reactor control circuitry as trim signals such as specific impulse trim.

(9) Computer-Sequenced Operations

Capability for the performance of sequenced operations by the computer shall be provided. This capability should be available for use in the performance of the sections of the checklist operations that become routine.

(10) Chronology

Capability to collect, store, and display on demand a list of significant events in chronological order with the associated run-time of the event shall be provided. The individual events shall be taken from the predetermined list of approximately 100 occurrences. The particular occurrence or event shall be identified automatically with the specific data channel which experienced the change.

(11) Simulation

An engine/facility simulation is to be provided as an independent item from the ADP long range plan. The simulated performance signals shall be available to the data processing system for processing and manipulation in the same manner as the actual data signals.

Capability shall be provided to input the simulation system with raw data signals from the facility and test articles, thereby to calculate or predict performance for automatic comparison with actual performance. Discrepancies between simulated and actual performance shall be identified and stored for post-test review, analysis and evaluation.

(12) Automatic Test/Facility Checkout

The ADP system shall be capable of performing the checks of the facility systems. This procedure shall be conducted in a count-down manner with graphic display of step-by-step procedures and indications of normal and anomalous response.

(13) Data Calibration and Performance Analysis

The ADP system shall be capable of performing a prerun calibration of the data system associated with the test article and facility systems. Anomalous performance shall be displayed on a CRT and/or printed out to serve as a record in maintenance files. The ADP system shall be capable of post-run calibration and analysis of the data system performance.

(14) Channel Engineering

In addition to the rapid access devices for the storage of test data, a random access storage device shall be provided in which all data channel information is stored. This information shall be retrievable on CRT display units. Update capability shall be provided directly from the CRT console and provision shall be made for adequate control and approval of changes to the stored information. The large quantity and type of information associated with each channel will require retrieval and display in more than one mode.

(15) Maintenance Record Storage

The ADP system shall be capable of accepting, recording and retrieving corrective and preventive maintenance data and trend data information for the facility and test system.

(16) Wide-Band Data Processing

The ADP system shall be capable of receiving the wide-band data signals, processing these data and presenting the processed result for display as transfer functions. Vibration data shall be processed and displayed as functions of time and frequency. In addition, capability for the reduction of accelerator output to displacement shall be provided.

(17) Management Information Storage and Retrieval

Accessibility to the NERVA Program Management Information Data Base shall be provided.

(18) Commercial Data Processing

The ADP system shall be capable of batch processing data and information to provide the accounting and cost analysis information, payroll, PERT, inventory control, and technical support as necessary for efficient management and administration of NRDS.

3. Task Descriptions

The hardware to accomplish these tasks should consist of a preprocessor, a central processor with associated peripherals and a display system such that personnel can rapidly obtain data from the computer.

The tasks required of the ADP system fall into four categories: (1) present, those activities directly leading to a major test; (2) real time, those activities taking place during a test; (3) posttest, those activities related to cooldown monitoring and test analysis; and (4) continuing (batch) those activities that are required on a regular basis, regardless of testing schedules.

a. Pretest

The following are activities that begin at R-2 days and are essential to the upcoming test. (All of these tasks are continuing in nature, but impact the ADP system due to increased activity just prior to a test.)

- (1) Maintenance of a Measurement System Information Data Base (MSIDB)

A number of files contain all measurement system data. The pretest impact will be the preparation of reports on the status

of the measurement system and the increased updating activities that occur just prior to a test. To provide the control group rapid update capability and to allow the users rapid access to the most current information, on-line CRT display of these files is required.

These files will supply all the information required for the conversion of digital counts to engineering units and therefore must be available to the real-time system.

(2) Digital Data System Calibration

This is a routine that will collect a Digital Data System (DDS) calibration on-line, process it and update the MSIDB files. The calibration processing will consist of statistical calculations and the preparation of history files and exception reports. On-line CRT display of the exception reports is required to provide rapid verification of data system integrity and readiness.

(3) Operator Training

The real-time system is used to simulate the upcoming test.

(4) Facility Steup and Checkout

The graphic display of step-by-step setup and checkout procedures with indications of normal and anomalous conditions.

b. Real Time

Real time is defined as the ability to update a parameter with new data at a rate of 0.1 sec. The following activities take place during a test:

(1) Setup for Real Time Operations

This consists of the processing of input constants and requirements for a given test that initialize the preprocessor, the real-time monitor, and the display routines.

(2) Preprocessing

Preprocessing is the inputting of the data stream, recording of raw data, compression, linearization, conversion to engineering units, and outputting of the data to the central processor.

The input data will be in the following formats from each of the three test stands:

	<u>Test Cell C</u>	<u>ETS-1</u>	<u>E/STS-2 (Proposed)</u>
Time Frames/sec	1	10	10
Words/Time Frame	400	2000	4000
Bits/Word	16	24	16
Mode	Binary	BCD	Binary
Data Channels	400 of 1500	960	1700

The preprocessor must be able to distinguish between and accept each input format. If raw data recording is not done at the test stand, it must be done by the preprocessor.

Evaluation of XE-Prime digital data indicates that the test data could be compressed to 10% of its original volume without degradation of quality, and that 50 million data points (one sample per channel per time point) would be collected during a test.

Only those data points which fail compression criteria will be linearized, converted to engineering units and output to the central processor.

(3) Real Time Operations

The real time operations consist of the acceptance of input data from the preprocessor, execution of an engineering calculations library, storage of data for future retrieval, preparation of run chronology, and the outputting of data to the graphite display system. A Real-Time Monitor will control the scheduling of these tasks and perform housekeeping tasks as required.

A last-best value of each data channel will be updated as newer data is received from the preprocessor. All the engineering calculations (flow rates, temperature profiles, reactivity, limit monitoring, control signals, simulation and prediction, etc.) will be contained in a library of subroutines that will be scheduled for execution by the Real-Time Monitor. A run chronology will be prepared using the binary event signals and test data. Rapid retrieval of data for posttest analysis requires that the data be stored on mass storage devices by data channel rather than by time frame. The Real-Time Monitor must reformat the data, store it on a mass storage device, and maintain address tables for retrieval. If the display system has its own processor, the central processor will output data to the display systems; if not, the central processor will output complete displays.

(4) Graphic Displays

CRTs are used to display test data in real time. This hardware will also be used for posttest data analysis, pre-test operator training, simulation and setup, MSIDB updating and inquiry, and as conversational time-sharing terminals. Hard copies and microfilm copies of displays will be required.

c. Posttest

The following activities take place immediately after a test is completed:

(1) Cooldown

The operation of the real-time system at a lower sampling rate to support cooldown parameter monitoring. Provides support for facility securing and posttest data system calibrations.

(2) Posttest Data Analysis

Retrieving and displaying current and previous test data for analysis and preparation of hard copies for reports.

(3) Posttest Data Processing

The preparation of data to be shipped off-site and data to store for future use. The completion of any data processing that was not done in real time such as wide-band data processing.

d. Continuing Activities

The following activities are required on a regular basis, regardless of testing schedules, and may be processed in a batch mode:

(1) Commercial Data Processing

All the commercial tasks required for the efficient management and administration of NRDS; accounting, payroll, PERT, inventory control, management information system, etc.

NRDS ADP HARDWARE CONFIGURATION
Figure 2

TYPICAL NRDS ADP UTILIZATION SCHEDULE

Figure 3

MEASUREMENT SYSTEMS INFORMATION DATA BASE

Figure 4

(2) MSIDB and Data System Calibrations

As mentioned previously.

(3) Test Data Retrieval

Transferring of old test data from tape to disc for display on the CRT's.

(4) Software Development

The maintenance and upgrading of software as required.

(5) Scientific

Engineering Analysis support.

4. Description of Proposed Operating System

From a review of the above requirements, a generalized computer format can be used as a basis for defining software requirements. Figure 2 is a schematic of the generalized hardware configuration. The central processor will be controlled by a Real-Time Multiprogramming Executive Routine. Figure 3 depicts a typical computer utilization schedule during a test period at one of the test stands. Following are the major software packages that make up the operating system.

a. Major Software Packages in Operating System

(1) Measurement Systems Information Data Base (MSIDB)

The MSIDB portion of the operating system is shown in Figure 4. Measurement system information for each test stand is contained

in a number of files on mass storage devices. Only the channel data file will be on-line during real time operations. The program consists of: (1) Update Routine, (2) Inquiry Routine, and (3) Report Generating Routine. The Update Routine will accept either batch input or input from an on-line graphics terminal and will be able to update the information in any of the files. Extensive use of the graphics terminals combined with a file security system will eliminate most of the paperwork required for the maintenance of the MSIDB. A control group will coordinate all the updating of the MSIDB. The Inquiry Routine will allow users at on-line terminals to interrogate any of the MSIDB files in predetermined formats. The Report Generating Routine will produce the standard reports. Most of the use of the MSIDB will be handled through the Inquiry Routine and hard copy reports will be generated infrequently. This assures that users will be getting the most current information.

The Real-Time Compiler will use the MSIDB files in setting up the Real-Time Operations. All the measurement system information required will be contained in the MSIDB files.

The Calibration Routine will update the MSIDB files whenever a Data System calibration is taken.

(2) Digital Data System Calibration Routine

The DDS Calibration Routine is shown in Figure 5. The input portion must be able to handle input from each of the three test stands and may be the Real Time System input routine. Once a DDS calibration is collected, it is processed using information from the MSIDB files. This processing would include slope, offset, noise, linearity, and statistical calculations, comparison against nominal values, calibration history preparation and report generation. Processing DDS calibrations on-line and preparing exception reports will alleviate one of the problem areas in XE-Prime data processing.

DIGITAL DATA SYSTEM CALIBRATION ROUTINE

Figure 5

(3) Operator Training Routines

Input to these routines can run the gamut from simply using "canned" data with the Real-Time Operating System to the use of an on-line analog computer to simulate the test. The requirements for this routine are not defined at this time.

(4) Facility Checkout and Setup

These routines can vary from simply paging through check lists on a CRT display to actual computer control of the activities. More definite requirements for these routines are not available at this time.

(5) Real-Time Compiler

The Real-Time Compiler is shown in Figure 6. The function of this routine is to prepare files for use in initializing the Real-Time Monitor, and the preprocessor and display routines. This will include constants for compression and engineering unit conversion, engineering calculation scheduling, and graphics display information.

(6) Preprocessor Routine

The Preprocessor Routine is shown in Figure 7. The preprocessor accepts the data stream from the test stands, compresses and converts it to engineering units and passes the data to the central processor. The input routine must be able to accept and differentiate between data streams from each of the three test stands. If simultaneous operation is required, the input routine must be able to handle the input from two test stands serially.

REAL-TIME COMPILER ROUTINE

Figure 6

PREPROCESSOR ROUTINE

Figure 7

The compression technique to be used is a zero order predictor. This scheme saves a data point if it varies from the previously saved data point by more than a predetermined value. Each data channel will have its own delta value that may change as the data moves through its range. Other compression techniques that may be considered are: (a) Zero Order Interpolator, where a data point is saved if a data point varies from the last saved data point by more than a predetermined delta value, but the data point saved is the average of the highest and lowest value since the last point was saved; (b) First Order Predictor, where a data point is saved if it varies more than a delta value from the slope of the last two saved data points.

Linearization of the digital counts converts the data to engineering units. Where these units are millivolts, the data must be subjected to a polynomial fit or a table lookup routine to convert to degrees Rankine.

The compressed data in engineering units will then be transmitted to the central processor.

(7) Real-Time Operations

The Real-Time Monitor (RTM) is shown in Figure 8. The central processor accepts compressed engineering unit data from the pre-processor and updates its data arrays. All engineering calculations are contained in a library of FORTRAN subroutines and are called as required by the RTM. The required output data is formatted and transmitted to the display processor where it is formatted into displays and sent to the CRTs. Requests for changes will be handled in real time by the RTM. The RTM will contain recovery routines, error diagnosis routines, and replay routines. For rapid data retrieval, the RTM will reformat the data and store it on the Mass Storage devices by channel rather than by time.

REAL-TIME MONITOR
Figure 8

(8) Graphics Display Routines

Three general modes of displays will be used:

(a) X-Y plots - Parameter versus time, parameter versus parameter, with multi-parameters per coordinate system and multi-coordinate systems displaying both previous and real time data. See Figures 9 and 10.

(b) Alphanumeric lists - Test data parameter values, problem solving routines, file interrogation and maintenance routines, run chronologies facility status reports and calibration data. See Figure 11.

(c) Pictorial graphics - Piping and instrumentation drawings, component diagrams and animation. See Figure 12.

The specific formats will be limited only by imagination of the users/programmers and by the time available to create them.

(9) Test Data Display

Test data will be displayed in all three modes. Special software routines would guide the users (Test Operators, TDC, SPEAR) in creating their own display formats on-line from several basic formats available, by selecting parameters, scales and other options. These completed formats would be saved and recalled by the user as required.

During pretest simulation and checkout, the user would select the formats and/or create new ones that he will use during the test. These would be rapidly interchanged (1 to 2 seconds) during the test by function key or light pen. Test Operators and TDC would probably use only one or two formats during a test while other users may use several. Posttest analysis would require a larger number of formats and could tolerate a slower

<u>Formats</u>	<u>Functions</u>	<u>Other Information</u>
F1	GO	
F2	STOP	
F3	CHANGE	

X-Y PLOTS

OPTIONS: Multiple scales, multiple parameters, multiple coordinate systems, test limit/alarm monitoring, real-time or static data, variable grids.

Figure 9

STRIP CHART

FOUR COORDINATES

POLAR COORDINATES

BAR CHART

VARIATIONS ON X-Y PLOTS

Figure 10

X SYSTEM AT LOCATION Y

<u>Channel</u>	<u>Value</u>	<u>Units</u>	<u>Rate</u>	<u>Other</u>
P1	80	psia	1/sec	-20 psia
P2	100	psia		
T1	350	°R		
V1	open			
V2	:25	% open		

Range Time 40000 seconds

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<u>Formats</u>	<u>Functions</u>	<u>Other Information</u>
F1	GO	
F2	STOP	
F3	CHANGE	

ALPHANUMERIC LISTS

OPTIONS: Multiple channels, real time or static data,
test limit/alarm monitoring, paging

Other Lists: Channel data, calibration data, management information,
inventories, file maintenance, facility status,
engineering problem solving, check lists.

Figure 11

PIPING & INSTRUMENTATION

Options: Zoom, Separate Systems

Other: Component diagrams, facility diagrams

Figure 12

response. Report quality hard copies and microfilm copies would be required by all users. Test data from at least one previous run should be available for test-to-test comparisons.

The calibration routine will process a data system calibration immediately and update data for several display options. Exception reports for various statistical calculations would indicate questionable data channels. Other display formats would provide more detailed information for analysis of problem areas.

(10) Engineering Support

Engineering Support routines would be used during non-test periods and the majority of displays would be alphanumeric. These routines would include:

(a) An on-line curve fitting routine, enabling the user to input data and have a best-fit curve produced.

(b) An on-line problem solving routine enabling the user to create FORTRAN type statements to perform mathematical operations.

(c) A facility status routine to provide the user with complete facility status information on request.

(11) MSIDB File Maintenance

File maintenance routines would produce alphanumeric displays and be primarily used to update the Measurement System Information Data Base.

5. Test Cell C Requirements

In addition to the ETS-1 requirements, there are projected requirements in support of Test Cell C. The assumption made is that the activity in support of Test Cell C will be performed much the same as in the past. This means using the CDC 160A and the DDP-116 for real-time data acquisition and test support. In addition to this, data tapes will be initially processed through the central facility at the A&E Building to engineering units and then transported to other facilities for plotting and data reduction.

Channel engineering and commercial applications will be performed as shown in Table 8. The assumptions for the table are:

a. That the existing CDC 160A and DDP-116 will be used at Test Cell C for real-time data acquisition and other test support.

b. That a process control type computer will be installed at the ETS-1 and E/STS-2 complex by 30 June 1973 to handle real-time data acquisition and facility checkout. Such a computer is called for in the approved E/STS-2 Budget Submittal.

c. That modification of ETS-1 will be completed by 30 June 1973.

d. That reactivation of ETS-1 will be accomplished between 30 June 1973 and 30 November 1974.

e. That E-1 will be tested at ETS-1 in December 1974 with a turnaround period between EPs similar to that used during testing of XE-P.

PROJECTED NRDS ADP WORKLOAD
FOR THE PERIOD FY 71 - FY 75
HOURS PER MONTH

FY & EQUIPMENT

FUNCTION	FY 71		FY 72		FY 73		FY 74	FY 75
	7094	1401	7094	1401	7094	1401	Replacement	Replacement
Data Reduction								
ETS-1	0	0	0	0	0	0	0	135
TC"C"	70	12	70	12	140	24	0	25
Channel Engineering								
ETS-1	20	8	20	8	40	16	0	5
TC"C"	0	75	0	75	0	90	0	3
E/STS-2								5
Scientific & Engr	5	3	5	3	9	5	0	3
Commercial	43	104	43	104	43	104	0	15
Program Development								
Pan Am							10	10
STO							150	65
Systems Software							40	10
Development & Checkout								5
TOTALS	138	202	138	202	232	239	200	276
NOTE: Hours shown are averages, not peaks.								

TABLE 8

f. That:

(1) Pewee II will be tested at Test Cell C during the third quarter of FY 1971.

(2) A nuclear furnace will be tested at Test Cell C during the fourth quarter of FY 1971.

(3) Pewee III will be tested at Test Cell C during the third quarter of FY 1972.

(4) R-1 will be tested at Test Cell C during the fourth quarter of FY 1973.

(5) R-2 will be tested at Test Cell C during the first quarter of FY 1975.

g. That a replacement computer for the IBM 7094/1401 system will be installed by July 1972, and that the IBM 7094/1401 system will be retired in June 1973.

h. The digital control requirements are discussed in Appendix C. Special purpose computers and checkout equipment to support digital controls development concepts in Test Cell C are not included in this report.

V. CONFIGURATIONS

Various combinations of computer configurations that would satisfy the overall requirements for the NERVA SNP-1 Program were considered. The

types of configurations were divided relative to the number of computing centers required for the NERVA Program and the individual hardware configurations for each computing center. The predictability of the requirements is greater in the near term than in the long term; therefore, the ability to adjust to the uncertainties in the requirements is considered in selection of configurations. The upward and downward compatibility of each manufacturer's equipment was considered in order to account for the uncertainty in the rate of funding available and requirements to the NERVA Program.

Table 9 is a chart showing the three manufacturers of large engineering data processing equipment and their compatibility in computer models versus equivalent IBM 360/65 hours. Each manufacturer is upwardly compatible; that is, programs developed on a smaller system will operate on the larger system. For instance, programs on the IBM 360/65 will run on the 360/75, /85, or /195 without modifications. The same is true for CDC and Univac equipment. However, programs developed for IBM equipment cannot be directly operated on CDC or Univac equipment. This is true of the other manufacturers also, and is true even if the programs are written in FORTRAN. This occurs because each manufacturer has certain special symbols peculiar to his equipment and uses a different equipment structure. As a result, in favorable long-term lease rates or purchase agreements once a certain manufacturer is selected, the tendency is toward a lengthy stay with that manufacturer.

A. DESCRIPTION OF EQUIPMENT (SACRAMENTO)

Three equipment manufacturers (IBM, CDC, and Univac) responded to the request for information about computing systems with proposals for specific systems that they felt would meet the present and future computing requirements for the scientific data processing. During the course of the study, a number of different configurations from each manufacturer were considered and evaluated. A general description of each of the systems is shown below with specific systems tabulated in Appendix B.

GROWTH FLEXIBILITY

EQUIVALENT IBM
360/55 HOURS

IBM

CDC

UNIVAC

4000

360/65

6400

1106

6000

360/75

6500

1106 MP

8000

360/75

6500

1106 MP
OR 1108

12,000

360/85

6600

1106 MP + 1106
OR 1108 MP

24,000

360/195

7500

TABLE 9

1. IBM (International Business Machines)

IBM proposed configurations that used their system 360 computer models 65, 75 and 85. The current computing system at Aerojet uses an IBM 360/65 computer. All of the system 360 computers use the IBM OS/360 operating system and thus are upwardly compatible. This means that programs currently running on the 360/65 could be run on the 360/75 or /85 without modification.

The reference system (IBM 360/65) has a 512K-byte core storage capacity. Regular word length is 4 bytes (32 bits). At the time of initial installation it was determined that the 32-bit word would not normally provide sufficient precision for engineering programs and that all programs would be run in double precision (8-byte, 64-bit word) unless a study indicated that this was not needed on specific programs. Proposed configurations for the 360/65 and/75 had 1024K-byte core storage and the 360/85 had either 1024K or 2048K bytes.

The operating system core requirements vary, depending on the particular needs of the installation but would be expected to be about 150K bytes here. The IBM CRBE (Conversational Remote Batch Entry) system allows input from a typewriter or CRT display terminal to manipulate files and submit jobs for batch processing. This currently takes about 130K bytes of core storage. Remote job entry from a card reader and line printer terminal can also be added. The standard IBM software for this requires 110K bytes. However, a new system (called HASP) is available that will increase the effectiveness of the operating system and allow remote entry terminals for 60K bytes of memory.

The 360/65 is the least powerful processor of those considered here. It performs instructions sequentially and has two-way core access interleaving to reduce the effective core access time. The model 75 has

shorter instruction execution times (about one-half of the 360/65) and allows overlapping of processing so that two instructions can be processed simultaneously. Up to 4-way core access interleaving is used. The model 85 uses a very fast processor with a high-speed buffer region and up to 4-way interleaving of storage. The use of the high-speed buffer results in a reduction in effective system storage-cycle time.

IBM has recently announced a new system, the 360/195. This machine has a high-speed buffer region similar to the 360/85 and allows up to 16-way interleaving of storage. The arithmetic unit is very fast--up to 20 times as fast as the 360/65 on some types of programs.

The same peripheral units are used with all of the systems. IBM has exceptional I/O capability, both in reliability and transfer rates. Direct access storage is from a 2314 disk unit. This can use up to eight removable disk packs and provides up to 233 million characters of storage. A wide range of tape drives is available up to the 2420-VII which transfers data on a 9-track, 1600-BPI tape at 320,000 characters per second.

The operating system has demonstrated its ability to effectively multiprogram under MVT and to automatically spool the card reading and printing tasks. Use of the system requires many complex job control statements. However, a standard control package has been written for use by engineers in an open shop environment to relieve them of the difficulty of learning this system control language.

2. CDC (Control Data Corporation)

CDC proposed configuration based on their 6000-series computers. There are two different central processing units (CPUs) available in this series. The 6400 processor is a unified arithmetic units each with a specific function so that several operations can be performed

simultaneously. The 6600 CPU is about three times as fast as the 6400 in running a typical program. Two other options are available: the 6500 system has a dual processor 6400; the 6700 system has one 6400 processor and one 6600 processor.

Maximum core storage available is 131,000 words. Configurations with 131K and 98K words were discussed for use at Aerojet. The CDC word length is 60 bits. This provides sufficient precision so that double precision would almost never be required.

All of the 6000-series systems use peripheral processors (PPUs) in addition to the CPU. There are normally 10 PPU's in a system and these perform all of the input, output, and data moving type of tasks. The CPU thus performs only computing, and the time devoted to the system overhead tasks associated with a multiprogramming operation is nearly zero.

All of the systems use the Scope operating system developed by CDC. This provides multiprogramming on up to seven tasks in central memory at one time. All input and output is spooled and scheduled, using a priority system. A cathode ray tube (CRT) display gives very complete information about system operation and job status at all times and the operator has a large amount of control over the system as he wants to intercede.

The operating system with the I/O spooling system takes about 14,000 words of central memory. A number of special routines are also resident in the memories of the 10 peripheral processors. CDC has a system called INTERCOM, which permits typewriter or CRT display tube input to manipulate files and submit jobs for batch input as well as to use FORTRAN and BASIC in a conversational mode. This system uses 1000 words of central memory plus eight additional words per terminal. Additional memory for the conversational jobs is dynamically allocated as required on a priority basis.

Import/Export allows remote batch entry from a card reader/printer terminal. This takes 1000 words plus eight words per terminal of central memory. The Import/Export is used at CDC data centers for remote entry of jobs over telephone lines and appears to be well checked out.

The CDC system is designed around a large disk file (the 6638) that stores 167 million characters and has a 1.68 million characters per second transfer rate. This disk stores the input and output, system files, program files, etc. Other disk units are available that use standard removable disk packs.

Use of the system is simple and straightforward for the programmer. The necessary control cards are simple and few in number. The benchmarks runs and observation of the Palo Alto data center indicate that the system provides effective multiprogramming and, in the case of the 6500, effective multiprocessing.

The CDC 7600 is Control Data's largest and fastest computer. The central arithmetic unit is similar to the CDC 6600 processor in that it contains a series of segmented, specialized arithmetic units, each with a certain function, that can operate simultaneously. The central memory consists of a small (65,536 60-bit word) core and a large (512,000 60-bit word) core memory. The large core memory (LCM) is the basic storage for the processor. A number of different programs reside here concurrently. Program execution is done only in the small core memory (SCM). A program is copied from LCM to SCM where processing is done. When it is complete or some input or output is requested, the program is copied back into LCM and a new program brought into SCM. Transfer of data to the peripheral devices is done from the files in the LCM.

The operating system is not the same as that used on the 6000-series computers, but is set up so that the processor machine code is

upward compatible from the 6000-series machines. The 7600 system uses a large (5.7 billion bits) high-speed disk file for system storage, program files, I/O spooling, etc.

3. Univac

The Univac proposal recommended a Univac 1106 computer system with possible expansion to the 1108 system. The 1108 has a relatively fast processor that operates sequentially on instructions. The 1106 system appears to be identical except that the basic cycle time has been increased to twice that of the 1108. Experience has shown that this results in programs running about 1.8 times as long on the 1106 as on the 1108. So, all further comments about system operations will normally apply to either the 1106 or 1108 systems except for the expected total execution time for a program.

Discussions were also held with Univac on the possibility of a dual processor 1106 system. This 1106 MP system is not now a standard product of Univac and no benchmark runs were made to determine the effectiveness of the multi-processor configuration. However, several 1108MP systems have been produced and sold.

Core storage has two-way interleaving to reduce the effective access time and is available in banks of 32K words up to a maximum size of 262K words. The word size is 36 bits. Previous experience with the IBM 7094 and similar machines has shown that this will normally provide sufficient precision for most engineering calculations. Occasional use will be made of the double precision mode for special problems.

The Univac multiprogramming operating system (EXEC VIII) has been operational over one year and has operated satisfactorily on the benchmark tests that contained batch jobs only. Under this system a large

number of jobs can be active at one time. These active jobs are swapped into core and out to a storage drum as required to keep the CPU as busy as possible. The system uses a priority scheduling arrangement that permits real-time computing to be done while lower priority batch jobs run simultaneously to use the remainder of the CPU time. A demand batch feature automatically arises the priority of a job to have it completed by a specified time, if this is requested when the job is submitted.

The core storage requirements for EXEC VIII are fairly large. The version for a single processor system currently takes about 43,000 words of resident central memory and the multiple processor version requires about 57,000 words. However, this includes the ability to use both teletype or a CRT type terminal and the card-reader/line-printer type terminals. In fact, in the recommended system, a 9300 remote terminal is used in the computer room to provide the primary source of input and output for the system. To promote effective multiprogramming, the system restricts the maximum size of a program for 65K words. Overlays must be used for larger programs.

An interpretive FORTRAN compiler is provided to allow conversational time-sharing on the machine from the teletype or CRT terminals. An interpretive compiler does not convert a program into a machine language but interprets each statement as it is executed. Thus, portions of a program can be changed during execution. Since this is not efficient for large jobs, a separate batch FORTRAN compiler is used for jobs that are not to be run in the conversational mode.

Univac normally uses drum storage units. The Fastran drum unit is a large (198-million-character) but relatively slow unit and is normally used only for storage of semipermanent files, such as programs, data files, etc. A new disk file system has just been announced (the 8414) that has eight removable disk packs and appears to be nearly identical to the IBM 2314 unit. This can directly replace the Fastran drum and has about the

same performance. A faster drum (the FM 1782 or FH 432) is used for system files, program overlay segments, etc. The uniservo VIII-C tape units provide a 86K characters/sec transfer rate at 800 BPI. A new 1600 BPI tape unit has just been announced. The system is simple to use and easy to learn and uses few control cards. This is important in an open-shop environment.

B. POSSIBLE SITE ARRANGEMENTS

The following site arrangements have been considered:

1. Central Facility (Figure 13)

A central facility to meet the major computing workload for the entire NERVA Program is one possible configuration. The advantage of one large computer facility would be to take advantage of cost effectiveness of larger computers. Weighted against the lower cost per computation, is the availability of a class of computers to handle the entire NERVA workload; classification problems associated with off-site operation; communication problems with distances of 2172 miles between the large quantities of engineering work performed in Sacramento and Pittsburgh, and an additional 311 miles from Sacramento to Jackass Flats, and 1954 miles from Jackass Flats to Pittsburgh. In the large central facility it was considered that all the work would have to be performed by one large computer to justify consideration of the communications cost. Two systems currently are large enough to handle the full anticipated growth of the NERVA Program. These are the IBM 360/195 and the CDC 7600. A configuration of the IBM 360/195 is provided in Appendix B. The CDC 7600 is similar in cost to the IBM 360/195.

2. Independent Sacramento, NTO and Pittsburgh Centers (Figure 14)

Separate facilities at WANL, ANSC and NTO were considered. Under this category it was assumed that the computing workload in each area

CENTRAL FACILITY

Figure 13
70

IBM 360/195

OR

CDC 7600

INDEPENDENT FACILITIES AT SACRAMENTO, PITTSBURGH, AND NTO

Figure 14

would be performed at that center. There would be some communications between the centers, such as the ability for NTO to input into programs at Sacramento or Pittsburgh or for terminals with data to be remotely located, but the principal computing load would be performed locally. The advantage of this arrangement is that classified data does not have to be transmitted, local access to the computer is provided, work scheduling is simplified, and communication costs are minimized. The apparent disadvantage, if only computer costs are considered, is that advantage can not be taken of the economy of size.

a. Sacramento

For Sacramento the IBM 360/65 with growth to the IBM 360/75 or /85; CDC 6500 with growth to the CDC 6600; and the Univac 1106 Multiprocessor with growth provided by addition of another 1106; or the 1108 with growth to the 1108 Multiprocessor, were considered.

b. Pittsburgh

The Westinghouse Telecomputing Center operation was evaluated against a separate facility to be located at WANL, Large. The facility at Large considered CDC 6600, 6500 and 6400 configurations as well as Univac 1106 Multiprocessor.

c. Jackass Flats

To perform the work as described in the preliminary draft of the F-004 document, the CDC 6400, XDS Sigma 5, and IBM 360/65 systems were used as representative of this type of system requiring large amounts of interactive graphics. Also reviewed were various machines of lesser capability that can be used for E-1 testing, including the CDC 6200, IBM 360/44 and UNIVAC 418 and 1106.

Possible configurations existing within NTO include:

- (1) Central ADP in the A&E Building.
- (2) A minimum size ADP in the A&E Building with satellite ADP's in Test Cell "C", ETS-1 and E/STS-2.
- (3) Central ADP in ETS-1 with a satellite ADP in Test Cell C.
- (4) Separate and independent ADP's for Test Cell C and ETS-1/ESTS-2.
- (5) Separate ADPs at Test Cell "C", ETS-1 and E/STS-2.

3. Independent Sacramento and Pittsburgh Centers, Satellite at NTO (Figure 15)

A combination of ANSC, Sacramento and NTO, Jackass Flats -- with WANL being an independent facility because of the geographical relationship, (WANL is already part of a major computer complex and would involve transmitting large quantities of classified data between sites) is another possible configuration.

The advantage of this system would be to obtain the most cost-effective computer for the combined ANSC-NTO operation without having to transmit classified data between the sites. WANL, through the Telecomputing Center, has the advantage of the economy of a large computer while sharing the expenses with other non-SNP-1 contract users. The decision to locate the computer in Sacramento rather than in Jackass Flats was made because of the high volume of classified work. It was easier to transmit high volumes of

INDEPENDENT FACILITIES AT SACRAMENTO, PITTSBURGH
SATELLITE FACILITY AT NTO

Figure 15

unclassified data than to handle transmission of classified data. Also, an evaluation was made of tieing NTO to the AEC facility in Las Vegas, doing the commercial work at Pan Am, or tieing into Pittsburgh.

VI. COMPUTER EVALUATION TECHNIQUES

Several techniques are available for use in evaluation of the various computer systems. Two techniques were used as part of this study. The first was to "benchmark" a number of programs representing a typical workload by several vendors. For this a series of 18 operating programs were given to each prospective vendor to run on configuration of his computers. The second technique is the use of a computer simulator. The program used is a product of COMRESS, Inc., called Systems and Computer Evaluation and Review Technique, abbreviated to SCERT. The simulation is used to evaluate new systems or study the effects of changes or additions to existing systems. As such, it represents a tool that provides for analysis of the structures, procedures, or systems that make up the computer by modeling the configuration and examining the impact of various alternative decisions based on predicted results. The primary functions of the simulator are: building a model of the problem; building a model of the hardware and software configurations to be analyzed; actual simulation of the requirements against the hardware models being analyzed; and the production of a series of output reports, such as the configuration simulated, Central Processor Utilization, Programming Requirements, Application Summary, Computer Capabilities, Cost Summary, Real Time Analysis, Multiprogramming Schedule, Detailed Analysis, Summary Analysis, and System Documentation.

A. BENCHMARK RUN DATA

During 1969, a number of Sacramento programs were given to the three manufacturers for conversion and demonstration runs on their proposed machine configurations.

IBM ran the programs on a 2-million-byte core IBM 360/85 and on a 2-million-byte core dual processor IBM 360/65 with one processor and half of the core not usable by the system. The cycle timing delay necessary to add the 2-million-byte core resulted in much longer CPU times on this machine than on the quarter-million-byte IBM 360/65 at Aerojet. However, a regular one-million-byte machine would not have this problem. A set of comparison runs was made on the in-house IBM 360/65.

Control Data Corporation ran the benchmark runs on a 131K-word CDC 6500 and on a 131K-word CDC 6600 computer. Univac ran on a 131K-word Univac 1106 and on a 131K-word Univac 1108.

Not all of the programs were run by all manufacturers. Conversion difficulties and insufficient time for conversion were the cause of this. Table 10 shows the central processing times for the various configurations run for each of the programs. Table 11 shows the estimated elapsed time for the standard batch under investigation. Row 1 gives the elapsed time for the batch as run by each manufacturer. Row 2 gives the CPU time for this batch while Row 3 shows CPU utilization. The same job mix was not run by each vendor. Some jobs were run in addition to the standard batch. These are shown in Row 4. Therefore, runs were made on the IBM 360/65 for direct comparison with other vendors. These are shown in Rows 5 and 6. Row 7 gives the CPU speed ratio to the IBM 360/65 using Rows 4 and 5.

An evaluation of elapsed times was made correcting to the standard batch. This was done as follows: Row 8 gives the CPU times of jobs not run by each manufacturer in terms of IBM 360/65; Row 9 is an estimate of CPUs that the manufacturer's computer would take using the results of Row 7; Row 10 then is an estimate of the total standard batch CPU times, with Row 11 being an estimate of the standard batch elapsed time; Row 12 gives the elapsed time speed ratio to an IBM 360/65. Because of the necessity of extrapolating the data to estimate the running time

PROGRAM NAME	JOB NO.	512K IBM 360/65	1 Meg IBM 360/65	2 Meg IBM 360/85	UNIVAC 1106	UNIVAC 1108	CDC 6500	CDC 6600
FINITE ELEM.STRESS	E11401	1.995	2.146	0.484	2.190	1.154	1.333	0.481
STDY.ST.TEMP.ANAL.	E12401*	0.208	0.251	0.048	0.383	0.195	0.177	0.080
WEIGHTS & BALANCES	E15304	0.590			0.664	0.332	0.345	0.190
QAD-P5	E16101	36.698	41.670	6.389	35.712	20.147	33.807	11.708
DOT	E16203	4.607	5.323	0.900	4.192	2.241	3.435	1.435
SOLID CHEM. COMP.	E23101	8.909	10.868	2.878				
REGEN.COOL.HT.TSFRE	E25106	1.400	1.683	0.333	2.415	1.264	0.687	0.372
NETAP	E31201	43.023	49.658	10.204	(51.3)***	(28.683)***	51.935	17.578
TITAN III BALANCE	E56303	2.033	2.436	0.494	2.129	1.097	1.133	0.580
77. XE DATA ANALYSIS	E57101	3.372	3.926	0.740			4.117	2.267
MULTILOT PROGRAM	E57103A-Z	(6.754)**	8.348	1.665			9.542	5.233
TAF	E61904B	0.072	0.113	0.024				
TAF	E61904D	0.674	0.809	0.248				
SPECIAL PROGRAM	ALEX ¹	1.739	2.046	0.298	1.169	0.611	0.772	0.340
" "	ALEX ²	0.506	0.600	0.126	0.986	0.440	0.340	0.185
" "	APT				3.666	2.010	2.208	1.263
" "	HEAT				5.926	4.240		
" "	RTØ						1.047	0.445

TABLE 10

$$\text{TOTAL CPU TIME} = \frac{\text{TOTAL IØ REQUESTS}}{\text{PARTIAL IØ REQUESTS}} \quad (\text{PARTIAL CPU})$$

* EXECUTE CPU TIME ONLY

** ESTIMATE BASED UPON NEARLY COMPLETED JOB

*** NOT INCLUDED IN LAPSED TIME CALCULATIONS; THIS WAS RUN SEPARATELY AT A LATER TIME.
THE 1106 TIME WAS ESTIMATED FROM THE 1108 RUN; NO 1106 RUN WAS MADE.

ESTIMATED LAPSE TIME OF STANDARD BATCH*

	512K IBM 360/65	1 Meg IBM 360/65	2 Meg IBM 360/85	UNIVAC 1106	UNIVAC 1108	CDC 6500	CDC 6600
1. LAPSE TIME OF BATCH RUN	188.548	146.370	42.683	66.167	49.133	73.5	54.56
2. CPU TIME OF BATCH	112.540	137.226	26.496	59.432	33.732	111.5	42.2
3. CPU UTILIZATION	59.69%	93.75%	62.08%	89.82%	68.65%	75.85%**	77.35%
4. CPU TIMES OF JOBS RUN IN ADDITION TO STANDARD BATCH	0.0	0.0	0.0	9.592	6.250	3.250	1.708
5. CPU TIME OF JOBS COMMON WITH STANDARD BATCH	188.548	137.226	26.496	49.840	27.481	107.623	40.451
6. CPU TIME ON 360/65 512K FOR JOBS IN ITEM 4	188.548	111.950	111.950	49.736	49.736	102.885	102.885
7. CPU SPEED RATIO TO 512K IBM 360/65	1.0	0.816	4.225	0.998	1.810	0.956	2.543
8. IBM 360/65 512K CPU TIMES OF JOBS NOT RUN	0.0	0.590	0.590	62.804	62.804	9.655	9.655
9. ESTIMATE OF CPU TIME OF JOBS NOT RUN, ITEMS 8/7	0.0	0.723	0.140	52.930	34.698	10.099	3.800
10. ESTIMATE OF CPU TIME OF STANDARD BATCH 2 - 4 + 9	112.540	137.949	26.636	112.644	62.179	118.349	44.292
11. ESTIMATE OF STANDARD BATCH LAPSE TIME 100 x 10 / 3	188.5	147.1	42.9	125.4	90.6	78.0**	57.3
12. LAPSE TIME SPEED RATIO TO IBM 360/65 512K	1.0	1.28	4.39	1.50	2.08	2.42	3.29

*TIMES IN MINUTES

**MULTIPLIED BY 0.5 FOR DUAL PROCESSOR

TABLE 11

for the standard batch, there may be a reduction in the accuracy of the results. However, there were enough programs common to all systems to give a reasonable indication of relative performance.

B. COST-EFFECTIVENESS STUDY

After an evaluation of the benchmark data, an estimate was made of the total throughput ratio of nine systems (shown in Table 12) to the IBM 360/65, 512K-byte core machine. Based upon operating experience with the IBM 360/65, 512K-byte computer, it has been estimated that 3600 hours of CPU computing can be expected from this machine in a year using three-shift, full-time operation. This was multiplied by the throughput ratio to obtain the number of equivalent hours of IBM 360/65 time that each machine could be expected to give. For those systems where benchmark data were not available (the 1106MP and the 98K CDC 6500). This throughput ratio was estimated from the data on the most similar machine. Because of the large core requirements for the Univac operating system, the 131K word core machines benchmarked were changed to 196K systems for the cost analysis. The throughput ratios from the 131K systems were used. The 1000K byte IBM 360/65 figures were adjusted to correct for the effects of the extra core already indicated. The cost ratio of each to the base IBM 360/65, 512K-byte computer, was then multiplied in to give a cost/effectiveness number for each system. This information is shown in Table 13. The engineering requirement for computer time for Sacramento is estimated to be a minimum of 8000 CPU hours until 1976. The machines that can exceed this requirement are listed in order of increasing cost on Table 14. (The cost data here is preliminary.)

The results of the benchmark test were used as a basis for selecting configurations for further analyses with SCERT.

CPU AND LAPSE TIME SUMMARY

The following table gives a comparison of CPU and lapse times of the standard benchmark batch. Figures indicate a ratio of 360/65 512K configuration to the machine configurations proposed by IBM, CDC, and UNIVAC.

	<u>Machine</u>	<u>CPU Speed Ratio</u>	<u>Throughput or Lapse Time Ratio</u>
IBM	360/65 (1 Megabyte)	0.816	1.28
IBM	360/85 (2 Megabyte)	4.225	4.39
CDC	6500 (131K Words)	0.956	2.62
CDC	6600 (131K Words)	2.543	3.49
UNIVAC	1106	0.998	1.50
UNIVAC	1108	1.810	2.08

SYSTEM COST EFFECTIVENESS

<u>Description</u>	<u>Throughput Ratio</u>	<u>Equivalent[*] 360/65 CPU Hours</u>	<u>Lease Cost/Month (Thousand Dollars)</u>	<u>Effectiveness/Cost</u>
512K IBM 360/65	1.00	3600	\$56.5	1.00
1000K IBM 360/65	1.50	5400	75.0	1.13
2000K IBM 360/65	4.39	15804	143.2	1.73
98K CDC 6500	2.25	8100	83.2	1.53
131K CDC 6500	2.62	9432	92.9	1.59
131K CDC 6600	3.49	12564	118.4	1.66
196K Univac 1106	1.50	5400	54.6	1.55
262K Univac 1106 MP	2.50	9000	69.8	2.02
196K Univac 1108	2.08	7488	83.6	1.41

* Represents maximum possible under 3-shift 7-day/week operation.

TABLE 13

SYSTEM COST SUMMARY

This table lists computer systems with sufficient capability to meet the Sacramento requirements through 1976 in order of increasing cost.

<u>Description</u>	<u>Equivalent 360/65 Hours</u>	<u>Preliminary Cost Estimate</u> (Thousand Dollars/Month)
Univac 1106 Multiprocessor	9000	69.8
CDC 6500 - 98K	8100	83.2
CDC 6500 - 131K	9432	92.9
Dual Univac 1106*	10800	101.4
CDC 6600	12564	118.4
IBM 360/85	15804	143.2

* Two computers but only one set of RJE and display terminals included.

TABLE 14

C. SCERT EVALUATION

The input to SCERT is a series of definitions outlining the workload and computer processing requirements of the system to be simulated. The requirements are the initial entry to the system because they are designed to be compatible with any hardware configuration simulated.

1. Phases of Evaluation

a. Phase 1, Requirements

The first phase has three primary functions:

- (1) To accept input definitions consisting of an environment definition, file definitions, and systems processing definitions.
- (2) To build a mathematical model of each computer run or random event.
- (3) To validate the models and to output diagnostic data if errors or inconsistencies are found.

Table 15 shows a part of the simulation deck listings. From these listings the simulation obtains the program number, file sizes, and other data required to define the projected workload.

b. Phase 2, Hardware/Software

Phase 2 is the hardware/software to be simulated. In this phase a specific configuration of hardware and software is introduced. This is accomplished by a series of definitions which outline the hardware components in the configuration, the software packages, and an environmental

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SCERT SIMULATION DECK LISTING

1	2	3	4	5	6	7	8	CARD NUMBER
123456789012345678901234567890123456789012345678901234567890								
SCSCERT EC211101	111 1	1111111	11					00001
0AGC 8	9635312500 2			20K				00002
21100E01A	750 80 80		10	X PC CARDS IN				00003
21105E01B	220 1800 1800		225	XMT PLOTTAPE				00004
21110E01C	1040 120 132		15	XPR PRINTREPT				00005
20135E02A	275 80 80		10	X PCCARDS IN				00006
20140E023	15 7000 7000		875	X RAWORK				00007
20145E02P	130 1800 1800		225	XMT PLOT TAPE				00008
20150 E2C	15 7000 7000		875	X RAWORK				00009
20155 E2J	15 7000 7000		875	X RAWORK				00010
20160 E2E	15 7000 7000		875	X RAWORK				00011
20165E02F	3750 100 132		14	XPRPRINT				00012
20170E03A	100 80 80		10	X PCCARDS IN				00013
20105E04H	800 7000 7000		875	X RAWORK				00014
20110E03P	130 1800 1800		225	XMT PLOTTAPE				00015
20115E03J	800 7000 7000		875	X RAWORK				00016
20120 E3L	2000 100 132		14	XPR PRINTER				00017
21020E03A	3200 80 80		10	X PCCARDS IN				00018
21025 E3J	800 480 480		50	X RAWORK AREA				00019
21030 E3C	700 100 132		14	XPRPRINT O/P				00020
20130E06A	332 80 80		10	X PCCARDS IN				00021
20135E06C	200 7000 7000		875	X RAWORK				00022
20130E06B	200 7000 7000		875	X RAWORK				00023
20135E06J	200 7000 7000		875	X RAWORK				00024
20140 E3G	1500 100 132		14	XPRPRINT				00025
20145 E3P	130 1800 1800		225	XMT PLOT				00026
21135E07A	2400 80 80		10	X PC CARDS IN				00027
21140 E7B	220 1800 1800		225	XMT PLOT TAPE				00028
21145E07C	500 2000 2000		250	X RAWORK DISK				00029
21150E07D	4125 100 132		13	XPR PRINTREPT				00030
21055E08A	1400 80 80		10	X PCCARDS IN				00031
21060 E8B	4300 1600 1600		200	X RAWORK AREA				00032
21065 E8C	220 1800 1800		225	XMT PLOT TAPE				00033
21070E08D	715 120 132		13	XPRPRINTDATA				00034
21120E09A	325 80 80		10	X PC CARDS IN				00035
21125E09B	1350 120 132		15	XPR PRINTREPT				00036
20200E11A	150 80 80		10	X PCCARDS IN				00037
20205E11B	125 76 76		10	X RAWORK DATA				00038
20210E11C	1000 132 132		17	XPRPRINT				00039
20215 E11P	130 1800 1800		225	XMT PLOT				00040
20220 E1A	325 80 80		10	X PC CARDS IN				00041
20225 E1B	250 80 80		10	XPC CARDS OUT				00042
20230E12C	12 7200 7200		900	X RAWORK FILE				00043
20315E12P	220 1800 1800		225	XMT PLOT TAPE				00044
20320E12J	2500 80 132		12	XPR PRINTER				00045
20590E13A	60 80 80		10	X PC CARDS IN				00046
20595E13B	2300 100 132		14	XPR RPT PRINT				00047
20730E14A	4925 80 80		10	X PC CARDINPUT				00048

84

6

TABLE 15

definition that shows how the hardware and software are to be operated. The primary functions of Phase 2 are:

- (1) To accept the hardware/software definitions.
- (2) To build a mathematical model representing that hardware configuration, subsidiary models representing certain software packages, and integrated models representing the effect of certain software on hardware characteristics.
- (3) To validate the compatibility of the models built in Phase 1, which represent the processing requirements, with the model of the hardware capabilities and capacities and to output diagnostic data when incompatibilities exist.

Table 16 shows a typical hardware configuration. In this example, the IBM 360/75 is configured. The data input into the system is the name (manufacturer's part number) and quantity of each unit. Stored in the SCERT system is the GSA purchase price, minimum monthly rental, floor space required, cooling requirements, and power requirements.

c. Phase 3, Presimulation Algorithms

Phase 3 is the presimulation algorithms. This phase passes the models built in Phase 1 against the model of the hardware and software built in Phase 2 and performs a series of calculations, which effectively structure and parameter the nonhardware-oriented models to the particular performance abilities and capabilities of the hardware. SCERT computes the following data for each program run or random event:

SCERT ANALYSIS PART 1 COMPUTER COMPLEMENT REPORT

FOR SYSTEM AGC 8, CONFIGURATION 075. (PRICES BASED ON FY69 GSA SCHEDULE)

MODEL NUMBER/MANUFACTURER	QUANTITY IN SYSTEM	PURCHASE PRICE IN \$	MINIMUM MONTHLY RENT \$	*** ENVIRONMENTAL REQUIREMENTS ***			
				FLOORING SQ FT	COOLING BTU/HR	POWER KW	SUPPLY KVA

CENTRAL PROCESSOR 2075J IBM	1	2920890	71286	1027	103200	31.8	39.8
MAGNETIC TAPE STATION 24205 IBM	6	180960	3480	108	21000	7.6	9.6
24012 IBM	2	45400	1000	36	7000	2.5	3.2
RANDOM ACCESS 231441 IBM	16	512800	11349	400	38800	13.1	16.3
CARD READER 250132 IBM	2	30560	660	80	2100	0.4	0.6
2540 IBM	1	33950	680	96	2600	0.9	1.2
CARD PUNCH 2540 IBM	1	-	-	-	-	-	-
LINE PRINTER 1403N1 IBM	4	164800	3600	220	18400	4.4	5.6
REMOTE COMM. TWO-WAY 22502 IBM	12	11640	372	-	-	-	-
27801 IBM	2	79200	1800	-	-	-	-

THE COST AND OTHER FACTORS FOR THESE FEATURES AND CONTROL				UNITS HAVE BEEN ADDED TO DEVICES ABOVE			
F75HS3	SOFTWARE						
S75I	SOFTWARE						
14161	IBM	4	3000	100			
23653	IBM	4	397700	9530			
27011	IBM	1	9410	206			
28032	IBM	1	38900	825			
28213	IBM	1	55880	1235			
28481	IBM	1	16200	370			
28602	IBM	1	143750	3090			
2870	IBM	1	106700	2265			
5450	IBM	1	40300	775			

THIS SOFTWARE WILL BE INCORPORATED IN THE SIMULATION

SR7510	SOFTWARE
Z05009	IBM

2 CHAN 2314 SORT
OS 360/75 MVT S

TOTAL CONFIGURATION		3980200	94227	1967	193100	61.1	76.4
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TABLE 16

(1) Internal processing time and memory requirements. As a by-product of these calculations, it also determines the number of program steps required to perform the internal processing.

(2) The assignment of all files to available peripheral devices and channels.

(3) The structuring of files to the hardware in terms of record format and size, file blocking or batching, and provision for alternate areas.

(4) Throughput timing for all input/output functions and the memory requirements for such functions.

(5) The timing of generalized software packages such as sorting, compilations, IOCS, and operating system overheads.

(6) Pre- and post-run timing such as program insertion, set-up time, multi-media change time, error correction time.

d. Phase 4, Simulation

Phase 4 performs the actual simulation in three stages:

In Stage 1, SCERT explodes each program run or random event into its maximum number of unique throughput iterations. For each exploded iteration, SCERT has obtained, via the presimulation algorithms, a composite representation of the input/output timing and internal timing. The processing simulates the flow of each of these throughput iterations through the specific computer configuration. The result of this simulation derives the net throughput timing in consideration of available simultaneity and in consideration of all possible simultaneity restrictions.

Stage 2 is entered only if the defined processing includes random-occurring events. Stage 2 builds models based on probability theory and distributes the occurrences of events in a probabilistic manner. These models are then related and interrelated via simulation to determine the flow of these models in a random manner through the computer system. Based on this simulation, potential queueing points are determined; and the delay of processing, resulting from such queues, is derived. If scheduled processing has been defined to occur simultaneously with random processing, a sub-stage is entered that derives the impact of interrupts to service random processing.

Stage 3 is entered whenever the computer hardware/software complex is capable of multiprogramming or multiprocessing and when the definition of the processing requirements reflects a requirement to use these features. In Stages 1 and 2, the net elapsed time (vertical utilization) and capacity requirements (horizontal utilization) of each scheduled run and real-time event have been derived. It is the function of Stage 3 to now schedule the concurrent processing of these events or computer runs based on probability and priority if multiprogramming is involved and/or, conversely, to schedule single runs or events among the processors involved if multiprocessing is involved. Upon completion of Stage 3, all simulations have been completed with the results stored in the mathematical models representing the processing requirements, and SCERT is now ready to produce the output reports.

e. Phase 5, Production of Reports

A series of output reports is available to evaluate a particular analysis.

(1) The Multiprogramming Detailed Schedule report, an example of which is given in Table 17, provides the predicted operation of the computer facility. All of the work is divided into time zones

SCERT MULTIPROGRAMMING DETAILED SCHEDULE FOR SYSTEM AGC 8. CONFIGURATION 075

TIME ZONE	TIME IN MINUTES	RUNS STARTED	PROGRAMS IN MEMORY	RUNS STOPPED	ANALYSIS OF LIMITING FACTOR	MEMORY BEING USED	PROCESSOR RATIO	UNUSED PERIPHERALS						
								MA	MT	MR	MT	PC	PC	PC
01	17.22		E230 Z0681 Y0121 E060 Z0301 E290 E120	E350	MEMORY CAPACITY	840160	1.15	04	04	02	00	01	01	01
01	17.50	E280	E230 Z0681 Y0121 E060 Z0301 E230 E120		NO PROGRAMS	892723	1.19	04	03	02	00	01	01	01
01	18.56	Y0101	E230 Z0681 Y0121 E060 Z0301 E280 E120		MEMORY CAPACITY	893043	1.20	04	03	02	00	00	01	01
01	19.53	Y0571	E230 Z0681 Y0121 E060 Z0301 E280 E120	Y0101	MEMORY CAPACITY PERIPHERALS	893043	1.20	04	03	02	00	00	01	01
01	19.60		E230 Z0681 Y0121 E060 Z0301 E280 E120	Y0571	MEMORY CAPACITY	892723	1.19	04	03	02	00	01	01	01
01	19.70	Z0111	E230 Z0681 Y0121 E060 Z0301 E230 E120		NO PROGRAMS	893251	1.21	04	03	01	00	01	01	01
01	19.82	Z0661	E230 Z0681 Y0121 E060 Z0301 E280 E120 Z0111		NO PROGRAMS	893779	1.22	04	03	00	00	01	01	01
02	20.00		E230 Z0681 Y0121 E060 Z0301 E280 E120 Z0111		MEMORY CAPACITY	893779	1.22	04	03	00	00	01	01	01
02	21.09	Y0671	E230 Z0681 Y0121 E060 Z0301 E290 E120 Z0111		NO PROGRAMS	894099	1.23	04	03	00	00	00	01	01
02	21.26		E230 Z0681	Y0671	MEMORY CAPACITY	893779	1.22	04	03	00	00	01	01	01

TABLE 17

for the simulation. Each time zone is representative of 20 minutes of work-load arriving in a random fashion. There are 24 time zones so that all work would arrive during an 8-hour period represented by the day shift. The actual time in minutes is recorded and the time when the run starts shows when a new program arrives. The next column, Programs in Memory, shows the various programs being worked on at that time interval in the multiprogram environment. As indicated, as many as 10 programs might be worked on at any given time. Runs Stopped shows when a program has been completed. The Analysis of Limiting Factor gives a reason that the computer has not worked on additional programs. The reason may be that there are no additional programs available, or the memory capacity has been completely used, or perhaps there are no peripheral devices available to introduce new programs into the system. In analysis of this factor, looking at a typical day's operation indicates whether the computer is balanced and how heavily it is being utilized. The next column provides a measure of size of memory being used during the given time interval. The processor ratio is a measure of the demands on the central processor at any given time. A value of one represents a constant demand on the CPU. When greater than one, it is a measure of queuing on the CPU. The unused peripherals indicate equipment at idle during a given time period.

A simulation of the multiprogramming environment provides a measure of the number of minutes it will take to perform a typical day's work, assuming a 28-day month for processing the work.

(2) An example of the Multiprogramming Throughput Summary is presented as Table 18. By program, it summarizes the performance of each program. A percentage of degradation in the last column shows the additional time it would take to run that program in a multiprogramming environment compared to a batch environment.

(3) Table 19 shows a sample page of the Multiprogramming Utilization Summary. It gives a measure of the processor capability being used during any given time zone.

SCERT MULTIPROGRAMMING THROUGHPUT SUMMARY
FOR SYSTEM AGC 8, CONFIGURATION 075

TIME IS IN MINUTES

RUN NUMBER	TIME ARRIVED IN QUEUE	TIME STARTED	TIME STOPPED	TOTAL JOB TURNAROUND	TIME ELAPSED IN QUEUE	ACTUAL RUN TIME	SERIAL RUN TIME	PER CENT DEGRADATION
AG1A	49.44	231.11	358.28	308.44	181.27	127.16	51.63	146.2
AG1A	410.93	1087.07	1143.37	728.38	670.09	58.29	51.63	12.8
AG1B	353.23	358.49	367.04	8.76	0.20	8.55	2.53	237.8
AG1C	1143.37	1181.40	1194.00	38.63	35.09	2.53	2.53	0.0
AG1C	367.04	368.49	370.57	3.52	1.43	2.09	1.09	91.4
AG1C	1184.00	1184.00	1185.09	1.09	-	1.09	1.09	0.0
AG1A	233.74	731.49	732.33	436.09	434.75	1.34	1.06	26.2
AG1B	732.33	889.83	951.37	218.23	157.00	61.23	12.74	380.5
AG1A	370.57	370.57	373.54	2.96	-	2.96	1.20	145.8
AG1A	1185.09	1185.09	1186.33	1.20	-	1.20	1.20	0.0
AG1A	373.54	373.54	375.23	2.72	-	2.72	0.62	319.3
AG1A	1153.70	1186.30	1186.92	0.62	-	0.62	0.62	0.0
AG1A	375.23	376.26	381.76	5.49	-	5.49	1.31	318.7
AG1A	1186.92	1186.92	1188.23	1.31	-	1.31	1.31	0.0
AG1C	381.76	490.05	505.25	123.50	108.29	15.20	4.69	223.9
AG1C	1188.23	1188.23	1192.92	4.69	-	4.69	4.69	0.0
AG1L	505.25	717.46	719.37	213.10	212.20	0.90	0.67	142.8
AG1L	1192.92	1192.92	1193.30	0.37	-	0.37	0.67	0.0
AG1A	717.46	718.37	722.67	4.30	-	4.30	1.11	279.7
AG1A	1193.30	1193.30	1194.43	1.13	-	1.13	1.13	0.0
AG1A	722.67	722.67	723.11	0.43	-	0.43	0.16	167.5
AG1A	1194.43	1194.43	1194.59	0.16	-	0.16	0.16	0.0
AG1A	723.11	723.11	731.74	8.63	-	8.63	4.01	119.8
AG1A	1194.59	1194.59	1198.51	4.01	-	4.01	4.01	0.0
AG1C	11.03	38.42	45.83	29.20	21.78	7.41	4.21	75.9
AG1C	271.50	722.66	727.51	450.01	451.10	4.91	4.21	16.5
AG1C	243.10	727.51	732.09	443.91	444.35	4.56	4.21	8.3
AG1C	367.50	889.83	894.05	526.44	522.23	4.21	4.21	0.0
AG1C	423.31	1034.48	1040.85	620.03	613.66	6.36	4.21	51.1
AG1C	462.33	1079.71	1084.34	621.49	617.06	4.43	4.21	5.2
AG1C	114.53	249.31	251.51	137.01	134.80	2.20	1.63	34.9
AG1C	221.13	501.80	504.10	283.02	280.66	2.35	1.63	44.4
AG1C	309.17	600.84	602.35	293.68	291.67	2.01	1.63	23.2
AG1C	334.27	916.18	918.31	534.03	532.40	1.63	1.63	0.0
AG1C	434.30	1062.15	1063.73	608.97	607.34	1.63	1.63	0.0
AG1C	214.13	477.10	495.71	280.70	262.19	18.51	9.60	92.7
AG1C	6.13	6.10	13.38	6.97	-	6.97	6.49	7.3
AG1C	26.64	112.24	124.55	97.91	85.59	12.31	6.49	89.4
AG1C	77.03	194.94	203.33	131.79	117.85	13.93	6.49	114.4
AG1C	198.31	291.41	293.11	139.59	132.90	6.69	6.49	3.0
AG1C	175.70	376.25	389.31	192.61	179.56	13.05	6.49	100.8
AG1C	231.66	647.20	655.39	364.22	355.53	8.68	6.49	33.6
AG1C	9.01	9.74	16.91	7.90	6.72	7.17	5.58	28.6
AG1C	9.74	13.08	21.59	11.84	3.33	6.50	5.58	52.4
AG1C	14.17	23.43	32.53	18.41	9.25	9.15	5.58	64.0
AG1C	22.31	32.58	42.39	19.57	9.77	9.80	5.58	75.6
AG1C	43.03	124.55	135.54	90.48	79.50	10.98	5.58	96.7
AG1C	65.26	135.54	147.56	82.29	70.27	12.02	5.58	115.4
AG1C	95.27	217.37	229.48	134.20	122.09	12.10	5.58	116.9

SCERT MULTIPROGRAMMING UTILIZATION SUMMARY
FOR SYSTEM AGC 8, CONFIGURATION 075

TIME ZONE	PERCENT USED	PERCENT IDLE	AVERAGE MEMORY USED	AVERAGE PROCESSOR CAPACITY RATIO
51	100.00	-	1001378	1.89
52	100.00	-	866117	1.82
53	100.00	-	941376	1.82
54	100.00	-	893677	1.55
55	100.00	-	902852	1.40
56	100.00	-	496603	0.79
57	100.00	-	496683	0.79
58	100.00	-	551732	0.91
59	100.00	-	571939	0.95
60	93.07	6.92	324378	0.19

TOTAL SYSTEM UTILIZATION 1198.61 MINUTES

(4) An example of the Central Processor Utilization report is given in Table 20. It provides the frequency for each program the run number, running time, total time, and the amount of core utilized by the program, plus the core utilized including the system overhead.

Other reports are provided for Central Processor Utilization, such as is shown in Table 21. However, these reports show utilization in a batch mode and not multiprocessing mode. Therefore, their value is limited to a comparison to the advantage obtained in multiprocessing.

Other reports predicting the programming effort required to write the programs and the cost of preparation are available to the user. A sample page of the Computer Capabilities report, shown in Table 22 provides measures of the use of each major type of equipment in a straight batch mode in a given month.

An example of the Computer Complement Cost Summary report is shown in Table 23. However, it is for a batch mode; therefore, is limited in application.

Following the Summary report for each program there is a Detailed Systems Analysis report. A typical example is shown in Table 24.

SCERT ANALYSIS PART 2 CENTRAL PROCESSOR UTILIZATION REPORT - DETAIL

FOR SYSTEM AGC 8, COMPUTER COMPLEMENT NUMBER 075

PERIOD	FREQ.	RUN NUMBER	PROGRAM RUNNING	OPERATIONAL IN MINUTES SET-UP	TIME TOTAL	MEMORY UTILIZED *SEGMENTED PROGRAM TOTAL
MONTHLY	179.19	E010	4.21	-	4.21	339963 461072
MONTHLY	147.89	E020	1.63	-	1.63	251066 372775
MONTHLY	31.36	E030	9.60	-	9.60	360491 421600
MONTHLY	165.79	E050	6.43	-	6.49	288011 409200
MONTHLY	1002.00	E060	5.58	-	5.58	200364 301173
MONTHLY	505.35	E070	15.70	-	15.70	250919 370028
MONTHLY	380.89	E080	4.43	-	4.43	201161 402270
MONTHLY	98.58	E090	2.29	-	2.29	80425 201534
MONTHLY	94.10	E110	4.00	-	4.00	252010 373719
MONTHLY	134.39	E120	8.64	-	8.64	239815 360924
MONTHLY	150.39	E130	5.72	-	5.72	161281 262390
MONTHLY	40.32	E140	8.43	-	8.43	266677 307736
MONTHLY	219.59	E150	0.64	-	0.64	221716 342025
MONTHLY	40.52	E160	9.67	-	9.67	262224 303333
MONTHLY	58.25	E170	9.66	-	9.66	119234 240343
MONTHLY	201.69	E180	24.30	-	24.80	162136 303245
MONTHLY	170.23	E190	2.70	-	2.70	233631 354740
MONTHLY	107.59	E200	9.04	-	9.04	152269 271378
MONTHLY	387.39	E210	11.26	-	11.26	254550 375659
MONTHLY	30.34	E220	21.53	-	21.53	208905 329114
MONTHLY	349.59	E230	12.67	-	12.67	165206 286305
MONTHLY	215.09	E240	4.62	-	4.62	04016 205125
MONTHLY	49.29	E250	4.95	-	4.95	200333 321442
MONTHLY	208.33	E260	6.35	-	6.35	80753 201862
MONTHLY	57.59	E270	0.11	-	0.11	309045 430154
MONTHLY	440.19	E280	11.20	-	11.20	32553 173072
MONTHLY	473.00	E290	0.75	-	0.75	374097 495806
MONTHLY	130.00	E300	1.51	-	1.51	236702 387871
MONTHLY	138.59	E310	0.24	-	0.24	224803 345912
MONTHLY	20.88	E320	6.09	-	6.09	224655 345764
MONTHLY	215.09	E330	3.02	-	3.02	139143 260252
MONTHLY	407.79	E350	2.66	-	2.66	170470 291579
DAILY	1.00	E990	7.85	-	7.85	253197 374306
MONTHLY	49.18	E300	9.44	-	9.44	165523 286032
MONTHLY	44.80	E370	0.39	-	0.39	213998 335107
MONTHLY	246.39	E390	36.09	-	36.09	450630 571939
MONTHLY	53.77	E400	6.50	-	6.50	84724 205833
MONTHLY	98.59	E420	1.74	-	1.74	217641 308750
MONTHLY	38.84	E450	9.09	-	9.09	310366 431475
MONTHLY	58.23	E490	0.08	-	0.08	04101 160210
MONTHLY	174.79	E500	0.61	-	0.61	115845 236754
MONTHLY	80.66	E510	0.67	-	0.67	131067 260176
MONTHLY	49.29	E520	6.19	-	6.19	290847 411956
MONTHLY	49.9	E550	3.20	-	3.20	201062 382171
MONTHLY	102.39	E560	0.03	-	0.03	247380 369097
MONTHLY	13.13	E570	1.33	-	1.33	187511 308020
MONTHLY	44.81	E580	2.99	-	2.99	301284 422393

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TABLE 20

SCIRT ANALYSIS P. RT 2 CENTRAL PROCESSOR UTILIZATION REPORT - TOTAL
 FOR SYSTEM AGC 8, COMPUTER COMPLEMENT NUMBER 075

PERIOD		PROGRAM	OPERATIONAL	TIME
		RUNNING	IN HOURS SET-UP	TOTAL
DAILY	RUNS TOTAL	3.71	-	3.71
DAILY	AVERAGE TIME	78.93	-	78.93
WEEKLY	RUNS TOTAL	-	-	-
WEEKLY	AVERAGE TIME	394.66	-	394.66
MONTHLY	RUNS TOTAL	1629.68	-	1629.68
MONTHLY	AVERAGE TIME	1710.23	-	1710.23
QUARTERLY	RUNS TOTAL	-	-	-
YEARLY	RUNS TOTAL	-	-	-
NORMAL MONTH	TOTAL	1710.23	-	1710.23
PEAK MONTH	TOTAL	1710.23	-	1710.23

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TABLE 21

SPECIAL SCERT ANALYSIS, COMPUTER CAPABILITIES REPORT

FOR SYSTEM AGC 8, CONFIGURATION 075

HOURS PER AVERAGE MONTH

RUN NUMBER	FREQUENCY	TOTAL TIME	CENTRAL PROCESSOR TIME				SORT TIME	MAGNETIC TAPE		RANDOM ACCESS		CARD EQUIPMENT		PRINTER	
			ARITH	MANIP	I/O	CTL		BUFRD	UNBUFRD	BUFRD	UNBUFRD	BUFRD	UNBUFRD	BUFRD	UNBUFRD
Z0801	M	38.84	0.9	-	-	0.04	-	-	-	2.93	0.91	-	-	0.04	3.01
Y0811	M	38.84	0.0	-	-	0.00	-	-	-	0.00	0.00	0.00	0.00	-	-
Z0821	M	58.23	0.0	-	-	0.00	-	-	-	0.00	0.00	-	-	0.00	0.01
Y0831	M	58.23	0.0	-	-	0.00	-	-	-	0.00	0.00	0.00	0.00	-	-
Z0841	M	174.79	1.1	-	-	0.01	-	-	-	0.77	0.24	-	-	0.01	0.86
Y0851	M	174.79	0.1	-	-	0.00	-	-	-	0.11	0.07	0.00	0.11	-	-
Z0861	M	30.55	0.3	-	-	0.00	-	-	-	0.27	0.08	-	-	0.00	0.30
Y0871	M	30.55	0.0	-	-	0.00	-	-	-	0.05	0.03	0.00	0.05	-	-
Z0881	M	49.29	1.7	-	-	0.03	-	-	-	2.61	0.87	-	-	0.03	2.85
Y0891	M	49.29	0.0	-	-	0.00	-	-	-	0.00	0.00	0.00	0.00	-	-
Z0901	M	49.29	1.3	-	-	0.01	-	-	-	1.29	0.40	-	-	0.01	1.43
Y0911	M	49.29	0.1	-	-	0.00	-	-	-	0.10	0.06	0.00	0.10	-	-
Z0921	M	102.39	0.0	-	-	0.00	-	-	-	0.00	0.00	-	-	0.00	0.00
Y0931	M	102.39	0.0	-	-	0.00	-	-	-	0.00	0.00	0.00	0.00	-	-
Z0941	M	13.43	0.2	-	-	0.00	-	-	-	0.16	0.03	-	-	0.00	0.16
Y0951	M	13.43	0.0	-	-	0.00	-	-	-	0.02	0.01	0.00	0.02	-	-
Z0961	M	44.81	3.1	-	-	0.01	-	-	-	0.06	-	-	-	0.01	3.01
Y0971	M	44.81	0.0	-	-	0.00	-	-	-	0.59	0.37	0.00	0.58	-	-
Z0981	D	1.00	0.0	-	-	0.00	-	-	-	0.00	-	-	-	0.00	0.07
Y0991	D	1.00	0.0	-	-	0.00	-	-	-	0.00	-	0.00	0.03	-	-
Z1001	D	1.00	0.0	-	-	0.00	-	-	-	0.00	-	-	-	0.00	0.07
Y1011	L	1.00	0.1	-	-	0.00	-	-	-	0.00	-	0.00	0.10	-	-
Z1021	D	1.00	0.1	-	-	0.00	-	-	-	0.00	-	-	-	0.00	0.10
Y1031	D	1.00	0.0	-	-	0.00	-	-	-	0.00	-	-	-	0.00	0.02
Z1041	L	1.00	1.1	-	-	0.00	-	-	-	0.02	-	0.00	1.18	-	-
Y1051	D	1.00	0.0	-	-	0.00	-	-	-	0.00	-	-	-	0.00	0.07
Z1061	D	1.00	0.1	-	-	0.00	-	-	-	0.00	-	-	-	0.00	0.19
Y1071	D	1.00	1.4	-	-	0.00	-	-	-	0.03	-	-	-	0.00	1.43
Z1081	D	1.00	33.4	-	-	0.22	-	-	-	1.11	-	-	-	0.22	34.2
Y1091	D	1.00	0.0	-	-	0.02	-	-	-	0.12	-	-	-	0.02	3.61
TOTAL SYSTEM			1701.7	372.73	45.78	11.07	6.01	16.06	20.25	616.14	727.24	1.58	134.13	4.62	382.44

TABLE 22

SCERT ANALYSIS PART 6

COST SUMMARY REPORT

FOR SYSTEM AGC 8, COMPUTER COMPLEMENT NUMBER 075

COST ANALYSIS PER MONTH
EQUIPMENT COST

RENTAL BASIS

PURCHASE BASIS

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ITEM	MODEL NUMBER	QUANTITY	ACTUAL HOURS	CONTRACT HOURS	EXTRA USE CHARGE PER MONTH	TOTAL MONTHLY RENTAL	TOTAL PURCHASE PRICE	MAINTENANCE FOR SYSTEM LIFE	TOTAL PURCHASE COST	MONTHS TO BREAK EVEN
CPU	2075J	1	1710.23	176	61374	132660	2920890	1729442	4650332	36
FAS	2311A1	16	4699.21	176	7250	18600	512000	103391	621191	34
MTS	24003	6	901.74	176	-	3400	180900	21600	202500	50
PFD	1401A1	4	473.72	176	-	3600	164000	43920	208720	58
MTS	24012	2	311.88	176	-	1000	45400	8400	53800	54
PCI	250132	2	199.03	176	-	600	30500	6600	37200	57
PCI	2540	1	-	176	-	680	33950	6900	40850	61
PLU	2540	1	10.74	-	-	-	-	-	-	-
KCE	22002	12	-	720	-	372	11640	5440	17580	48
KCE	27801	2	-	720	-	1800	79200	25800	105000	59
TOTAL EQUIPMENT COST FOR 60 MONTHS						9771140			5037253	37

TABLE 23

SCERT DETAIL SYSTEMS ANALYSIS REPORT

FOR RUN NUMBER E070 , STRESS ANAL SOLIDS SYSTEM AGC 8 , CONFIGURATION 075.

FREQUENCY MONTHLY 506.39 PRIORITY 5.

TIMING DATA IS IN SECONDS

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PART 1 INPUT/OUTPUT ANALYSIS

INTERNAL INPUT/OUTPUT

INPUT	FILES	FILE	LOGICAL	RECORD	SIZE	RECORDS	BUFFER	MEDIA	FILE	ASSIGNMENT	CPU	PROC.	INCEPEND	CHANNEL	CPU
		NUMBER	RECORDS	AVG.	MAX.	/BATCH	SIZE	UNITS	DEVICE	MD CH M	INT	TIME	TIME	TIME	WAIT
CARDS IN	E07A	4000	80	80	1	160	16	2314A1	RA 02 R	0.01	2.18	240.00	51.09	2.81	
WORK DISK	E07C	250	1000	1000	1	2000	03	2314A1	RA 01	0.01	0.11	0.02	6.22	0.38	

OUTPUT FILES

PRINTREPT	E07D	8553	100	132	1	264	15	2314A1	RA 01 R	0.04	5.59	504.00	317.87	793.34	
WORK DISK	E07C	250	1000	1000	1	1000	07	2314A1	RA 02	0.01	0.11	0.02	12.44	9.56	
PLOT TAPE	E07B	220	1800	1800	1	3600	1	24012	MT 02	0.02	0.06	0.66	8.35	7.69	

* TOTAL CPU WAIT 813.80

PART 2 INTERNAL PROCESSING ANALYSIS

FUNCTION	PROGRAM STEPS	MEMORY REQUIRED	INTERNAL TIME
ARITHMETIC	15366	88335	106.50
DECISION AND CONTROL	19400	107579	0.32
DATA HANDLING	9233	53132	11.87
INPUT/OUTPUT CONTROL	130	747	6.10
INPUT/OUTPUT BUFFERS		7123	
TOTAL	43160	TOTAL 256919	

* TOTAL INTERNAL TIME 124.81

PART 3 SPECIAL TIME ANALYSIS

** TOTAL PROGRAM TIME 938.61

PROGRAM INSERTION TIME	0.95
END OF JOB REWIND TIME	1.82
OPERATING SYSTEM OVERHEAD TIME	1.09

*** TOTAL ELAPSED COMPUTER TIME 942.48

**** TOTAL JOB TURNAROUND TIME 942.48

TABLE 24

VII. EVALUATION OF VARIOUS CONFIGURATIONS TO MEET PROGRAM REQUIREMENTS

The determination of a configuration for separate facilities in Sacramento, Pittsburgh, and NTO will be made. These results will then be compared to having a single central site. Finally, a comparison will be made with having separate facilities in Sacramento and Pittsburgh with NTO as a satellite facility.

A. SEPARATE FACILITIES IN SACRAMENTO, PITTSBURGH, AND NTO

1. Sacramento Facility Analysis

a. Workloads

Studies were made of the Sacramento facility assuming the minimum and maximum workloads projected under the requirements. An initial screening of configurations was made using benchmark data. These results were then used for further refining by SCERT simulation. The SCERT results for the maximum Sacramento requirements are summarized in Table 25. They indicate that for the maximum workload of 12K hr, the IBM 360/85, the CDC 6600, and the Univac system of an 1106 Multiprocessor plus a stand-alone 1106 would be able to perform the work. This is seen in the total elapsed time column in the multiprogramming mode.

Several observations were made during the analysis which indicate the limitations currently existing in the simulation. The SCERT simulation tended to do a better job simulating single processing systems than multiprocessing systems, and did a poor job in handling multiprocessing with a series of peripheral processors. The assumptions made in defining the workload requirements in the simulation were quite significant in the results obtained from the simulation. For instance, relative to Table 26, the Univac system was run three different ways. It was originally run with the 1106 Multiprocessor plus the 1106, as recommended by the manufacturer. SCERT

SACRAMENTO WORKLOAD SCERT EVALUATION

<u>EQUIPMENT</u>	<u>WORKLOAD</u>	<u>SERIAL ELAPSED TIME HR/MO.</u>	<u>SERIAL PROCESSING TIME HR/MO.</u>	<u>MULTIPROGRAMMING DEGRADATION</u>	<u>TOTAL ELAPSED TIME MIN/DAY</u>	<u>HR/DAY</u>
IBM 360/85	12K - IBM	1552	219	80%	884	14.7
CDC 6600	12K - IBM	1486	252	48.5%	1071	17.9
UNIVAC 1106 MP + 1106	12K - IBM	2045	884/3X	100%	948	15.8

TABLE 25

SACRAMENTO UNIVAC ANALYSIS (12K HOURS)

<u>SYSTEM</u>	<u>SERIAL ELAPSED TIME HR/MO.</u>	<u>SERIAL PROCESSING TIME HR/MO.</u>	<u>MULTI- PROGRAMMING DEGRADATION</u>	<u>MULTIPROGRAMMING TOTAL ELAPSED TIME</u>	
				<u>MIN/DAY</u>	<u>HR/DAY</u>
1106 MP + 1106	2045	884/3X	380%	2246	37.4
1106 MP + 1106 + PERIPHERALS	2047	884/3X	100%	948	15.8
1106 MP + PERIPHERALS	2047	884/2X	175%	1193	19.9

TABLE 26

predicted it would take 37.4 hr to do the required workload. A review of the serial processing time where three processors are available indicates that each processor would be utilized somewhere around 300 hr per month, less than half the time available. The SCERT analysis indicated a lack of peripherals to do the work. Extra tape drives were added to the system and the results show that the work could be performed in 15.8 hr per month. A review of the procedures used in the simulation showed that in a multiprogramming environment, all of the peripheral devices were considered to be tied up throughout the running time of a program. A check with the manufacturer showed that the ability exists to release peripheral devices such as tapes once they are no longer being utilized in that program. Therefore, the requirement for these tapes is questionable. SCERT provided insight into the definition of the system, but if the results were taken without further investigation, the conclusions would be wrong. A further study was made with SCERT, removing one of the processors but adding the extra peripheral devices. This indicates that the 1106 Multiprocessor would have the capability of handling the maximum workload in 19.9 hr. This appears to be an optimistic estimate of the ability of the 1106 Multiprocessor based on benchmark projections.

Table 27 reviews the relative central processing times as experienced in the benchmark runs and the SCERT runs. It states that SCERT is overpredicting the Univac 1106 ability to process data by 20% and the IBM 360/85 by 13%. The comparison was made using the same programs that were benchmarked and simulated. For the CDC 6600, SCERT indicates a CPU time 78% faster than benchmark data on the same program. These differences may be accounted for in the program instruction mix. In setting up the SCERT simulation, a representative group of instructions was used rather than an exact set of instructions. An exact set could not be used because the iterative nature of the programs results in a variable number of program steps each time the program is run.

An estimate of throughput between benchmark test and SCERT indicates good agreement. Extrapolations made based on the benchmark

CENTRAL PROCESSING TIME
RATIC TO IBM 360/65

	<u>BENCHMARK</u>	<u>SCERT</u>
UNIVAC 1106	0.998	1.21
IBM 360/85	4.23	4.80
CDC 6600	2.54	4.55

tests indicate the IBM 360/85 can perform 10% more work than the Univac 1106 Multiprocessor plus 1106 while SCERT shows a 7-1/2% increase. The IBM 360/85 throughput using benchmark data indicates 25% more throughput than the CDC 6600, while SCERT indicates 21% more throughput. Although the CDC 6600 CPU times appear to be much faster in SCERT, throughput is not correspondingly overstaged. The results of the investigation of throughput led to the conclusion that the three configurations considered can do the projected maximum workload, with the IBM 360/85 having 5 to 10% more reserve than the Univac and the CDC 6600 having 20 to 25% less reserve.

The results of analyzing the minimum workload are shown on Table 28. An analysis was made to determine the expanded capability of the current computer. It shows that the IBM 360/65 would take some 33 hr per day to perform the workload predicted. Obviously the IBM 360/65 is too small a machine to meet the requirements. Moving up to a larger processor, represented by the IBM 360/75, the hours per day drop to 20 hr. These results are about what can be expected in terms of experience with IBM machines. The CDC 6500 in the SCERT analysis indicates it would take 28.8 hr per day. However, the SCERT does not seem to get good results in a multiprocessor environment with peripheral processors. Benchmark data in Table 28 indicates that the CDC 6500 should have no trouble handling the 8,000-hr predicted workload. The difficulties with the CDC 6500 simulation were never fully resolved during the study. The Univac 1106 Multiprocessor was predicted to take 17.3 hr per day indicating that it could handle the total projected workload in the shortest period of time of any of the machines analyzed.

An evaluation of the IBM 360/75, CDC 6500, and Univac 1106 MP, using all data available, indicates the Univac 1106 MP would perform 15% more work in a multiprogramming mode than the IBM 360/75. The CDC 6500 can perform about 5% more work than the Univac 1106 MP.

SACRAMENTO WORKLOAD SCERT EVALUATION

(8K Hours)

<u>EQUIPMENT</u>	<u>WORKLOAD</u>	<u>SERIAL</u>	<u>SERIAL</u>	<u>MULTIPROGRAMMING</u>	<u>TOTAL</u>	
		<u>ELAPSED TIME</u>	<u>PROCESSING TIME</u>		<u>ELAPSED TIME</u>	
		<u>HR/MO.</u>	<u>HR/MO.</u>	<u>DEGRADATION</u>	<u>MIN/DAY</u>	<u>HR/DAY</u>
IBM 360/65	8K - IBM	1988	718	110%	1982	33.0
IBM 360/75	8K - IBM	1326	425	100%	1206	20.1
CDC 6500	8K - IBM	1856	919/2X	92%	1731	28.8
UNIVAC 1106 MP	8K - IBM	1615	585/2X	55%	1050	17.5

TABLE 28

b. Software

CDC, IBM and Univac all have an operating system that allows multiprogramming (several active programs in core sharing the use of the central processor), and on at least some of their systems, multiprocessing (more than one central processor in a system) is possible. The CDC system (SCOPE) and the IBM (OS/360 MVT) both appear to be very well checked out and have been in use for several years. The Univac system (EXEC VIII) is the newest of the three and has been in use for about one year. It operated satisfactorily on the benchmark runs.

The CDC system uses about 14,000 words of central memory for the operating system. This represents about 11% of the maximum core available (131K words). IBM uses about 120 to 150K bytes of core storage or about 14% of the one million bytes available on the IBM 360/65 and 360/75 systems. The Univac system uses up to 57,000 words in the multiprocessor version. Because of this large requirement the Univac systems with less than 196K words were not considered.

c. Conversion Costs

A study was made in the fall of 1969 to determine the approximate amount of effort required to convert the FORTRAN programs being used by ANSC from the IBM 360/65 computer to some other machine. The programmers in charge of each program were asked to give a best estimate and a pessimistic estimate of the number of manhours required to convert their programs to a CDC 6600 computer. The CDC 6600 was felt to be the most difficult to convert to and should thus represent a maximum effort. No programs containing machine language subroutines were included in the study. Table 29 shows a tabulation of the results of this estimation.

A number of programs were converted to run on the CDC 6600 during this same time period. Table 30 shows the results of this

TABLE 29

ESTIMATED HOURS FOR PROGRAM CONVERSION - IBM TO CDC

	<u>Program No.</u>	<u>Estimated Hours</u>	<u>Pessimistic Est. Hours</u>
Active	12203	40	80
	12401	8	20
	13901	80	100
	15301	16	20
	*16101	40	45
	16202	90	100
	16302	100	125
	16501	40	45
	16502	20	20
	16503	30	30
	16504	30	30
	16505	60	80
	16506	30	30
	16507	80	90
	16508	25	30
	*25104	--	--
	*31201	200	300
	*32209	8	32
	33101	20	40
	51101	60	80
	51301	40	40
	51302	60	80
	51303	100	140
	51309	30	40
	*57101	160	200
	*57103	100	300
	*57107	100	400
	58901	24	80
	61901	20	20
	61904	250	500
	69902	--	--
	Subtotal	1253	1820 (excluding programs already converted)

* Converted already

TABLE 29 (cont.)

	<u>Program No.</u>	<u>Estimated Hours</u>	<u>Pessimistic Est. Hours</u>
Inactive	16102	40	50
	16902	20	40
	25102	30	60
	32203	30	60
	33602	80	120
	51308	20	20
	57108	80	200
	61211	80	150
	61212	80	150
	61905	20	20
		<hr/>	<hr/>
	Subtotal	480	870
	TOTAL	1733	2690

EXAMPLES OF CONVERSION TO CDC

<u>Program</u>	<u>Size</u>	<u>Type</u>	<u>Actual Manhours</u>	<u>Pred. Pessimistic Manhours</u>	<u>Predicted Manhours.</u>
E11401	1 box	360 Fort IV	12	160	80
E34101	5 boxes	360 Fort IV	16	40	25
E25104	2 boxes	360 Fort IV	16	--	--
10041	1/2 box	7094 Fort II	None	--	--
E32201	1/2 box	360 Fort IV	8	32	8
Stiger	1/2 box	1130 Fort	4	--	--
E12401	1/2 box	360 Fort IV	12	20	8
E62302	1/2 box	360 Fort IV	16	80	40
42088	3 boxes	7094 Fort IV, II	8		
8103	1 1/4 boxes	7094 Fort IV	8		
E16101	1 box		12	45	40
E57101)				(200	160)
E57103)			60	900 { 300	100 } 360
E57107)				(400	100)
E31201)					
TABTP)	8 boxes		200	300	200
TABXR)					
ALEX 1	1/2 box		4		
ALEX 2	1 box		12		
RTO	1/2 box		2		
E25106	2 boxes		20	20	10
ODR	3 boxes		20		
			<hr/>	<hr/>	<hr/>
			356	1597	771
Ratio				4.48	2.17

TABLE 30

conversion effort together with the estimates of the effort. If the Table totals of the estimates are divided by the ratios of predicted to actual effort found in Table 30, it appears that the conversion effort should be about 800 manhours for the remainder of the programs to be converted.

During the benchmark tests many of these same programs were also converted to the Univac computer. Based on this experience, conversion of all of the Fortran programs to Univac should require about the same amount of time (800 manhours) as to the CDC system.

Operation of a terminal system with a computer requires both the hardware system and the software or control programs which operate the hardware. All of the manufacturers provide terminal hardware in each of the following three classes: (1) typewriter or CRT devices that accept input from a keyboard and type the output or display it on a cathode ray tube; (2) batch entry terminals which have a card reader and a line printer; and (3) graphics terminals which use a keyboard input and a CRT display output that can generate graphic displays as well as alphanumeric data.

These terminals can be used for three types of operation: time sharing, remote job entry, and graphics. Both CDC and Univac have a time sharing system in operation. The typewriter or CRT terminals are used as input and the computer performs operations as they are typed in allowing the programmer to interact with the computer as the job is processed. Many terminals are serviced simultaneously by the computer by time-slicing, or processing on each job for a very short time then switching to another job, etc. IBM has a time sharing system (TSO) that will be available in the first part of 1971. Remote job entry is commonly done two ways. The first is by using a card deck, reading it in from a remote card reader/line printer terminal and receiving the output printed at the terminal. The second is by possibly storing the major portion of the program on high speed storage at the computer and using a typewriter or CRT terminal to create, modify or arrange it and to submit it to the computer. In either case, after the job is submitted to the computer, it waits

for its turn in the processing schedule then is completely processed before any output is returned to the terminal.

All three of the manufacturers have similar systems that allow both types of remote batch input.

Graphics systems are fairly new and only a limited amount of software is available for them. All of the manufacturers have the basic software to generate lines, circles, letters, numbers, etc., but only a few specialized applications programs have been developed. The IBM system uses a graphics tube tied directly to a computer. The Univac or CDC systems use either a terminal that has some computing capability or a small computer as an interface to a large system to cut down the load on the large system.

e. Cost Estimates

Cost data were requested from each manufacturer with facilities to handle the Sacramento requirements for a period from 1971 to 1975. The information furnished the manufacturer was as follows:

(1) The workload for the years 1971 through 1975 in terms of equivalent IBM 360/65 hr is as follows:

1971	- 6000 hr
1972	- 7000 hr
1973-1975	- 8000 hr each year

These hours are the Central Processing Unit times. The workload is based on the SCERT simulation of the engineering workload and is similar to the benchmark data run in September 1969. The computer should be sized to handle the workload in six days per week at an average of 18 hr per day. The pricing should include 12 time-share terminals, six of these to be teletype and six CRT. Also priced should be two remote batch terminals with a card

reader capability of 300 cards per minute and a printer with a capability of 300 lines per minute.

(2) Assume the equipment will be acquired for delivery in the fall of 1970, updated as required from 1971 to 1975, and have all equipment leases terminated in the fall of 1975. The equipment should be priced on the basis of the most favorable lease arrangements to Aerojet Nuclear Systems Company.

(3) Funding limitations in 1971 and 1972 should limit the equipment proposed to \$75,000 lease cost per month, including sales tax. This cost should include the equipment, maintenance thereof, and any software charges. If this funding constraint limits the equipment offered to less than the requirements for the years 1971 and 1972, this should be so noted, but the cost limitation should take precedence.

(4) Separately price the additional cost of graphite terminal.

In addition to this, estimates were made projecting the larger workload for the 1973 to 1975 period.

First, examining the IBM system, the restriction of \$75K/mo in 1971 and 1972 for leasing computing equipment results in the continued use of the IBM 360/65. It is estimated that this equipment will handle only 75% of the workload in 1971 and 63% in 1972. In 1973 the system would be updated to either an IBM 360/75 or /85, depending on the workload growth. This is depicted in Figure 16. For the IBM 360/75 the cost would go to \$89K/mo and for the larger 360/85 the cost would go to \$155K/mo. IBM tends towards a short-term or yearly lease. Therefore, cost advantage of long-term commitments is mainly through third-party lessors. If equipment coming off of third-party lease can be located, the cost could be quite attractive. AGC experience shows that equipment as large as the IBM 360/85

Figure 16
113

NOTE: IN 1971, HANDLE 75% WORKLOAD; IN 1972, PERFORM 63% WORKLOAD; PERFORM FULL WORKLOAD 1973-1975.

is difficult to lease through a third party because of the limited release market.

Similar curves are depicted for CDC. Figure 17, shows that CDC provides some flexibility in their leasing plan so that they would be willing to commit to a lower-level cost during the years when limited funding is available (Table 31). Thus, the figure shows a CDC 6500 for use in the Program in the years 1971 and 1972 would be \$75K/mo, with the same machine from 1973 to 1975 at a cost of \$95K/mo. If a larger machine is needed at that time, the cost would rise to \$135K/mo.

Table 32 illustrated the effect of various lease arrangements on computer costs. These figures are different than those shown in Table because it does not show the maintenance or software support (CDC has unbundled their hardware from software). Thus, a computer that would lease for \$111K/mo for one year would lease for \$99.6K/mo for five years. In addition, CDC could make arrangements to a subsidiary, Consumer Credit Investors Corporation, which would be a third-party lease, at \$83.9K/mo. As can be seen from the table, there is a large cost advantage to a long-term lease with probably the greatest advantage being through the third-party leasing.

Figure 18 shows the system for Univac computers. A declining-balance type of lease allows equipment exchange. This lease would start at \$66K/mo during the early years. If a larger workload were needed in the period from 1973 to 1975 it would jump to about \$95K/mo. Lease arrangements are shown in Table 33.

A comparison of the various configurations is presented in tabular form in Table 34. No final recommendation is being made on the system because detailed bids, considering various leasing arrangements, such as third-party leases, could lead to a change in the final cost picture.

SACRAMENTO - CDC

NOTE: COMPUTER WORKLOAD HANDLES 1971 AND 1972 AS WELL AS 1973-1975.

Hardware Budget 1970/71	\$75,000/mo.
Less: Personal Property Tax	\$ 670/mo.
Use Tax on System	3,000/mo.
Max. Software Charges	2,700/mo.
Maintenance on System	12,200/mo.
Estim. TTY and Modems	1,000/mo.
Total	<u>19,570/mo.</u>
Funding Available for Hardware	\$55,430/mo.

Use Tax at 5% of Monthly Lease Payment

Personal Property Tax on CCC Leased Equipment

Assessed Value = 23.6% of Market Value

Rate per \$100 Assessed Value = \$10,517

$(\$3,200 \times .236 \times \$10,517) \div 12 = \$661/\text{mo.}$

MRD

440

EFFECT OF LEASE ON MONTHLY COST

EXAMPLE CDC 6600 (THIS DOES NOT INCLUDE MAINTENANCE* OR SUPPORT)

<u>EQUIPMENT</u>	<u>PURCHASE</u>	<u>1 YR</u>	<u>3 YR</u>	<u>4 YR</u>	<u>5 YR</u>	<u>CCIC 5 YR</u>	<u>CCIC 8 YR</u>
CPU	\$3,896 K	\$85.6 K	\$81.3 K	\$79.6 K	\$77.0 K	\$63.8 K	\$53.2 K
117 PERIPHERAL EQUIPMENT	<u>1,221 K</u> \$5,117 K	<u>25.8 K</u> \$111,4 K	<u>24.5 K</u> \$105.8 K	<u>24.0 K</u> \$103.6 K	<u>22.6 K</u> \$99.6 K	<u>20.1 K</u> \$83.9 K	<u>18.7 K</u> \$71.9 K

TABLE 32

* MAINTENANCE ADDS \$12.3 K/MO.

SACRAMENTO - UNIVAC

NOTE: COMPUTER WORKLOAD HANDLES 1971 AND 1972 AS WELL AS 1973-1975.

TABLE 33

UNIVAC PAYMENT SCHEDULE AND AGREEMENT FORM

MONTHLY RENTAL	\$61,839.
MONTHLY MAINTENANCE	8,560.
TOTAL MONTHLY RENTAL	<u>\$70,399.</u>

LEVEL PAYMENT LEASE PLAN

<u>MONTHS</u>	<u>3 YEARS</u>	<u>4 YEARS</u>	<u>5 YEARS</u>
1-12	\$55,655.	\$51,017.	\$46,379.
13-24	"	"	"
25-36	"	"	"
37-48	"	"	"
49-60	"	"	"

REDUCED PAYMENT LEASE PLAN

<u>MONTHS</u>	<u>3 YEARS</u>	<u>4 YEARS</u>	<u>5 YEARS</u>
1-12	\$58,747.	\$55,655.	\$52,563.
13-24	55,655.	52,563.	49,471.
25-36	52,563.	49,471.	46,379.
37-48		46,379.	43,287.
49-60			40,195.

NOTE: The above Lease Plan are Monthly Rental ONLY, Maintenance is not included. If you add the Maintenance you will have the Total Monthly Rental.

THE ABOVE PRICE GIVE YOU UNLIMITED USAGE OF THE SYSTEM.

All prices and conditions in this Payment Schedule are valid for 60 days from April 14, 1970, unless extended in writing by UNIVAC.

UNIVAC

EXTENDED TERM USE & SERVICE AGREEMENT

REDUCING PAYMENT

FIGURE VII-9
Page 2 of 3

Term of Agreement: _____ Years

TABLE 33 (cont.)

C U S T O M E R	NAME	_____
	STREET ADDRESS	_____
	CITY and STATE	_____
	ZIP CODE	_____

AGREEMENT NUMBER

SPERRY RAND CORPORATION, UNIVAC Division, hereinafter called UNIVAC, upon its acceptance of this Agreement at its Home Office, hereby agrees to furnish to the CUSTOMER, and the CUSTOMER hereby orders and agrees to the furnishing, at the above address or such other locations as may be specified herein and on the terms and conditions hereinafter stated, the use of the below listed equipment and maintenance service with respect thereto.

SCHEDULE OF EQUIPMENT

TYPE NUMBER	GROUP	SERIAL NUMBER AND DESCRIPTION	QUAN- TITY	PURCHASE PRICE	BASE MONTHLY EQUIPMENT CHARGE	BASE MONTHLY MAINTENANCE CHARGE
<p><u>EXTENDED TERM LEASE RATES FOR REDUCING PAYMENT AND LEVEL PAYMENT LEASE AGREEMENTS</u></p> <p><u>EXTENDED TERM LEASE AGREEMENTS</u></p> <p>The following Extended Term Lease Agreements are available:</p> <p><u>Reducing Payment Agreement:</u></p> <p>The monthly equipment charges under this Agreement will be reduced at the expiration of each twelve (12) month payment period. This Agreement incorporates equipment exchange privileges and is UNIVAC's preferred Agreement.</p> <p>In the event that a customer does not wish to execute the Reducing Payment Agreement and if the customer is absolutely certain that no exchange of equipment will be requested during the term of Agreement, UNIVAC will then accept a Level Payment Agreement described below.</p>						
<p>TABLE I</p> <p>PAYMENT RATE SCHEDULE</p> <p>FOR</p> <p>REDUCING PAYMENT LEASE AGREEMENTS</p> <p>(See Table IV for Exact Dollars)</p>						
<p>TABLE I</p> <p>PAYMENT RATE SCHEDULE</p> <p>FOR</p> <p>REDUCING PAYMENT LEASE AGREEMENTS</p> <p>(See Table IV for Exact Dollars)</p>						

EQUIPMENT CLASS	PAYMENT PERIOD	PAYMENT RATES (EXPRESSED AS % OF MONTHLY EQUIPMENT CHARGE)		
		3 YEAR LEASE	1 YEAR LEASE	5-YEAR LEASE
1	Months 1 - 12	95.0%	90.0%	85.0%
	Months 13 - 24	90.0%	85.0%	80.0%
	Months 25 - 36	85.0%	80.0%	75.0%
	Months 37 - 48	-	75.0%	70.0%
	Months 49 - 60	-	-	65.0%

Year	Payment Rate
1	_____ %
2	_____
3	_____
4	_____
5	_____

SPERRY RAND

Term of Agreement: _____ Years

TABLE 33 (cont.)

C U S T O M E R	NAME _____
	STREET ADDRESS _____
	CITY and STATE _____
	ZIP CODE _____

AGREEMENT NUMBER

SPERRY RAND CORPORATION, UNIVAC Division, hereinafter called UNIVAC, upon its acceptance of this Agreement at its Home Office, hereby agrees to furnish to the CUSTOMER, and the CUSTOMER hereby orders and agrees to the furnishing, at the above address or such other locations as may be specified herein and on the terms and conditions hereinafter stated, the use of the below listed equipment and maintenance service with respect thereto.

SCHEDULE OF EQUIPMENT

TYPE NUMBER	GROUP	SERIAL NUMBER AND DESCRIPTION	QUAN- TITY	PURCHASE PRICE	BASE MONTHLY EQUIPMENT CHARGE	BASE MONTHLY MAINTENANCE CHARGE
<p><u>Level Payment Agreement:</u></p> <p>The monthly equipment charges under this Agreement will be a level monthly amount for the full term of the Agreement. Equipment exchange privileges are not available with this Agreement.</p>						
<p>TABLE 11</p> <p>PAYMENT RATE SCHEDULE</p> <p>FOR</p> <p>LEVEL PAYMENT LEASE AGREEMENTS</p> <p>(See Table IV For Exact Dollars)</p>						

EQUIPMENT CLASS	PAYMENT PERIOD	PAYMENT RATES (CENTS PER DOLLAR MONTHLY EQUIPMENT CHARGE)		
		3-YEAR LEASE	4-YEAR LEASE	5-YEAR LEASE
1	Months 1-12	91.0%	92.0%	75.0%
	Months 13-24	90.0%	91.0%	76.0%
	Months 25-36	89.0%	90.0%	77.0%
	Months 37-48		89.0%	78.0%
	Months 49-60			79.0%

Year

1
2
3
4
5

Payment Rate %

EQUIPMENT COST - SACRAMENTO
(THOUSANDS OF DOLLARS PER MONTH)

	<u>Univac</u>		<u>CDC</u>		<u>IBM</u>	
	<u>Min.</u>	<u>Max.</u>	<u>Min.</u>	<u>Max.</u>	<u>Min.</u>	<u>Max.</u>
1971	66	66	75	75	75	75
1972	63	63	75	75	75	75
1973	59	95	95	135	89	155
1974	56	92	95	135	89	155
1975	53	88	95	135	89	155
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
AVERAGE MONTHLY COST	59	81	87	111	83	123

NOTE: (1) Operational costs run about \$35K per month.

(2) Graphic terminals not included. Add \$3K - 4K per month.

TABLE 34

f. Detailed Equipment Projection

A review was made of the Univac equipment by projecting additional equipment that might be added each year. The data is presented in Table 35. The table does not include the operational cost of the equipment, only the lease cost per month. In 1971 and starting with a five-year lease, the basic Univac 1106 Multiprocessor is used, with the addition of a graphics display package for initiating studies, making possible graphics interplay between the engineers and the computer. Twelve alphanumeric terminals are also included in the basic system. In 1972 the system would be expanded with the addition of six alphanumeric terminals, additional disk drives, and two additional interactive graphic terminals. From 1973 to 1975, additional graphics and terminals are added. Finally, in 1975 there are a total of 36 alphanumeric terminals and three graphics terminals.

2. Pittsburgh Facility Analysis

The configurations studied are as follows:

One: The Westinghouse Telecomputer Center (TCC)

Two: Local WANL facilities involving a

- a. CDC 6400 (131K Core)
- b. CDC 6500 (131K Core)
- c. CDC 6600 (131K Core)
- d. Univac 1106 MP (130K Core)

a. Local Facility at WANL

For the local facility considerations, the bulk of analysis involved the CDC configurations to compare local vs remote operations costs for the same work load since 85 percent of load is programmed for CDC. An option considered in the cost analysis is maintaining one data link to the Telecomputer Center for added system flexibility. For this cost study, the

TABLE 35

UNIVAC PRICE LIST--5-YEAR DECLINING LEASE

<u>Fiscal Year</u>				
1971	1.	Basic Univac 1106 MP with 6 ea. DCT 500; 6 ea. Uniscope 100; 8 disk drives (dual access); 8 tapes; 2 RJE terminals - on on 5-year lease (declining payment)		\$63,373
	2.	Graphics Display Package - 1 scope (5-yr. decl. lease)		<u>3,355</u>
				\$66,728
1972	1.	Computer as above		\$60,199
	2.	Graphics as above		3,189
	3.	4 add'l DCT 500 \$320 2 add'l Uniscope 100 250 2 CTM VI - LS 190 1 CTM - HS 125	\$885 (1-yr. lease)	885
	4.	8414 control 1,280 buffer exp. 50 4 disk drives 2,700	\$4,030	4,030
	5.	2 add'l graphics tubes		<u>3,540</u>
				\$71,843
1973	1.	Computer as above		57,026
	2.	Graphics as above		3,022
	3.	Additional graphics		3,540
	4.	Upgrade disk to dual access - 8 pack		7,810
	5.	Two sets of extra terminals @ \$885 ea.		<u>1,770</u>
				\$73,168
1974	1.	Computer		58,853
	2.	Graphics		2,856
	3.	Additional graphics		3,540
	4.	Disk		7,810
	5.	Three sets of terminals @ \$885 ea.		<u>2,655</u>
				\$70,714
1975	1.	Computer		\$50,680
	2.	Graphics		2,689
	3.	Additional graphics		3,540
	4.	Disk		7,810
	5.	Four sets of terminals @ \$885 ea.		<u>3,540</u>
				\$68,259

IBM 360 work load, which is 15 percent of the total, was assumed to be handled at TCC over the data link. This option could be used for a data link to either the TCC CDC or IBM systems, but once chosen could not be switched between the two systems.

The estimated work load for the CDC configurations, the IBM 360 and total are shown in Table 36.

A comparison of this work load compared to the computing capacity of the CDC machines are shown in Figure 19. The following hours available per month based on a five-day work week were used to compare the work load against.

<u>Number of Shifts</u>	<u>Operating Hours, Month</u>	<u>Maintenance Hours, Month</u>
1	147	26
2	294	52
3	420	99

From Table 37 it is concluded that three shift operations with the CDC 6400 will satisfy the load requirements for Contract Years 1970, 1971, 1979, and 1980. A CDC 6500 is capable on a two- and three-shift basis to satisfy the middle years and the CDC 6600 is more powerful than required.

b. SCERT Simulation Results

For purposes of SCERT simulation, the CDC 6500 configuration was selected to study the peak load years of 1974 and 1975. The CDC 6500 hardware configuration provided for SCERT simulation is listed in Table 38.

The results of the first SCERT simulation were adequate to conclude that the CDC 6500 configuration is capable of handling the work load. Specifically, the results are as follows:

ESTIMATED COMPUTING REQUIREMENTS TO PROCESS THE NERVA COMPUTER LOAD

CONTRACT YEAR	<u>UNITS IN HOURS/MONTH</u>				TOTAL COMPUTING HOURS CDC 6600 + IBM 360
	CDC 6400	CDC 6500	CDC 6600	IBM-360	
1970	423	202	141	25	166
1971	423	202	141	25	166
1972	558	266	186	33	219
1973	675	322	225	40	285
1974	759	362	253	45	298
1975	759	362	253	45	298
1976	726	346	242	43	285
1977	600	286	200	35	235
1978	465	222	155	27	182
1979	381	182	127	22	149
1980	228	108	76	13	89

NOTES: 1) THE NUMBERS IN THE CDC 6600 AND IBM 360 COLUMNS REPRESENT 85% AND 15% OF THE TOTAL COMPUTING HOURS RESPECTIVELY, WHICH IS BASED ON CY 1969 STATISTICS.

2) CDC 6600 HOURS WERE CONVERTED AS FOLLOWS:

CDC 6500 HRS. = 1.43 X CDC 6600 HRS.

CDC 6400 HRS. = 3.0 X CDC 6600 HRS.

TABLE 36

INFORMATION CATEGORY

Unclassified

W. H. G. L. G. L. G. L.

AUTHORIZED CLASSIFIER

6/12

DATE

REQUESTED BY:

APPROVED BY:

CHARGE NO.

NERVA COMPUTING LOAD VS CAPACITY LOCAL WANL CDC FACILITY

Figure 19

REQUESTED BY:

APPROVED BY:

CHARGE NO.

INFORMATION CATEGORY

Unclassified

6/12

DATE

AUTHORIZED CLASSIFIER

CDC OPTION IHardware Requirements:

- SAC - ANSC 6500 System
1700 System
PIOC System
Telemetry Interface
- EST-1 - Interactive Graphic Terminals
Alpha Numeric Terminals
- A and E Bldg. - Remote Batch Terminals
Alpha Numeric Terminals

Software Considerations:

- SAC - Use Standard CDC Telemetry Software Package
Scope 3.3, Intercom, Major rewrite would be Plot
Command for Graphics
- ETS-1 - Graphics OK - Application Packages to be Written
Alpha Numeric OK Under Intercom
- A and E Bldg. - Remote Batch OK {200 UT} Under Intercom
Alpha Numeric - OK Under Intercom

Communication Requirements:

- SAC -- ETS-1 - Micro Wave Link
4800 BPS Phone Lines for Interactive Graphics
2400 BPS Lines for Alpha Numeric Terminals
- SAC -- A and E Bldg. - 2400 BPS Lines for Alpha Numeric Terminals
2400 BPS Lines for Remote Batch Terminals
- EST-1 -- A and E Bldg. - No Requirement

Benefits:

1. Uses Standard Software
2. All operational personnel on computer located SAC
3. Remote Batch and Application Programming available at site
4. No site prep required at NRDS
5. Data Base in SAC available all identified users through
ANCS Terminals.

Limitations:

Cost of Telemetry and Telephone Communications

Estimated degradation of 6000 System in SAC would be 15%
during test

CONFIGURATION USED FOR SCERT AND LOCAL CDC FACILITY ESTIMATES

MODEL	NAME	INPUT TO SCERT NO. UNITS	5 YEAR LEASE COSTS*	
			\$/MO	
			CDC 6400	CDC 6500
CDC 6513/6413	CENTRAL FACILITY	1	48,805	53,265
CDC 6512	CONSOLE DISPLAY	1	980	
6638	DISK SYSTEM	1	8100	
6638-2	DISK	1	3975	
10037	DISK READ/WRITE	1	625	
6681	DATA CHANNEL CONVERTERS	3	810	
3228	TAPE CONTROLLERS	2	720	
607	TAPE UNITS	8	5800	
3447	CARD READER CONTROLLER	1	175	
405	CARD READER	1	335	
3446	CARD PUNCH CONTROLLER	1	390	
415	CARD PUNCH	1	235	
3256	LINE PRINTER CONTROLLER	2	840	
501	LINE PRINTERS	2	1140	
1 SHIFT MAINTENANCE			10,807	11,883
TOTAL LEASE COSTS/MONTH			83,737	89,273

* DATA PROVIDED BY CDC CORPORATION

INFORMATION CATEGORY

Unclassified

Edgely

AUTHORIZED CLASSIFIER

6/12

DATE

REQUESTED BY:

APPROVED BY:

CHARGE NO.

- (1) The multiprogramming-multiprocessing run time was 22 hr/day and required a 28 day month, i.e., 616 hr per month.
- (2) The serial run time with multiprocessing only was 28 hr/day, i.e., multiprocessing reduced the run time 6 hr/day.
- (3) The average degradation was 30 percent, i.e., on the average, a program took 30 percent longer to complete in the multiprogramming mode than if the program was run by itself.
- (4) The serial elapsed time was 848 hr/month.
- (5) The serial CPU time was 658 hr/month.

Statement 1 above is significantly different than the projected data presented in Table 37, being about 1.76 times greater. Several factors contribute to this. From the SCERT Multiprogramming Detailed Schedule Analysis Report, it is concluded that the 22 hr/day run time can be reduced by revising the system to include additional random access disc storage or change some files from disc to tape storage. This will improve the multiprocessing capability and also the multiprogramming capability on each processor. This modification is estimated to reduce the 22 hr/day to 18 hr/day, i.e., an 0.82 reduction ratio. Another factor is the higher run frequency simulated than planned as shown in Table 6. This results in a 1.36 increase in the CPU time over the 2000 hr/year peak load. These two factors applied to the 1.76 overstatement in the SCERT run time would reduce it to $(1.76 \times 0.82 \times \frac{1}{1.36})$, a 1.06 factor. Hence, it is concluded without requiring another SCERT simulation for this report that the CDC 6500 configuration is capable of handling the load.

c. UNIVAC 1106MP

The UNIVAC 1106MP was included in local consideration only since the May 6 oral presentation to SNPO because of a cost advantage consideration, since ANSC had presented data showing this particular machine is priced at approximately 70 percent of the comparable CDC 6500 machine.

No detailed technical evaluation was made for the UNIVAC since the cost analysis showed no cost advantage over Telecomputer Center in the early years. SCERT simulation for the WANL load was not considered necessary for the same reason. There are, however, some general technical comments about the 1106MP that seriously questions its effectiveness in handling the WANL work. These are:

(1) The EXEC Program limits all user programs to 65K core and many of the WANL programs exceed this limitation. Hence, overlay techniques and complicated reprogramming would be required. Run times would likely be increased due to this complication and hence be inefficient.

(2) The lower precision (36 bit words) of the UNIVAC compared to CDC would require double precision in many programs which have already large core requirements. This further reduces the size of the programs compatible with the 65K core.

Both of these limitations represent regressive trends in computers and would be technically unacceptable to WANL.

d. Overall Technical Comments

From an overall technical evaluation, the following general statements are applicable.

For the Telecomputer Center, the benefits to NERVA are:

(1) The capability of handling load variations to accommodate current needs and uncertain projections, with good flexibility and minimum advanced planning.

(2) The access to modern, updated equipment as it is developed and the Corporate-wise needs are accommodated by the incorporation of the CDC 7600 fourth-generation equipment into the Corporate operations.

(3) The access to both CDC and IBM systems that permit optimum matching between computer programs and machines.

For the local facility, the benefits to NERVA are:

(1) The handling of classified programs is less restrictive although the new ROVER Classification Guide will in itself minimize this benefit.

(2) The development of interactive graphics is more favorable.

(3) Link up between the hybrid and the general purpose computer may be possible to accomplish digital controls analysis.

e. Cost Comparisons

To obtain cost comparisons, the projected costs of doing the work at Telecomputer Center is the baseline. Costs of doing the work at a local facility are compared with this baseline.

Assumptions associated with the cost estimates are:

(1) Current cost data are used, which are adequate for purposes of comparison.

(2) Preparation of a local facility to accommodate the computer would require no less than \$100,000. This cost is relatively small, since a partial facility still exists from an earlier time when a local computer facility was utilized.

(3) No reprogramming costs are considered.

(4) No costs of parallel operation with the Telecomputer Center while a local facility is being established was considered.

The baseline costs for the work load projected in Table 36 are shown in Table 39. The "local terminal operating costs" include staff, equipment, and supplies. The "adder costs" at Telecomputer Center for the CDC and IBM systems are for manual operations and overhead associated with the computer runs. The other cost columns are self-evident.

The costs of computing with a local CDC facility are shown in Table 40.

The costs of computing with a local UNIVAC 1106MP facility are shown in Table 41.

Three cost comparisons are made in Tables 42, 43, 44.

Table 42 compares the TCC cost with the local CDC 6500 costs for the total load being handled by each facility.

Table 43 is a cost comparison assuming that the TCC IBM load is processed at TCC while maintaining the data link and the CDC load is processed on the local CDC facility.

Table 44 is the same as Table 39 except for the UNIVAC 1106MP as a local facility. In addition, cost comparisons are shown if all the load is processed on the local UNIVAC 1106MP.

TABLE 39

BASELINE COST ESTIMATE IN \$/MONTH
FACILITY - TELECOMPUTER CENTER

CONTRACT YEAR	CDC 6600 LOAD					IBM 360 LOAD			
	LOCAL TERMINAL OPERATING COSTS	PLOTTING COSTS	TCC ADDER COSTS	CDC 6600 MAIN FRAME COSTS	TOTAL CDC* COMPUTING COSTS	TCC IBM ADDER COSTS	TCC IBM MAIN FRAME COSTS	TOTAL IBM COMPUTING COSTS	TOTAL COMPUTING COSTS
1970	30,700	2,500	1,680	56,400	91,380	433	10,000	10,433	101,800
1971	30,700	2,500	1,680	56,400	91,380	433	10,000	10,433	101,800
1972	33,500	3,670	3,720	44,500	114,500	650	13,200	13,850	128,300
1973	36,000	6,250	4,400	90,000	136,650	920	16,000	16,920	153,600
1974	40,400	7,500	5,500	101,000	154,400	1,280	18,000	19,280	173,700
1975	40,400	7,500	5,500	101,000	154,400	1,280	18,000	19,280	173,700
1976	37,200	6,500	5,400	99,000	146,100	1,250	17,200	18,450	164,500
1977	33,500	5,330	4,125	80,000	122,950	930	14,000	14,930	137,900
1978	30,700	2,920	2,160	62,000	97,780	500	10,800	11,300	109,000
1979	29,100	1,250	860	51,000	82,210	366	8,800	9,166	91,400
1980	26,400	415	333	31,000	58,150	75	5,200	5,275	63,400

* LOCAL TERMINAL OPERATING COSTS AND PLOTTING COSTS INCLUDED IN THIS TOTAL.

TABLE 40

ESTIMATED COST OF COMPUTING AT LOCAL FACILITY WITH CDC EQUIPMENT
COSTS IN \$1000 PER MONTH

CONTRACT YEAR	COMPUTER TYPE	SHIFTS	COMPUTER LEASE COST	CURRENT* OPERATIONS	PLOTTING COST	ADDED SUPPLIES	ADDED STAFF	ADDED EQUIPMENT	TOTAL COST
1970	CDC 6400	3	83.8	30.7	5.0	0.0	12.9	1.25	133.
1971	CDC 6400	3	83.8	30.7	5.0	0.0	12.9	1.2	133.
1972	CDC 6500	2	89.3	30.7	6.0	0.5	11.0	1.25	138.
1973	CDC 6500	3	89.3	30.7	6.5	1.0	15.0	1.3	143.
1974	CDC 6500	3	89.3	30.7	7.5	2.0	17.1	1.4	148.
1975	CDC 6500	3	89.3	30.7	7.5	2.0	17.1	1.4	148.
1976	CDC 6500	3	89.3	30.7	6.5	1.0	15.0	1.3	143.
1977	CDC 6500	2	89.3	30.7	6.0	0.5	11.0	1.25	138.
1978	CDC 6500	2	89.3	30.7	5.0	0.0	10.0	1.2	136.
1979	CDC 6400	3	83.8	30.7	3.0	-0.5	11.9	0.0	128.
1980	CDC 6400	2	83.8	30.7	2.0	-1.0	8.0	-0.1	121.

* INCLUDES CURRENT STAFF, EQUIPMENT, AND SUPPLIES

TABLE 41

ESTIMATED COST OF COMPUTING AT LOCAL FACILITY WITH UNIVAC 1106MP EQUIPMENT

COSTS IN \$1000 PER MONTH

CONTRACT YEAR	COMPUTER ⁽¹⁾ LEASE COST	OTHER COSTS ⁽²⁾	TOTAL COSTS
1970	62.5	49.9	112.4
1971	"	49.9	112.4
1972	"	49.5	111.9
1973	"	54.5	117.0
1974	"	58.7	121.2
1975	"	58.7	121.2
1976	"	54.5	117.5
1977	"	49.5	112.0
1978	"	48.0	110.5
1979	"	45.1	107.6
1980	"	40.0	102.5

(1) BASED ON ANSC DATA FOR AVERAGE LEASE COSTS OF 70% OF CDC 6500 COSTS

(2) THESE COSTS ARE THE SAME AS SUM OF THE NON-COMPUTER LEASE COSTS ON
TABLE 40

INFORMATION CATEGORY	
<i>Unclassified</i>	
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TABLE 42

COST COMPARISON

LOCAL CDC FACILITY VERSUS TELECOMPUTER CENTER

COST IN \$1000 PER MONTH

CONTRACT YEAR	TELECOMPUTER CENTER ⁽¹⁾					LOCAL FACILITY ⁽¹⁾	
	(FROM TABLE 39)					(FROM TABLE 40)	
	CDC 6600		IBM 360		TOTAL COST	CDC 6500	
	HOURS	COST	HOURS	COST		TOTAL COST	COST ⁽²⁾
1970	141	91.4	25	10.4	101.8	133.1	+31.3
1971	141	91.4	75	10.4	101.8	133.1	+31.3
1972	186	114.5	33	13.9	128.4	138.7	+10.3
1973	225	136.7	40	16.9	153.6	143.8	- 9.8
1974	253	154.4	45	19.3	173.7	148.0	-25.7
1975	253	154.4	45	19.3	173.7	148.0	-25.7
1976	242	146.1	43	18.5	164.6	143.8	-20.8
1977	200	123.0	35	14.9	137.9	138.7	+ .8
1978	155	97.8	27	11.3	109.2	136.2	+27.0
1979	127	82.6	22	9.2	91.8	128.9	+37.1
1980	76	58.2	13	5.3	63.5	121.4	+57.9

(1) TOTAL LOAD PROCESSED AT EITHER FACILITY

(2) + MEANS LOCAL COSTS ARE HIGHER

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6/12

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REQUESTED BY:

APPROVED BY:

CHARGE NO.

TABLE 43

COST COMPARISON

LOCAL CDC FACILITY VERSUS TELECOMPUTER CENTER

COST IN \$1000 PER MONTH

CONTRACT YEAR	TELECOMPUTER ⁽¹⁾ CENTER	LOCAL FACILITY ⁽²⁾		TOTAL COSTS	COST ⁽³⁾
	(FROM TABLE 39)	(FROM TABLE 40)	(FROM TABLE 39)		
	TOTAL COST	CDC 6500 LOCAL COST	IBM 360 TCC COST		
1970	101.8	133.1	10.4	143.5	+41.7
1971	101.8	133.1	10.4	143.5	+41.7
1972	128.4	138.7	13.9	152.6	+24.2
1973	153.6	143.8	16.9	160.7	+ 6.1
1974	173.7	148.0	19.3	167.3	- 6.4
1975	173.7	148.0	19.3	167.3	- 6.4
1976	164.6	143.8	18.5	162.3	- 2.3
1977	137.9	138.7	14.9	153.6	+15.7
1978	109.2	136.2	11.3	147.5	+38.4
1979	91.8	128.9	9.2	138.1	+46.7
1980	63.5	121.4	5.3	126.7	+63.2

(1) TOTAL LOAD PROCESSED AT TCC

(2) TCC CDC LOAD PROCESSED AT LOCAL FACILITY AND IBM LOAD PROCESSED AT TCC
WHILE MAINTAINING DATA LINK

(3) + MEANS LOCAL COSTS ARE HIGHER

INFORMATION CATEGORY

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E. A. Gentry 6/12
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CHARGE NO. _____

COST COMPARISON

LOCAL UNIVAC FACILITY VERSUS TELECOMPUTER CENTER

CONTRACT YEAR	TELECOMPUTER ⁽¹⁾	COST IN \$1000 PER MONTH			Δ COSTS ⁽⁵⁾	
	CENTER	LOCAL FACILITY ⁽²⁾				
	(FROM TABLE 39)	(FROM TABLE 41)	(FROM TABLE 39)			
	TOTAL COST	UNIVAC 1106MP LOCAL COSTS	IBM 360 TCC COST	TOTAL COSTS	(3)	(4)
1970	101.8	112.4	10.4	122.8	+20.8	+10.4
1971	101.8	112.4	10.4	122.8	+20.8	+10.4
1972	128.4	111.9	13.9	125.8	- 2.6	-16.5
1973	153.6	117.0	16.9	133.9	-19.6	-36.6
1974	173.7	121.2	19.3	140.5	-33.2	-52.5
1975	173.7	121.2	19.3	140.5	-33.7	-52.5
1976	164.6	117.0	18.5	135.5	-29.1	-47.6
1977	137.9	112.0	14.9	126.9	-11.0	-25.9
1978	109.2	110.5	11.3	121.8	+12.6	+ 3.7
1979	91.8	107.6	9.2	116.8	+25.0	+15.8
1980	63.5	102.5	5.3	107.8	+44.3	+42.0

(1) TOTAL LOAD PROCESSED AT TCC

(2) TCC CDC LOAD PROCESSED AT LOCAL FACILITY AND IBM LOAD PROCESSED AT TCC WHILE MAINTAINING DATA LINK

(3) Δ COSTS IF NOTE (2) CONFIGURATION APPLIES(4) Δ COSTS IF THE IBM 360 LOAD AT TCC IS COMPUTED LOCALLY ON THE UNIVAC

(5) + MEANS LOCAL COSTS ARE HIGHER

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f. Conclusions

To obtain conclusions from the cost data, Table 45 is included, which shows the delta cost integral over selected time intervals for the four local facility options studied.

The delta cost integral for the years 1970 through 1972 are included as they are an index of the near term situation. It appears that no local configuration is competitive with the Telecomputer Center. The UNIVAC 1106MP handling the total NERVA work load is almost equivalent to TCC. Therefore, no immediate action is necessary from a NERVA cost effectiveness standpoint.

A similar analysis is presented for the five years, 1973 through 1977, since these are indicative of normal lease times and contain the peak years of the projected load where the cost advantage for a local facility would be most attractive. In this period, the local CDC 6500 shows no cost advantage if a data link is maintained with TCC to retain this flexibility while handling 15 percent (IBM 360) of the projected load. A 10 percent reduction over TCC costs is estimated if the total projected load is handled by a local CDC 6500 and no data link is maintained to TCC.

For the same period, a local UNIVAC 1106MP results in a 16 and 27 percent reduction over TCC costs for similar considerations. Major reprogramming costs would reduce this advantage. This and other technical concerns mentioned in the report must be resolved before this configuration can be given further consideration.

The cost data beyond the 1976-1977 point may be unrealistic since stage and flight-program support are not included.

TABLE 45

INTEGRAL COST COMPARISONS

FIGURES IN \$1000

INTEGRAL PERIOD CONFIGURATION	1970 THRU 1972			1973 THRU 1977		
	TCC COST	Δ \$	COST ⁽¹⁾ %	TCC COST	Δ \$	COST %
LOCAL CDC - TOTAL LOAD (TABLE 42)	3984	+ 875	+22	9642	- 974	-10
LOCAL CDC WITH IBM LOAD AT TCC (TABLE 43)	3984	+1291	+32	9642	- 80	- 1
LOCAL UNIVAC - TOTAL LOAD ⁽²⁾ (TABLE 44)	3984	+ 52	+ 1	9642	-2581	-27
LOCAL UNIVAC WITH IBM LOAD AT TCC (TABLE 44)	3984	+ 468	+12	9642	-1514	-16

(1) + MEANS LOCAL COSTS ARE HIGHER. ALL LOCAL COSTS DO NOT INCLUDE \$100,000 ESTIMATED AS MINIMUM FACILITY PREPARATION COSTS.

(2) DOES NOT INCLUDE REPROGRAMMING COSTS WHICH ARE CONSIDERED MAJOR.

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A CDC 6500 configuration can be configured to handle the projected peak years of 1974 and 1975.

The Telecomputer Center is capable of handling the present and projected computer work load.

g. Recommendations

It is recommended for the Pittsburgh site at WANL that:

1. NERVA continue to use the Telecomputer Center through CY 1972 as being the most cost effective.

2. NERVA reevaluate the computer facility cost effectiveness by the end of CY 1972, assuming that NERVA Program schedules and requirements are more firm.

3. NTO Facility

The requirements for the NTO facility are still not well defined. Therefore, a study was made of various manufacturer's equipment to determine the cost of doing different items up to the full extent of the proposed F-004 document (January 1970 issue).

A CDC 3200 computer was used during the XE tests to process test data and support the NRDS facility at Jackass Flats, Nevada. During this period of time, experience was gained with methods to reduce the processing and analysis time and provide improved and greater computer capability at minimum cost. As more capability is added, cost is likewise increased. Therefore, it is desirable to describe what the computer provides for the added cost, and the required NERVA computer capabilities can be determined.

The analysis is performed using CDC, IBM and XDS equipment and cost as a guide. Since the XE-P tests were originally run using a CDC 3200, this will be the initial starting point.

During the XE-P tests, the computer performed and successfully demonstrated the capability of processing data in real time. A total of 980 channels of raw data were received and 300 channels were converted into engineering unit data; the required computations were made, resulting in 128 computed channels, which were then transmitted back to the control room (Test Diagnostic Center) within a 0.4-sec period. The desired data was observed on meters. Also, 980 channels were collected as raw data to be processed as needed. The raw data were also collected on approximately 50 to 60 reels of data at the control room data center and these data were processed after the test was completed. The following processing functions were performed:

a. Raw data were converted to gapped form from gapless and reformatted in one pass. It was then converted into engineering units in a second pass and the necessary computations and the merging of the two subsystems were performed during a third pass of the data. This procedure required approximately 36 to 48 hours.

b. The data were listed at one sample per second for all channels. This operation required 24 hours. Additional time was required for special requests of 10, 50 and 100 samples per second listing.

c. From 24 to 48 hours were required to make 1500 to 2000 plots at Aerojet Sacramento, WANL Pittsburgh, and at NRDS. This included transportation time to ship tapes 300 miles to Sacramento and 2000 miles to Pittsburgh.

d. Wide-band tapes were duplicated and sent to Sacramento and Pittsburgh 24 hours after the test. Aerojet processed the data within

a 72-hour period and returned the final listings and plots to NRDS. Calibration data on wide-band tapes were evaluated at AGC by performing the calibration three days before each test at NRDS and shipping the tapes to AGC for processing and analysis.

At the conclusion of the XE-P tests the CDC 3200 computer cost approximately \$21,000 per month (excluding the support equipment such as IBM 1401). This cost included 16K of storage and eight tape-drive units.

Although the CDC 3200 could again be used with added capability at similar cost, there are definite disadvantages, such as core expansion limitation and no CRT or microfilm capability, limited cycle, and register time, which are desired for real time and post-test processing.

a. CDC Matrix

Table 46 was prepared to show the increase of computer capability by increasing its capability or going to a higher level computer. The cost of purchasing is presented. However, a factor of 0.02 to 0.025 would provide a monthly rental rate for a 5-year rental term.

(1) CDC 3200 - NERVA Application

A CDC 3200 could be obtained at a reduced rate, since refurbished models are available. Also, several of the recent improvements, such as the programmed I/O channels and large disc files and peripherals, could be used with the CDC 3200. However, there are also several disadvantages for its use. These are:

(a) 32K is the maximum core capacity; therefore, no upgrading will be possible.

<u>CDC</u>				
<u>What</u>	<u>Why</u>	<u>Added Equipment</u>	<u>Added Cost</u>	<u>Total Cost</u>
Two week turnaround in data processing.	To process data prior to next test.	CDC 3200 (XE)	\$700,000	\$700,000
Increased data storage for greater programming flexibility and computation capability	Increase computer capability in real time. Reduces processing by approximately 10-20%. Have all channels available for immediate post-test processing.	Add 16K core plus disk	236,000	936,000
Data compression and conversion to engineering units all channels in front end.	Increase capability to process all channels during test in real time. In post test analysis, reduces processing time in half (20 hours).	PIOC	170,000	1,106,000
<u>One Week Turnaround</u> Graphic Displays and improved computer cycle and register time	Provides graphic displays of data listings and data plots in pre and post test analysis and some real time capability as well as to provide for 30% more computations in real time. Reduce processing time by 30%.	Replace with CDC 3500 3 graphic display units and controller, hardcopy and micro-film reader.	326,480	1,432,480
145		Computer has 900 nanosecond cycle times (1250 for 3200) and ten times register speed for 2.5 increased computer capability.	Approx. \$300,000	1,732,480
<u>Two Day Turnaround</u> Real time graphics capability and Software System	Provide test director and test diagnostic center with real time and recall graphic display capability. Large costs can be saved by using experience generated from Grumman Aircraft	Basic CDC 6400-7 system 49K memory and 7 peripheral processing units. 13 control room graphics 4 TDC (plus 3 from data)	618,000 1,360,000	2,350,000 3,710,000
Recall of all data in real time	Assist TDC and Test Director for immediate recall of data and evaluation of all data in real time upon demand in evaluating performance.	Extended core storage 125K of 60 bit words	371,000	4,081,000
Graphic display units	Facilitate evaluation of performance on a real time and instantaneous basis. Provided immediate post test evaluation.	Graphic Display Unit at approximately \$80,000 per unit 8 off-site to AGC, Sacto & WANL 2 SNPO-C, SNPO-W	800,000	4,881,000
Systems Integration and Engineering	Requirement of System	None	100,000 est.	4,981,000
Special Software	Software that may be best performed by CDC - Can be performed by AGC, also.	None	500,000 est.	5,481,000

TABLE 46

ETS-1 TESTING UTILIZING CDC EQUIPMENT

(b) The 1250-nanosec cycle time has not been decreased as was done in other models. The faster time was one of the pacing items for real time analysis.

(c) Graphic display units cannot be used with the CDC 3200.

(2) CDC 3500 represents the following added capabilities:

(a) For faster computer speed, the central processing unit will have an increased speed of 900 nanosec, compared with 1250 nanosec for the CDC 3200. This faster speed means 30% decrease in computation, especially the computations that were a pacing item in the XE-P data processing schedule.

(b) The register speed is increased by a factor of ten to increase the computer capability by an overall factor of 2.5.

(c) The core is 32K, which can also be made available for the CDC 3200. However, the CDC 3500 has expansion capability to 128K, which is an important consideration when extra capability is required. During XE-P tests, the computer was core-limited, resulting in very little flexibility. With added core, greater efficiency can be obtained by providing improved flexibility in the software and by requiring fewer instructions.

(d) The core is doubled from previous 16K to 32K. This extra core provides a capability of combining the three passes as required in XE-P to be performed in one pass. This will reduce processing time substantially.

No disc file existed for XE-P. By use of the disc file, all data collected can be organized by time during the test.

This will provide capability of having all 2000 channels available during the test in the form of time, not channel, orientation. This will increase the real time capability substantially. The disc file will have all time-oriented data immediately available during and after the test so that post-test processing can be confined to conversion to channel orientation; therefore, only one pass need be considered.

The Programmed I/O Channel (PIOC) is a special hardware at the front end of the computer that performs several functions and provides a wide range of flexibility to the computer. The two functions that will be most directly used for NERVA are the compression tests and the engineering unit conversion. Compression tests will be made by performing limit tests on the data so that only 10% of the data will be accepted for data analysis. The remaining data will not have changed appreciably to be retained. This obviously represents a 90% saving in processing of data. A second feature of the PIOC is that it performs an engineering-unit conversion prior to inputting into the computer, thereby saving computer time for other functions. The PIOC and disc drives are also available with the CDC 3200 computer.

It is expected that the 36 to 48 hours processing time can be reduced to 12 hours; therefore, all the data can be available the next morning after a test.

(e) No graphic units were available for XE-P tests. The CDC provides capability for pre- and post- (no real-time) test data.

The large quantity of listings and plots described above were necessary because the engineers and analysts were unable to decide immediately after the test what was needed until they had an opportunity to review the data and by then it was too late to order specified plots. Therefore, large quantities of data that may not have been required

were processed to insure that the needed data were available. Cathode ray tubes (CRTs) are expected to be available so that listings and plots can be observed in large quantities quickly for quick-look and evaluation purposes. When plots are required, hard-copy prints will be made. This provision will save numerous listings and plots and provide an even larger amount of data to the engineers in less time period (less than 12 hours). For future analysis, microfilms will be provided that recorded the significant parameters for each time period. Approximately 1000 plots and listings will be provided by microfilm within five hours after the test. The extra cost of this capability is about \$8,300 per month.

During 36 hours of processing time, 24 hours of listing time, and 24 hours of plotting time could be saved in addition to having data available within 12 hours, thereby saving SPEAR team personnel time. By the use of graphics, data capability can be expanded three or four times. Also, wideband data, which were processed off-site during XE-P tests, can be performed during post-test analysis at NRDS. As seen in Table 46, approximately \$40,000 monthly would be required for computer hardware, which is twice the CDC 3200 XE-P cost.

Instead of expanding to the CDC 3500 it would be possible to go to a CDC 6200. This has the advantage of having software compatible for the next possible growth configuration.

(3) CDC 6400

The CDC 3500, is at the top of the 3000 series of CDC computers and the upgrading of this system would require additional computers of the same type or a complete change of hardware to the 6000 series. This change of hardware would have a serious impact on the operating system.

There are seven peripheral processors with a cycle time on a single processor of 140 nanosec. Thus, several functions can be performed simultaneously, such as two or three test stands, special calibrations or checkouts, or data evaluation and analysis.

The core contains 65K of 60-bit words. The 3000 series has 24-bit words. Since the computations were performed with 48-bit words, extra memory was necessary. Also, a high degree of flexibility and potential for efficient programming is possible.

Also provided is a 125K 60-bit word extended core. This core permits data to be stored during the test by means of time and channel file orientation, and permits all data to be retrieved in real time. This means that no post-test processing on these data would be necessary.

Software for the extra computer capability could be substantial for the NERVA Program. However, each computer manufacturer has accumulated experience in preparing software that could be made available to Aerojet at a modest cost. For example, Grumman Aircraft developed software for the CDC 6400 at a cost of \$2,500,000 on a system very similar to the one suggested for NRDS. This savings alone could justify considering a CDC 6400 computer for NRDS.

Without considering additional graphics, approximately \$65,000 per month would be required, or an increase of \$25,000 per month.

(4) CDC 6400 with added graphic display units:

Three graphic units were described for the CDC 3500. These units were considered as a minimum for pre- and post-test

data evaluation. With the added computer capability of the 6400 series, real time processing of all channels is possible. Therefore, a greater potential could also be made available for use of graphic displays. The following activities were considered for graphic displays:

- (a) 14 graphic displays - operating control room
- (b) (+ 3 from data) available for other activities
 - 6 at Test Diagnostic Center
 - 4 at Sacramento, ANSC
 - 4 at WANL, Pittsburgh
 - 2 at SNPO-C and SNPO-W

As shown in Table 46, the cost of these extras graphic display units would be approximately \$2,000,000, or \$45,000 per month. In addition, telephone costs for transmitting to the remote facilities must be considered.

The total cost, including modifying software, is estimated at approximately \$5.5 million, using CDC equipment. If the requirements are reduced in scope, the cost can be as low as \$700,000 for performing what was done during XE-P testing.

b. IBM and XDS Matrices

A similar chart was developed, based on IBM equipment, as shown in Table 47. It shows that a start would be made with an IBM 360/44 to perform the two-week turnaround and update to an IBM 360/65 to perform two-day turnarounds. Total cost of the same job would vary from \$547,000 to \$6.5 million dollars.

A similar matrix was developed for XDS equipment, as shown in Table 48, starting from a Sigma 5 for 2-week turnaround and expanding to a Sigma 7 for 2-day turnarounds. Costs range from \$500,000 to \$4 million dollars.

WHAT	WHY	ADDED EQUIPMENT	ADDED COST	TOTAL COST
TWO-WEEK TURNAROUND IN DATA PROCESSING	TO PROCESS DATA PRIOR TO NEXT TEST	IBM 360/44 1000 NANOSEC, 16K 32-BIT WORD	\$547,000	\$547,000
INCREASED DATA STORAGE FOR GREATER PROGRAMMING FLEXIBILITY AND COMPUTATION CAPABILITY	INCREASE COMPUTER CAPABILITY IN REAL TIME. REDUCES PROCESSING BY APPROXIMATELY 10-20%. HAVE ALL CHANNELS AVAILABLE FOR IMMEDIATE POST-TEST PROCESSING.	Add 16K CORE PLUS DISK (15 MILLION WORDS)	182,000	729,000
DATA COMPRESSION IN ALL CHANNELS IN FRONT END	INCREASE CAPABILITY TO PROCESS ALL CHANNELS DURING TEST IN REAL TIME. IN POST-TEST ANALYSIS, REDUCES PROCESSING TIME IN HALF (20 HOURS).	COMPRESSION ONLY - NO ENGINEERING UNITS IN FRONT END	120,000	849,000
<u>ONE WEEK TURNAROUND</u> GRAPHICS DISPLAYS AND IMPROVED COMPUTER CYCLE AND REGISTER TIME	PROVIDES GRAPHIC DISPLAYS OF DATA LISTINGS AND DATA PLOTS IN PRE- AND POST-TEST ANALYSIS AND SOME REAL TIME CAPABILITY AS WELL AS TO PROVIDE FOR 30% MORE COMPUTATIONS IN REAL TIME. REDUCE PROCESSING TIME BY 30%.	3 GRAPHIC DISPLAY UNITS, CONTROLLER, HARD COPY (NO MICROFILM READER) INCREASE CORE TO 100K AND ADD HIGH-SPEED REGISTER	499,000 393,000	1,348,000 1,741,000
<u>TWO DAY TURNAROUND</u> REAL-TIME GRAPHICS CAPABILITY AND SOFTWARE SYSTEM	PROVIDE TEST DIRECTOR AND TEST DIAGNOSTIC CENTER WITH REAL-TIME AND RECALL GRAPHIC DISPLAY CAPABILITY. LARGE COSTS CAN BE SAVED BY USING EXPERIENCE GENERATED FROM IBM OPERATIONS	REPLACE WITH IBM 360/65 64K CORE, 2 SELECTOR AND 1 MULTIPLEX CHANNELS EXTENDED CORE STORAGE 250K OF 32-BIT WORDS 13 CONTROL ROOM GRAPHIC DISPLAYS AND 4 IN TDC (PLUS 3 FROM DATA) \$125,000 PER UNIT	509,800 300,000 2,125,000	2,250,800 2,550,800 4,675,800
RECALL OF ALL DATA IN REAL TIME	ASSIST TDC AND TEST DIRECTOR FOR IMMEDIATE RECALL OF DATA AND EVALUATION OF ALL DATA IN REAL TIME UPON DEMAND IN EVALUATING PERFORMANCE.			
GRAPHIC DISPLAY UNITS	FACILITATE EVALUATION OF PERFORMANCE ON A REAL TIME AND INSTANTANEOUS BASIS. PROVIDE IMMEDIATE POST-TEST EVALUATION.	8 OFF-SITE GRAPHIC DISPLAY UNITS to ANSC, AND WANL. 2 OFF-SITE UNITS TO SNPO-C AND SNPO-W	1,250,000	5,925,800
SYSTEMS INTEGRATION AND ENGINEERING	REQUIREMENT OF SYSTEM	NONE	100,000 EST.	6,025,800
SPECIAL SOFTWARE	SOFTWARE THAT MAY BE BEST PERFORMED BY IBM- CAN BE PERFORMED BY ANSC ALSO.	NONE	500,000 EST.	6,525,800

TABLE 47

ETS-1 TESTING UTILIZING IBM EQUIPMENT

XDS

<u>What</u>	<u>Why</u>	<u>Added Equipment</u>	<u>Added Cost</u>	<u>Total Cost</u>
Two week turnaround in data processing.	To process data prior to next test.	Sigma 5	\$500,000	\$500,000
Increased data storage for greater programming flexibility and computation capability.	Increase computer capability in real time. Reduces processing by approximately 10-20%. Have all channels available for immediate post-test processing.	Add 16K core plus disk,	120,000	620,000
Data compression and conversion to engineering units all channels in front end.	Increase capability to process all channels during test in real time. In post test analysis, reduces processing time in half (20 hours).	Delta pre-processor.	20,000 est.	820,000
<u>One Week Turnaround</u> Graphic Displays and improved computer cycle and register time.	Provides graphic displays of data listings and data plots in pre and post test analysis and some real time capability as well as to provide for 30% more computations in real time. Reduce processing time by 30%.	Convert to Sigma 7 3 graphic display units, controller, and microfilm reader (graphic units \$50,000/unit).	250,000	1,070,000
<u>Two Day Turnaround</u> Real time graphics capability and Software System	Provide test director and test diagnostic center with real time and recall graphic display capability. Large costs can be saved by using experience generated from Douglas Aircraft DC-10.	Sigma 7 has 64K core, 4 peripheral processors and 650 nonoseconds cycle time. Convert to multiple Sigma 7's	175,000 424,000	1,245,000 1,669,000
Recall of all data in real time.	Assist TDC and Test Director for immediate recall of data and evaluation of all data in real time upon demand in evaluating performance.	Extended core storage - 6 million bit rad unit & 4 49 MB disks.	352,000	2,021,000
Graphic display units	Facilitate evaluation of performance on a real time and instantaneous basis. Provided immediate post test evaluation.	13 control room graphics 4 TDC (plus 3 from data) @\$50,000/unit	850,000	2,871,000
Systems Integration & Engineering	Requirement of System	10 off site graphic, AGC,	500,000	3,371,000
Special Software	Software that may be best performed by XDS - can be performed by AGC, also.	None	100,000 est	3,471,000
		None	500,000 est	3,971,000

TABLE 48

ETS-1 TESTING UTILIZING XDS EQUIPMENT

Besides investigating the various options available to perform the workload in the F-004 document, costing information was generated for the period of time between 1971 and 1975 for NTO. The schedule of NERVA Test Operations was based on Table 4. The requirements discussed in the beginning of Section IV.C (where for E-1, it would be required to demonstrate the techniques of turn-around between tests of two days to one week with a minimum computer configuration) were used to develop cost data. The assumption was made that initial engine testing in ETS-1 would start at the end of calendar year 1974.

To support the 1971, 1972 and 1973 activities in Test Cell C, as well as other site activities, such as the commercial work, the IBM 7094 was determined to be adequate. Since the equipment is government-owned, only maintenance and operation involve costs, no other system was found to be competitive in price. The IBM 7094 would not be adequate to perform testing in ETS-1 because of the larger data handling requirements and the requirement to support real-time graphics. Therefore, computers in the systems were reviewed that could perform the requirements of ETS-1 during the period of time starting with ETS-1 reactivation. Once a facility was defined for ETS-1, it seems likely that the same computer would support all test site ADP functions.

During 1973 it was assumed that both the IBM 7094 and the new computer facility would be maintained to provide a smooth transition of work from the IBM 7094 to the new computer system. The IBM 7094, as a second generation computer, has been found to require a major rewrite of all software programs to other equipment, based on experience in Sacramento and by other users.

Table 49 shows the details of equipment cost for NTO for the period 1971 through 1975. The results show less than a 4% spread in cost. A final selection would be based on a more detailed evaluation of software support, as well as cost refinements.

TABLE 49FACILITY COST FOR NTO

1971 - 1975

(Thousands of Dollars)

	<u>Equipment</u>	<u>Cost/Month</u>	<u>Monthly Cost of Operation</u>	<u>Monthly Total</u>	<u>Yearly Total</u>
<u>CDC</u>					
1971	IBM 7094	5	17	22	264
1972	IBM 7094	5	17	22	264
1973	IBM 7094 + CDC 6200	48	17	65	780
1974	CDC 6200	43	17	60	720
1975	CDC 6200	43	17	60	720
CDC FIVE YEAR TOTAL					\$2,748
<u>IBM</u>					
1971	IBM 7094	5	17	22	264
1972	IBM 7094	5	17	22	264
1973	IBM 7094 + IBM 360/44	47	17	64	768
1974	IBM 360/44	42	17	59	708
1975	IBM 360/44	42	17	59	708
IBM FIVE YEAR TOTAL					\$2,712
<u>Univac</u>					
1971	IBM 7094	5	17	22	264
1972	IBM 7094	5	17	22	264
1973	IBM 7094 + Univac 1106	45	17	62	744
1974	Univac 1106	40	17	57	684
1975	Univac 1106	40	17	57	684
UNIVAC FIVE YEAR TOTAL					\$2,640

B. COMPARISON OF CENTRAL FACILITY AND SEPARATE FACILITIES

A comparison was made between having a central facility and separate facilities located at Sacramento, Pittsburgh, and NERVA Test Operations. The factors to consider in the cost evaluation are the computer purchase price, the cost per month, communication cost, and operational costs. In addition, the ability to handle classified data over a communication network, together with associated costs, was investigated but was not included in the cost matrix.

Both the IBM 360/195 and the CDC 7600 were considered for the central facility. It was expected that either could perform the full workload within the computer capability. One system, the IBM 360/195, was selected as representative for simulation on SCERT, to see if there would be any unexpected conditions. The workload projected for Sacramento was 12,000 equivalent CPU hours to an IBM 360/65. The workload projected for Westinghouse was 4,000 hours of CDC 6600 time. The NTO workload was not simulated because of the limitations of handling real-time applications by SCERT. It was assumed that if an 8-hour shift were reserved for operation during an NTO test, the computer would be able to handle the SNP-1 workload. SCERT shows a serial elapsed time to perform the work on an IBM 360/195 of 1590 hours per month. Of this time, SCERT predicted that the processing time would be 92 hours per month and that in the multi-programming mode the degradation would be only 4%. The conclusion was that the computer would not be very heavily loaded. The SCERT analysis confirmed that a machine of the class of the IBM 360/195 could easily handle the entire NERVA workload. The next smaller system to consider was the IBM360/85. However, evaluation showed that this would not be adequate to perform the computing workload of Sacramento, Pittsburgh and NTO combined.

The analysis of the computers for each individual site was discussed in Section VII.A. This data will be used in determining the cost matrix for comparison of the central facility with the separate facilities.

Communication costs estimates were made for transmissions between Sacramento, Pittsburgh and NTO. Various classes of communication services are available. It is possible to obtain multiples of units of any class in order to provide various sizes of service. The communication requirements between the various sites would be on the order of 250,000 bits of data per second (bods). There is a class of service using microwave at that transmission rate. The next lower class of service is 40,800 bods, much too slow for this application, and the next largest class of service is a million bods. The transmission rates between the two major engineering sites, Sacramento and Pittsburgh, were estimated based on the quantity of input and output data. This shows that, on the average, the 250,000 bits of data per second would handle the workload, but peak requirements might require 500,000 bods. The NTO requirements to a central site facility were based on estimating the real-time operation requirements, the class of service again fell into the region between 250,000 and possibly 500,000 bods to be transmitted during a test.

Bell Telephone Company was contacted for transmission communication costs. The Bell Telephone Company can provide the service using 300 modals of Tel-Pak Class "C" service at \$30 per mile per month. In addition, terminal costs at each end run \$650 per month for a C-5 type terminal, plus a one-time charge of \$200 for installation of each terminal. The system is capable of simultaneous transmission in both directions at the 250,000-bods rate. In addition, the NERVA test site, because of its isolated location, requires the installation of special equipment that cannot be used elsewhere in the Bell Telephone System. As such, there is a construction cost of \$130,000 that is amortized over a 10-year period. Cost is amortized at the rate of 1/120 per month. At any given time of cancellation prior to the end of the ten-year period, there would be a charge to the Government for the remaining unamortized costs. The cost of amortizing the construction work is part of the \$30/mill/month rate. For information, the million bods rate costs \$85/mill/month. The communication cost is as follows:

Pittsburgh to NTO	1954 miles @ \$30 per mile per month =	\$58,620 per month
NTO to Sacramento	311 miles @ \$30 per mile per month =	9,330 per month
Sacramento to Pittsburgh	2172 miles @ \$30 per mile per month =	65,160 per month
Three terminals at \$650 per month	=	1,950 per month

A lead time of approximately 1 year is required by the Bell Telephone Company to provide the communication services. During this period of time, the Bell Telephone Company will perform the engineering required and the installation of the transmission links.

As can be seen in the figures above, the minimum computing communication costs between the central facility and each site would be to run from WANL to NTO to ANSC at a cost of \$69.9K per month.

A cost summary for comparing the central site and individual sites is shown in Table 50. The data was generated for each year from 1971 through 1975. Apparently it would take a minimum of 2 years to get a central facility in operation. Therefore, for the central site costs, the first 2 years would assume the continuation of the equipment currently in use at Sacramento, Westinghouse and NTO. Starting in 1973, the central site was assumed to be in operation. Costs were not included during the activation of the central site to cover the overlapping analyses at the central site and the individual sites. The central site costs used an IBM 360/195. The details of the equipment are included in Appendix B. The cost of such equipment would be \$10 million dollars if purchased outright. Terminals were included at two sites, consisting of IBM 360/30's. In order to minimize communication costs it was assumed that the central site would be at NTO, since this would be the central station between the various types of equipment. However, when classification problems are considered, it would probably be more desirable to locate the equipment at Sacramento in order to minimize the transmission of classified data.

TABLE 50

NOTE: These costs do not include costs associated with transmitting classified data.

COMPARISON OF COST BETWEEN CENTRAL FACILITY AND SEPARATE FACILITIES
(THOUSANDS OF DOLLARS/MONTH)

	Sacramento			Pittsburgh			NTO			Central Site*				Overall Total
	Equipment	Oper.	Total	Equipment	Oper.	Total	Equipment	Oper.	Total	Equipment	Oper.	Communications	Total	
<u>CENTRAL FACILITY</u>														
1971	75	35	110			102	5	17	22			70	287	234
1972	75	35	110			128	5	17	22					260
1973	17	15	32	17	15	32	22		22	177	40	70	287	373
1974	17	15	32	17	15	32	17		17	177	40	70 - 140	287	373 - 443
1975	17	15	32	17	15	32	17		17	177	40	70 - 140	287	373 - 443
* Assume located in NTO														
<u>SEPARATE FACILITIES</u>														
1971	67 - 75	35	102 - 110			102	5	17	22					226 - 234
1972	72 - 75	35	107 - 110			128	5	17	22					257 - 260
1973	73 - 135	35	108 - 170			161 - 154	45 - 48	17	62 - 65					331 - 389
1974	71 - 135	35	106 - 170			167 - 174	40 - 43	17	57 - 60					330 - 404
1975	68 - 135	35	103 - 170			167 - 174	40 - 43	17	57 - 60					327 - 404

The communication costs contained a large uncertainty. A single microwave system of a quarter-million bds would normally handle the communications between the central site and the satellite facilities. However, during periods of peak load operation, the system would tend to saturate, making it questionable whether this would be adequate. If two quarter-million bds microwave systems are required, it would add an additional \$70K per month to communication costs. An additional cost which has not been added, would be the requirement to transmit classified data. To do this, special operators and equipment must be obtained from the National Security Administration. The rooms at each end cost about \$40,000 each. The National Security Administration prefers to restrict the number of scrambler systems as much as possible. In the past, attempts have been made by WANL to obtain scrambler systems but these have been unsuccessful. These attempts were to connect the Waltz Mills operation to the central Telecomputing Center.

1. For comparison with the central facility, minimum and maximum cost data was considered for each of the separate sites.

For Sacramento, the minimum data was based on the Univac 1106 Multiprocessor as shown in Table 35, and the maximum data assumed a different manufacturer and the maximum workload requirements. In this case, the next competitive manufacturer was the Control Data Corporation (CDC) with the data being taken from Table 33.

For Pittsburgh, the Telecomputing Center was assumed for the first two years. From 1973 to 1975 the minimum costs are represented by establishing a facility at WANL Large and the maximum costs used the Telecomputing Center. These figures are from Table 43.

For NTO, 1971 and 1972 assumed maintaining the present equipment located at NTO. The figures for 1973 through 1975 are from Table 49, using the minimum and maximum of the three manufacturers.

In summary, the central facility equipment would cost \$373 to \$443K per month, including equipment and operational costs. Separate facilities during the peak years of 1974 and 1975 would be between \$330K and \$404K per month.

For a central facility to be feasible, considering the expense of establishing such a facility, the difficulties of integrating that facility into the Program, and the problems of handling classified data, there would need to be economic advantages. The data shows that under rare circumstances there may be some cost savings, but there is probably no real saving and the central facility may prove to be more costly than separate facilities.

The major communication cost of tying Pittsburgh into a network (\$59K to \$118K per month) makes the central facility economically unfeasible for further investigation.

C. EVALUATION OF INDEPENDENT SACRAMENTO AND PITTSBURGH CENTERS, SATELLITE AT NTO

An evaluation was made of various configurations that could perform the workload projected for both the Sacramento plant and NTO as a satellite of the Sacramento system, compared with having the NTO as a stand-alone operation. Sacramento was selected as the site of the main computer facility because the larger workload would be located at this site, especially for the period of time from 1971 through 1975; the advantage in not having to transmit classified data; and because the communication requirements are the same for either location. Other sources for the larger computer, such as the AEC facility in Las Vegas, were considered but none of these was competitive with Sacramento.

Control Data Corporation, Univac and IBM equipment were each evaluated separately to provide a consistent set of numbers within themselves

and to see if the conclusions would be different, whatever equipment is finally selected for Sacramento. The results of this comparison are discussed below.

1. Control Data Corporation (CDC)

Since the requirement is to demonstrate the capability during the E-1 tests at a minimum cost, as provided in the Requirements Section, systems that would not require developing new software in the future were investigated. Thus, CDC considered only 6000-series equipment and not any 3000-series equipment. The data CDC provided was based on the following:

- a. Three interactive graphic terminals.
- b. Six alphanumeric terminals.
- c. Provision for the compression and engineering-units conversion of test data.
- d. Disc storage for test data.
- e. The ability to calculate 100 channels in real time.
- f. Sort 300 channels by channel identification in a real-time file.
- g. Record remaining channels in a time-sequential file.
- h. Use of 500 computed channels and 1000 recorded channels.

The study considered alternate locations for the hardware and costs for the required hardware for each configuration were analyzed.

To arrive at costs, four different options were analyzed. Control Data Corporation reported that there would be no difference in configurations for interfacing with either a CDC 6500, 6600 or 6700 system located in Sacramento.

(1) Option I

This configuration would provide for all hardware to be located in Sacramento, except for appropriate terminals to be located at the test site. A remote batch terminal has been added to the services to provide 6000-series computing power for test site users. The features of Option I are presented in Table 37 and Figures 20 to 23.

Communication from the test site to ANSC would be by a microwave link. The link could be used in a duplex mode to return data to the test site. In this case, independent telephone line service from ANSC to the terminals was used to provide complete flexibility.

This system would use the standard CDC telemetry software with minor modifications to meet the requirements. Estimated total systems software and system integration with this approach would be approximately \$500,000.

The NRDS Data System hardware would be approximate \$500,000 (see Table 51, with a detailed equipment list in Appendix %). Additional hardware at ANSC would be approximately \$538,000. The total system value for ANSC and NRDS would be approximately five million dollars, with the monthly lease cost being approximately \$90,000. No effort has been made to minimize monthly lease rates for NRDS or additional ANSC hardware.

(2) Option II

This configuration provides for the NRDS Data Stream hardware to be located in the A&E Building. User services would be provided through terminal hardware, with independent communication links to provide flexibility. The communication link from NRDS to ANSC is a 40,800 bits of data per second (bods) line, and would provide only limited real-time

TABLE 51OPTION I

COSTS

	<u>Purchase</u>	<u>Mo. Lease</u>	
ANSC 6500	\$3,948.530	\$64,806	(5 yr EEIE)
<u>Hardware Required for NRDS</u>			
1-3553-2 Disk Cont.	39,220	770/mo.	1 yr Rate
1-821-1 Disk	148,400	2,750	" " "
1-6671 Data Set Cont.	44,520	1,100	" " "
3 ea 241 GRID	213,060	4,710	" " "
3 ea 248-1 4K ea.	20,670	495	" " "
6 ea. 214	37,500	840	" " "
1 ea. 217-14	8,500	250	" " "
1 ea. 222-14	20,500	390	" " "
1 ea 224-14	5,000	110	" " "
			200 U.T.
Sub Total	537,370	11,415/mo	
NRDS Data Stream Hardware	497,460	13,000	Estimate
Sub Total to Add NRDS	1,034,830	24,415	
TOTAL SYSTEM	<u>\$4,983,360</u>	<u>\$89,221/mo.</u>

CDC 6500 - 131K for
ANSC Requirements

FIGURE 22

FIGURE 23

capability (monitor approximately 150 channels). Details are given in Table 52 Figures 24 through 27.

A 500 card-per-minute reader, 80 card-per-minute punch, and a 300 line-per-minute printer have been added to the standard data stream hardware at NRDS. The 1700 system in Nevada can be used as a high-speed, remote-batch terminal, utilizing the full power of the CDC 6000 system at ANSC for routine work or program development. The 1700 system can also be used on a stand-alone basis.

This system would use the standard CDC telemetry software with minor modification to meet the requirements. Estimated total systems software and system integration would be approximately \$500,000.

The NRDS Data Stream hardware would be approximately \$580,000 (see Table 53 and Appendix B). The additional hardware at ANSC would be \$540,470. The total hardware cost to add NRDS to ANSC would be approximately \$1,200,000. The total system value would once again be approximately five million dollars and the monthly lease rate, on an unoptimized basis, would be approximately \$92,000.

The Data Stream hardware with this configuration would be capable of functioning independently of the ANSC system in a degraded mode with capability similar to the XE Program in the event of communication link failure or management decision.

(3) Option III

This configuration proposes the location of the Data Stream hardware to be located at the A&E Building with communication to be by microwave link to ANSC. Investigation indicated that special microwave interface equipment would be required at both the A&E Building and at ANSC to become operational. In addition, there would be requirements for

TABLE 52
OPTION II

Hardware Requirements:

SAC - ANSC 6500 System
40,000 Baud Communication Interface
NRDS Supplemental Hardware

EST-1 - Interactive Graphics
Alpha Numeric Terminals
Existing Telemetry Link to A&E

A and E Bldg. - 1700 System
PIOC System
Remote Batch
Alpha Numeric Terminals
40,000 Baud Communication Interface

Software Considerations:

Use standard Scope software with Data Acquisition Software 75% in existence.

Plot routines and critical Parameter Acquisition software would be needed.

Communication Requirements:

SAC -- A and E Bldg. - 40,000 Baud Telepak A Type Telephone Line
Dial Up or Dedicated 2400 BPS Lines for
Alpha Numeric Terminals

A and E Bldg. -- ETS-1 - Existing Telemetry Link

SAC -- ETS-1 - 4800 BPS Lines for Interactive Graphic Terminals
2400 BPS Lines for Alpha Numeric Terminals

Benefits:

Lower Cost for Communication

1700 System at Test Site can provide off line

- A. High Speed Batch Terminal
- B. Stand Alone System
- C. Calibration and Simulation

TABLE 52 (cont.)

D. 1700 PI0C Stand Alone by Management decision or
Failure Communication Link

1. No Data Lost -
Continuous Recording or Tape 100%
2. Calibration
3. Simulation Meter Reading
4. Post Test Data Analysis
5. Selected On Line Analysis
6. Batch Processing

Note: Stand Along operation very much like XE 3200
operation. However, because of added power
of PI0C, 1700 PI0C System could be configured
to accomplish greater control, data acquisition
and display.

Independent display of Data on Pen Recorders
Oscillographs and Discrete Alpha Numeric Displays

Limitations:

Possible to handle 100 to 200 most critical channels on Real
Time mode due to communication capability A and E Bldg. to SAC.
Balance of Data handled as time available and post test.

•Immediate• access to data delayed until completely xmitted.

OPTION II

FIGURE 24

OPTION II

FIGURE 27

TABLE 53

OPTION II

COSTS

	<u>Purchase</u>	<u>Mo. Lease</u>
ANSC 6500	\$3,948,530	\$64,806 (5 yr EEIE Lease)
<u>Hardware Required for NRDS</u>		
1-6673 Data Set Cont.	37,100	815 1 yr Lease
1-3553-2 Disk Cont.	39,220	770 " "
1-821-1 Disk	148,400	2,750 " "
1-6671	44,520	1,100 " "
3 ea 241	213,060	4,710 " "
3 ea. 248-1	20,670	495 " "
6 ea 214	37,500	840 " "
Sub Total	540,470	11,480
NRDS Data Stream Including High Speed Batch Hardware	578,250	15,000 Estimate
Sub Total to Add NRDS	1,118,720	26,480
TOTAL SYSTEM	<u>\$5,067,250</u>	<u>91,286</u>

substantial modification to the standard telemetry software package to insert a microwave link between the 1700 PIOC system and the 6000 system. (See Table 54 and Figure 28.)

Further analysis of Option III was stopped when identified costs exceeded the costs of Option IV.

(4) Option IV

Option IV established a completely independent CDC 6200 system at NRDS to provide the required services. (See Figures 29 and 30 for details.)

This system would utilize the standard CDC telemetry software package. The major system software to be developed would be the Plot Command Package to provide for complete flexibility in the selection of interactive graphic terminal locations.

The cost of the CDC 6200 system (Table 55 and Appendix B) would be approximately \$2,322,000, with an unoptimized lease rate of \$51.5K per month on a five-year plan.

Using the above data, a matrix was developed for separate facilities compared to a satellite facility at NTO. A CDC 6500 was assumed to be selected for Sacramento to meet the minimum workload requirements. For NTO, IBM 7094 equipment was selected for 1971 and 1972 to meet the Test Cell C and other site requirements, with a transition to the CDC 6200 in 1973 and continuing with the CDC 6200 until 1975. During the year 1973 it was assumed that both the IBM 7094 and the CDC 6200 would be in use at NTO in order to provide a smooth transition of equipment. Beyond 1975, NTO could expand to the CDC 6400 without a software change. The second system considered in the matrix is a CDC 6500 to handle the work in

TABLE 54

OPTION III -

Hardware Requirements:

- SAC - ANSC 6000 System
Telemetry Interface
NRDS Supplemental Hardware
- ETS-1 - Interactive Graphics
Alpha Numeric Terminal
Existing Telemetry Link
- A and E Bldg. - 1700 System
PIOC System
Remote Batch
Alpha Numeric Terminals
Telemetry Interface

Software Considerations:

- SAC - Scope 3.3 - High Speed Export - 8070 90% CDC Telemetry Package OK - Major rewrite would be Plot Command Program for Graphics. Telemetry package would require revision to handle reformatting for transmission and receipt 1700 to 6000.
- ETS-1 - Graphics OK - Application Package would have to be written
Alpha Numeric - OK under Intercom?
- A and E Bldg. - MSOS 2.1 - Import High Speed - CDC Telemetry Package is OK.

Communication Requirements:

- SAC -- A and E Bldg. - Telemetry Link
Dial Up or Dedicated 2400 BPS Lines for Alpha Numeric Terminals
- A and E Bldg. - ETS-1 - Existing Telemetry Link
- SAC -- ETS-1 - 4800 BPS Telephone Lines for Intergraphic Terminals
2400 BPS Telephone Lines for Alpha Numeric Terminals

Benefits:

1. Accomodate All Channels in Real Time Mode
2. High Speed Remote Batch at Site
3. Full 6000 System Capability Available at Test Site
4. Stand Alone Capability at Site for Channel Engineering simulation, etc.
5. No Computer Operational Personnel in Block House

TABLE 54 (cont.)

Benefits {cont.}::

6. Expand by Adding 6200 Main Frame at Site
No Software Changes Required
7. Data Base in SAC - Accessable to all properly identified
users through ANSC remote terminals.

Limitations:

Cost of Telemetry Link SAC to A and E Bldg.

Estimated Degradation of 6000 System in SAC would be 15%.

Cost of Telemetry interface hardware between 1700 and 6000.

Cost of Software Rewrite on Telemetry package.

OPTION III

FIGURE 29

CDC 6215-7
+ 10177-1

OPTION IV

FIGURE 30

TABLE 55

OPTION IV

COST

	<u>Purchase</u>	<u>Mo. Lease</u>
ANSC 6500	\$3,948,530	\$64,806 (5 yr EEIE)
NRDS 6200 System	2,321,810	51,467*(5 yr std. lease)
TOTAL	<u>\$6,270,840</u>	<u>\$116,273</u>

* Note: 6200 lease rate can be reduced by using
5 year EEIE lease plan.

Sacramento, with this equipment being sufficient to handle the major work in ETS-1 and eventually Test Cell C. In this configuration, the IBM 7094 is maintained at NTO through 1973, and at that time there would be no large central computer at NTO but satellite equipment tied directly into the Sacramento computer. The third system in the matrix assumes a larger computer would be required in Sacramento by 1974 to absorb the higher workload requirements of NTO.

The results (shown in Table 56 indicate that 1971 and 1972 would be unaffected, no matter which option is selected, because it was assumed that a computer activation in support of ETS-1 would be required at 2 years before the test, with the test occurring at the end of calendar year 1974. It was assumed that the peak load would hit in the 1974-75 period, at which time the CDC 6200 at NTO would increase the cost, in combination with Sacramento, to \$190K per month. Also, the assumption was made that the current operator crew would be sufficient to handle the CDC facility. Since the CDC 6500 in Sacramento is able to handle the Sacramento workload, as well as the testing operation at NTO, a savings of \$30K per month is projected. If the computer in Sacramento must be expanded to handle the larger workload, then the cost would be increased by \$10K per month in this time period. Thus, more economical use depends on determining whether the Sacramento workload will meet or exceed the minimum requirements, especially with NTO requirements added to the Sacramento requirements. To complicate the communication problem, the 250,000 bits-of-data-per-second system was used throughout the study. An investigation was made of a 40,800-bods system. However, the smaller system was found to be usable during the first few years of operation. There is a fixed cost of \$90,000 to \$100,000 for the smaller data system and \$130,000 for the microwave system. When starting with the smaller system and updating to the larger system, these costs do not cancel each other but are additive. Therefore, the Program would be faced with paying off the costs of both systems. The savings in using the smaller system for a short period are canceled by the fixed-cost obligation.

SEPARATE FACILITIES AT SACRAMENTO AND NTO
 COMPARED TO COMBINED FACILITIES
 BASED ON CDC EQUIPMENT

(THOUSANDS OF DOLLARS/MONTH)

Contract Year	Sacramento			Communi- cations	NTO			Total
	Computer	Equip. Cost	Oper. Cost		Computer	Equip. Cost*	Oper. Cost	
SEPARATE FACILITIES								
1971	CDC 6500	75	35	0	IBM 7094	5	17	\$132K/mo.
1972	CDC 6500	75	35	0	IBM 7094	5	17	132
1973	CDC 6500	95	35	0	IBM 7094/CDC 6200	48	17	195
1974	CDC 6500	95	35	0	CDC 6200	43	17	190
1975	CDC 6500	95	35	0	CDC 6200	43	17	190
FIVE-YEAR TOTAL								\$10,068
COMBINED FACILITIES								
1971	CDC 6500	75	35	0	IBM 7094	5	17	132
1972	CDC 6500	75	35	0	IBM 7094	5	17	132
1973	CDC 6500	95	35	11	IBM 7094/Data Str.	18	17	176
1974	CDC 6500	95	35	11	Data Stream	13	6	160
1975	CDC 6500	95	35	11	Data Stream	13	6	160
FIVE-YEAR TOTAL								\$9,120
COMBINED FACILITIES, LARGER SACRAMENTO								
1971	CDC 6500	75	35	0	IBM 7094	5	17	132
1972	CDC 6500	75	35	0	IBM 7094	5	17	132
1973	CDC 6500	95	35	11	IBM 7094/Data Str.	18	17	176
1974	CDC 6500	135	35	11	Data Stream	13	6	200
1975	CDC 6500	135	35	11	Data Stream	13	6	200
FIVE-YEAR TOTAL								\$10,080

*Includes graphics and front-end costs

Since there is a 10-year obligation to the Program, the communication costs tend to cancel out the flexibility of preparation, starting with a tie-in between Sacramento and NTO and then adding a separate computer later at NTO. A network type of computer system should still be considered, with a facility at both places in the future and the tie link used to off-load work during heavy periods of utilization.

The total cost for separate facilities for the period from 1971 through 1975 is \$10 million dollars. Combined facilities would cost \$9.1 to \$10.1 million dollars for the same period of time. The biggest question in making a selection is determining whether the Sacramento facility could handle the extra workload from NTO without expanding to a larger computer. The uncertainty in this area increases with time projections.

2. Univac

A similar study was performed with Univac equipment. Front-end and alphanumeric costs were not discussed and were assumed to be the same order of magnitude as those for CDC. In the case where the separate facility would be provided for NTO, both the Univac 418-III and the Univac 1106 were considered. The Univac 418-III was rejected for several reasons. It would not be compatible with the expanded requirements at NTO that will be expected when turn-arounds of 2 days to 1 week would be required. To handle the NTO workload would require a Univac 418-III of maximum possible configuration and replacing it with another machine would require a complete software rewrite. The word size in the Univac 418-III is 16 bits and this was judged to be too small to meet the requirements. Even in maximum configuration, the Univac 418-III would not be able to provide full real-time capability at NTO. The Univac 418-III, in a more minimum configuration, would be Univac's candidate for the front-end processor and stand-alone terminal hooked to a Univac 1106 or 1108 system. The Univac 1106 was costed for the NTO configuration, shown in Appendix B.

The ground rules used in costing were basically the same as with CDC equipment (see Table 57). The cost figures show that separate facilities would run \$9.6 million during the 5-year period. Inter-related facilities would run between \$8.3 and 9.2 million during the 5-year period.

If Sacramento can handle both the workload at Sacramento and the NTO workload, there is a cost savings to the Program for combining the facilities during the peak years. If not, from 1974 on, the computing costs would be the same with separate facility and expanded Sacramento facility. This would be expected since the expansion costs in Sacramento is the cost of adding an additional Univac 1106, which could just as conveniently be placed at NTO.

A comparison of communication costs and operational costs with equipment at Sacramento or at NTO indicates no advantage for either place.

3. IBM

Similar cost figures were developed for IBM, using basically the same ground rules as with the CDC equipment. These are shown in Table 58. The basic computer for NTO in a separate facility would be the IBM 360/44. The separate facilities over the 5-year period would cost \$9.9 million. Combined facilities would cost between \$9.0 and \$10.6 million.

IBM believes that the IBM 360/44 or the ANSC facility would handle the engineering-unit conversion function and would require the front-end equipment to do compaction and formatting only.

D. CONCLUSIONS

Apparently it may be possible to reduce computing costs by making NTO a satellite of the Sacramento computing facility. The communication

COMPARISON OF SEPARATE AND COMBINED SACRAMENTO AND NTO FACILITIES

BASED ON UNIVAC EQUIPMENT
(THOUSANDS OF DOLLARS/MONTH)

Contract Year	Sacramento		Communi- cations	NTO			Graphics & Data Stream	Total
	1106 MP	Oper.		Computer	Cost	Oper.		
SEPARATE FACILITIES								
1971	67	35	0	IBM 7094	5	17	0	124
1972	72	35	0	IBM 7094	5	17	0	129
1973	73	35	0	IBM 7094/ Uni.1106	45	17	17	187 (NOTE 1)
1974	71	35	0	Uni.1106	40	17	17	180
1975	68	35	0	Uni.1106	40	17	17	177
FIVE-YEAR TOTAL								\$9,564

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NO UPDATE OF SACRAMENTO 1106 MP

1971	67	35	0	IBM 7094	5	17	--	124
1972	72	35	0	IBM 7094	5	17	--	129
1973	73	35	11	IBM 7094	5	17	17	158
1974	71	35	11	----		6	17	140
1975	68	35	11	----		6	17	137
FIVE-YEAR TOTAL								\$8,256

INCREASED SACRAMENTO FACILITY, 1106 MP + 1106

1971	67	35	0	IBM 7094	5	17	--	124
1972	72	35	0	IBM 7094	5	17	--	129
1973	73	35	11	IBM 7094	5	17	17	158 (NOTE 2)
1974	111	35	11	----		6	17	180
1975	108	35	11	----		6	17	177
FIVE-YEAR TOTAL								\$9,216

- NOTES: (1) Allow one-year overlap of equipments at NTO
(2) Add capacity to Sacramento for impact

TABLE 57

COMPARISON OF SEPARATE AND COMBINED SACRAMENTO AND NTO FACILITIES

BASED ON IBM EQUIPMENT

(THOUSANDS OF DOLLARS/MONTH)

Contract Year	Sacramento Facility			Communi- cations	NTO			Graphics & * Data Stream	Total
	Computer	Cost	Oper.		Central Computer	Cost	Oper.		
SEPARATE FACILITIES									
1971	IBM 360/65	75	35	0	IBM 7094	5	17	0	132
1972	IBM 360/65	75	35	0	IBM 7094	5	17	0	132
1973	IBM 360/75	89	35	0	IBM 7094/ IBM 360/44	30	17	17	188
1974	IBM 360/75	89	35	0	IBM 360/44	25	17	17	183
1975	IBM 360/75	89	35	0	IBM 360/44	25	17	17	183
FIVE-YEAR TOTAL									\$9,816
NO UPDATE OF SACRAMENTO									
1971	IBM 360/65	75	35	0	IBM 7094	5	17	0	132
1972	IBM 360/65	75	35	0	IBM 7094	5	17	0	132
1973	IBM 360/75	89	35	11	IBM 7094	5	17	17	174
1974	IBM 360/75	89	35	11	----		6	17	158
1975	IBM 360/75	89	35	11	----		6	17	158
FIVE-YEAR TOTAL									\$9,048
UPDATE SACRAMENTO									
1971	IBM 360/65	75	35	0	IBM 7094	5	17	0	132
1972	IBM 360/65	75	35	0	IBM 7094	5	17	0	132
1973	IBM 360/75	89	35	11	IBM 7094	5	17	17	174
1974	IBM 360/85	155	35	11	----		6	17	224
1975	IBM 360/85	155	35	11	----		6	17	224
FIVE-YEAR TOTAL									\$10,632

* Estimated costs

costs between sites tend to be canceled by the operational costs. Therefore, the final results depend on whether the Sacramento facility can handle the workload at NTO without requiring a bigger computer.

Another factor that needs to be considered besides cost is the ability to operate with a remote computer. ETS-1 has already operated with a computer that is 5 miles from the test stand through a microwave system during XE testing. Several manufacturers have set up networks, such as the CDC Cybernet, for providing remote computer capability. From an operational point of view, the remote computer systems have been demonstrated to work satisfactorily. The difference in reliability of the system is mainly in the communications. There should be high reliability in a dedicated system, such as this.

A better evaluation of this situation will be possible in 1971. This would be sufficient time to make and implement the decision within the 1 year requirement on adding the communication ties and also would provide a firmer basis for both the productivity of the Sacramento facility and the actual workload growth being experienced.

E. CONCLUSIONS FROM SITE EVALUATION

A summary chart was developed, comparing the central facility, separate facilities, and Pittsburgh and Sacramento as separate facilities with NTO as a satellite. This used the data in the previous Sections. The chart is shown as Table 59. Reviewing the results shown on the chart, the cost-advantageous systems are either separate facilities, or Pittsburgh as a separate facility with Sacramento having NTO as a satellite facility.

The decision to make NTO a satellite facility from Sacramento depends on whether the central computer in Sacramento can handle the workload projected for Sacramento without being increased in size to handle the

NOTE: These costs do not include costs associated with transmitting classified data.

COMPARISON OF COST BETWEEN FACILITY OPTIONS
(THOUSANDS OF DOLLARS/MONTH)

	Sacramento			Pittsburgh			NTO			Central Site*				Overall Total
	Equipment	Oper.	Total	Equipment	Oper.	Total	Equipment	Oper.	Total	Equipment	Oper.	Communications	Total	
<u>CENTRAL FACILITY</u>														
1971	75	35	110			102	5	17	22			70	287	234
1972	75	35	110			128	5	17	22					260
1973	17	15	32	17	15	32	22		22	177	40	70	287	373
1974	17	15	32	17	15	32	17		17	177	40	70 - 140	287	373 - 443
1975	17	15	32	17	15	32	17		17	177	40	70 - 140	287	373 - 443
* Assume located in NTO														
<u>SEPARATE FACILITIES</u>														
1971	67 - 75	35	102 - 110			102	5	17	22					226 - 234
1972	72 - 75	35	107 - 110			128	5	17	22					257 - 260
1973	73 - 135	35	108 - 170			161 - 154	45 - 48	17	62 - 65					331 - 389
1974	71 - 135	35	106 - 170			167 - 174	40 - 43	17	57 - 60					330 - 404
1975	68 - 135	35	103 - 170			167 - 174	40 - 43	17	57 - 60					327 - 404
<u>PITTSBURGH AND SACRAMENTO FACILITIES WITH NTO SATELLITE</u>														
1971	67 - 75	35	102 - 110			102	5	17	22			0		226 - 234
1972	72 - 75	35	107 - 110			128	5	17	22			0		257 - 260
1973	73 - 95	35	108 - 130			161 - 154	22	17	41			11		321 - 336
1974	71 - 135	35	106 - 170			167 - 174	17	6	23			11		307 - 378
1975	68 - 135	35	103 - 170			167 - 174	17	6	23			11		304 - 378

additional workload from NTO. This final decision can be made in the summer of 1971 after the Sacramento facility computer selection has been finalized and there is some operational experience on the new system.

APPENDIX A

XE-PRIME COMPUTER
APPLICATION

The processing requirements to support XE-Prime consisted of direct support of test operations during a test represented by the Test Diagnostic Center; data reduction and analysis support; and continuing automatic data processing support represented by channel engineering. These activities are briefly described below.

I. TEST DIAGNOSTIC CENTER AND DATA LINK

To support test activities, a real-time data acquisition, processing and display system is provided that permits the insertion of the CDC 3200 computer into the digital data system by means of a two-way microwave data link between the test stand and the A&E Building, which houses the test site computing center.

The data link-computer system permits the on-line display of computed and measured parameters in engineering units in the Test Diagnostic Center (TDC). Center personnel evaluate component and system performance and relay conclusions and recommendations to the Test Director and operators during testing. The microwave data-link system accomplishes an additional purpose in that it permits establishment of a visitor's test information display center in the A&E Building.

Figure A1 is a block diagram of the microwave system. The two sub-systems of the Digital Data System (DDS) are formatted by System Engineering Laboratory equipment at the test stand, where 10 data channels can be selected, converted to analog signals, and, by appropriate patching, delivered to the TDC, the Control Room, or strip-chart recorders. This function is entirely independent of the microwave data-link system. In addition, all 980 channels of data in BCD format are converted to a serial sequence by additional interface equipment and then delivered to the microwave transmitter for transmission to the A&E Building. The microwave transmission also includes two video and one audio channel.

Figure A-1 - Data Link System Block Diagram

The output of the receivers at the A&E Building is channeled to additional System Engineering Laboratory equipment, from which 10 data channels can be selected, converted to analog signals, and displayed directly on meters in the visitor's display panels. All data are sent in parallel to the computer for duplicate recording and real time processing. The output of the computer is transmitted to a serial coder, which converts the processed data to a serial form for retransmission to the test stand by a return microwave link. At the stand, 32 channels of the returned data are converted to analog form and displayed on appropriate meters and plotters. Similarly, 12 channels of data from the serial coder are converted to analog form and made available for display in the A&E Multipurpose Room.

The computer programs required to support the TDC data-link system consist of executive, applications, and support types.

The executive program (called MIRACLE) provides for: (1) the receipt of raw data (2000 words per frame, 10 frames per second) by the computer; (2) recording of raw data on magnetic tape; (3) conversion of raw data to engineering units; (4) calling of many selected calculation routines (e.g., mass flow rate and the linearized average temperature or reactivity of the reactor); (5) scheduling of the performance of these calculations; (6) distributing the processed data to appropriate channels for retransmission through the microwave link to the stand and to magnetic tape recorders; (7) processing of instrumentation to change the input data and the location or range of display of the output; (8) comparing of raw or computed data with other preset or calculated values; and (9) the setting of alarms if the comparison criteria are not met. Fifty alarm-light possibilities exist.

Each frame of data is first read into a 2000-word buffer and every other frame is transmitted to the recorder. A preselected portion of these data (i.e., to 300 words) is also read into a small buffer from which the data are accessible by any of the computation routines or for conversion to engineering units. Only data in the small buffer can be converted to

engineering units. A second portion of the executive routine (called "data base") permits the introduction of corrected calibration data, the selection of appropriate computational subroutines and their associated input data channels, the selection of desired channels to be output for display, and the setting of masks which determine the repetition rate for the individual calculations. The data-base portion of the executive program is prepared individually to support each test run.

The application programs are a library of subroutines, each of which calculates a specific parameter (e.g., the average of several temperatures or pressures, a flow rate, or reactor reactivity). A separate application subroutine determines density from temperature and pressure and makes it available to any "calling" subprogram.

Several support routines permit "debugging" of the other routines and periodic confirmation of their proper performance.

The combination of digital and analog equipment with the CDC 3200 and associated software packages permits: (1) the computation of approximately 50 separate parameters and the transmission of any 32 at any one time; (2) provision of 960 digital data channels delivered by the microwave data link system in the A&E Building; (3) change of any input parameter to any other while the computer is on-line and operating; (4) change of any output parameter to any other while the system is on-line and operating; (5) identification, display, and storage of singular data (e.g., parameters outside prescribed tolerances) and retrieval of such data on command; (6) duplicate recording of 960 input channels at the A&E Building; (7) recording of all output channels or channels available for output on a separate tape at the A&E Building; and (8) accommodation separately of the drift and nonlinearity of each channel of the DDS.

Engineering unit calculations are contained in approximately 10 FORTRAN subroutines which are scheduled by MIRACLE. There is room for 128 computed

values. Approximately 500 words of converted engineering units and calculated channels are prepared on a tape. This tape is immediately available after the test to be used in a plot program that is prepared for each test. Time segments for plots are selected and the range, channels, and identification of each multiplot is specified. A plot tape is prepared and plots are prepared from Cal Comp plotters located in the Test Cell C Control Building.

II. DATA REDUCTION AND ANALYSIS

A. SEQUENCE OF DATA PROCESSING

Immediately after each test the following sequence of events was completed:

1. Data from the data link (a microwave data link between the computer located in the A&E Building and the control room in ETS-1 with data processed in real time) were processed onto a plotting tape and data link plots were prepared to be available to the SPEAR team for quick-look examination and for selection of time slices for multiple plots. These plots were also available for identifying major events during the test run. The processing of the data link plotting tape took approximately 1 hr and the plotting consumed an additional 3 to 4 hr for approximately 40 to 50 plots. These plots were processed immediately after the test and were available the same evening of each test.

2. The wide-band tapes were duplicated immediately after a test and a set of wide-band tapes was sent to WANL and to AGC for processing. Approximately 8 to 16 hr were required, depending on the number of analog tapes that were generated. AGC-Sacramento evaluated all of the specified wide-band data channels and returned the analyzed data to the SPEAR team within a 72-hr period. A list of the requirements that were to be analyzed was specified prior to each test. Westinghouse analyzed their wide-band data tapes for a transfer function report issued three to four weeks after each EP.

3. Narrow-band tapes from the digital data system were recorded continuously during each test in the form of raw counts. These were called DN1 tapes. These tapes (approximately 50 to 60 reels per test) were delivered after the test to the A&E Building, NRDS, and the data were gapped and reformatted into a form defined as DN2 tapes. The raw count data were then converted into engineering unit data and into the final form that was used for data analysis. These tapes were called the DN3 tapes. One set each of DN3 tapes was sent to WANL Pittsburgh and to AGC-Sacramento for preparing plots. Approximately 36 hours elapsed before the DN3 tapes could be made available to AGC and WANL.

Three types of data listing outputs were obtained at NRDS from the DN3 tapes. Thinned data listings were made for each measured channel during a given test. The thinned data listings are data that are selected at the rate of one frame out of each ten frames of data recorded and are listed for the entire test. This represents one sample of data for every second when data is recorded at 10 frames per second. Included in the thinned data listings were approximately 500 computations.

Additional data were processed for selected time segments on a request basis only. This included "short" data at 10 samples per second and "long" data at 10 samples per second and "long" data (which included all of the data available in the channel) at 10, 50 or 100 samples per second. NRDS also provided facilities for preparing multiple plots. These were done on Cal Comp equipment and were time-limited, taking approximately 5 minutes per plot with two plots being prepared simultaneously.

The time that was required to perform the narrow-band processing was approximately 48 hr. This 48 hr was divided into 24 hr for processing the data and 24 hr for preparing listings. The data were scheduled so that the more important listings could be available approximately 24 hr after the test. Therefore, the DN3 tapes were delayed a few hours to allow for this provision. AGC-Sacramento was able to process the DN3 tapes and complete

the plots, including reproduction, within 24 hr after receipt of their tapes. WANL Pittsburgh required approximately 12 to 24 hr more due to the longer distance. An approximate schedule of data, including wide-band data calibration, is shown as follows:

R - 72 hours	Analog tape calibration at NRDS
R - 48 hours	Analysis of analog tape calibration at AGC-Sacramento
R hours	Test
R + 4 hours	Data link plots
R + 8 hours	Analog tapes duplicated
R + 24 hours	Primary listing (eight priority data lists for 120 channels)
R + 36 hours	DN3 tapes to AGC-Sacramento and WANL Pittsburgh
R + 40 hours	Data listing
R + 48 hours	AGC plots and first set of wide-band data returned to NRDS
R + 72 hours	WANL plots returned to NRDS
R + 72 hours	AGC wide-band data analysis completed and returned to NRDS
R + 72 hours	All data listing completed
R + 80 hours	NRDS plots and special requests available

B. DATA HANDLING AND PROCESSING SYSTEM

To insure that valid and reliable data were obtained during the XE-P test series, a complete and controlled data measuring system was established. A brief schematic is shown in Figure A-1, which defines the data activities that were carried out for each Experimental Plan. As seen in Figure A-2, there are five primary sources of data. These are calibration, analog traces, real-time analysis, digital data system outputs, and analog wide-band data, as well as plots prepared by AGC and WANL, and wide-band data analysis performed by AGC and WANL. Each of these activities will be defined, together with the procedures, controls and illustrations of the forms that were utilized.

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ETS-1 NARROW-BAND CALIBRATION LISTING

XE-PRIME DATA HANDLING PROCEDURE

Figure A-2

1. Calibration

Calibrations for narrow-band and for wide-band data were prepared for each EP. Narrow-band calibrations were run several times prior to a test. All data for calibrations were available on computer tab runs. The final calibration was utilized unless anomalies were revealed, based on the manual surveillance of the final calibration run. When these anomalies were detected in a given channel, a more reliable prior calibration and/or modification was selected for application to the data. A typical listing of a sequence of calibration is shown in Table 1. A rather complete set of data is available to include noise, linearity, and slope and intercepts. There were no provisions for automatic selection or rejection of the calibration data. As a result, a large amount of manual review time was required after each test. Also, the calibration data were reviewed by persons who were extremely familiar with both the facility hardware and the data processing system. A noise data goal within 20 counts (2 standard deviations) or $\pm 0.2\%$ of full-scale and a linearity and drift goal of 15 counts or $\pm 0.15\%$ of full scale were established for the calibration data. Linearity is determined as the deviation from a line usually determined by the 0% and 75% corrected averages. If the 75% level was not appropriate, provision for an alternate level was made. All wide-band (analog tape) calibrations were analyzed at AGC-Sacramento. The procedure used was to run a prescribed final wide-band data dc and ac calibration at R - 3 and ship the five analog tapes to AGC Sacramento. Within 24 hr after receipt of the tapes the results of the calibration were called in to NRDS and appropriate corrections were made. To facilitate communicating these problem areas, a standard form containing information on each channel, as shown in Table 2, was maintained at AGC and NRDS. This form describes all the discrepancies reported and highlighted those recurrent discrepancies as well as those discrepancies which were considered acceptable.

For the piezoelectric transducers, a wide-band ac calibration was also performed by inserting a square wave charge and a square wave

TABLE 1
WIDE-BAND DATA RF-PRIME - PH AM LOG CALIBRATION EVALUATION

		Test No.				
		Date				
		Reported by:				
		Received by:				
P Channel	Title	Measurement Range				
F101	MG043..F DCT INERT WALL MID PAN CTR	±2 FUIN/IN				
F102	MX902..A AC-CPLD MG702..A	±45 KPSI				
F103	MX903..A AC-CPLD MG703..A	±9 KPSI				
F104	MX904..A AC-CPLD MG704..A	±9 KPSI				
F105	MX905..A AC-CPLD MG705..A	±9 KPSI				
F106	MX906..A AC-CPLD MG706..A	±9 KPSI				
F107	MX907..A AC-CPLD MG707..A	±18 KPSI				
F108	MX908..A AC-CPLD MG708..A	±45 KPSI				
F109	MX909..A AC-CPLD MG709..A	±18 KPSI				
F110	MX910..A AC-CPLD MG710..A	±9 KPSI				
F111	MX901..A AC-CPLD MG701..A	±9 KPSI				
F112	MG042..F DCT INERT WALL MID PAN CTR	±2 FUIN/IN				
F201	VC900..E FUNCTION GENERATOR	±20 V				
F202	DX901..E Z.S. DP870..E AV TURN TLV	±4.5 DEG				
F203	DX902..E Z.S. D 800..E AV CNTL DRUM POS	±4.5 DEG				
F204 **	DX903..E Z.S. D 801..E CNTL DRUM POS	±4.5 DEG				
F205	MX902..H Z.S. MC815..F AV TLST S LOG PWR	±2.5 Z				
F206	MX903..E Z.S. MC804..V PNC LOG PWR	±2.5 Z				
F207	CX901..E Z.S. CP624..F TPCV DRND	±4.5 DEG				
F208	CX902..E Z.S. CC800..E CNTL DRUM DRND	±4.5 DEG				
F209	PX901..F Z.S. PT104..E PUMP INLET	±2.5 PSI				

* Require manual calibration

** Negative calibration steps

TABLE 2

FORM FOR RECORDING WIDE-BAND DATA DISCREPANCIES

WIDE BAND CALIBRATION ANALYSIS

ETS-1 CALIB. EC0776 JAF (FS TAPE) 02-05-69 1167-06-122 CAL-REF= 75
MANUAL CALIBRATION 57740 TO 57860

			C-PERCENT	25-PERCENT	50-PERCENT	75-PERCENT	100-PERCENT	NO POST ZERO
UTTC0Y.F	AVG		-123.2	1902.4	3783.6	5636.5	7383.3	
ALL-LN.	STU-LEV	0	386.7400	215.8962	263.9673	414.2290	343.8713	
TAPE-TAK	LEV-REF	1		1.362	0.880	-0.1100	-2.243	
UTTC0Z.F	AVG		6386.1	6374.1	6364.9	6364.9	6364.9	
ALL-LN.	STU-LEV	2	374.2798	301.3752	341.5406	301.2454	281.1541	
TAPE-TAK	LEV-REF	2		-0.0	33.3.3	-0.0	-33.333	
MUAC10.A	AVG		-2892.5	-3557.5	-4080.6	-4943.4	-2977.4	
ALL-LN.	STU-LEV	3	475.7871	1265.7468	1000.7168	954.5735	1187.6382	
TAPE-TAK	LEV-REF	25		-72.222	-211.112	-0.001	-2122.221	
MUAC12.A	AVG		*****	*****	-9637.3	-5504.9	*****	
ALL-LN.	STU-LEV	4	14.4868	439.4241	354.6712	281.1074	411.6035	
TAPE-TAK	LEV-REF	26		6.349	-15.673	-0.000	-284.127	
MUAC14.A	AVG		7149.9	7142.9	7171.1	7109.4	7157.0	
ALL-LN.	STU-LEV	5	25.0441	39.6414	33.2403	31.3246	40.7416	
TAPE-TAK	LEV-REF	27		-333.333	-166.667	-0.000	-833.333	
MUAC16.A	AVG		-1394.6	-8401.7	-8373.4	-8244.5	-8316.8	
ALL-LN.	STU-LEV	6	32.0693	54.6776	59.1859	22.8468	47.4384	
TAPE-TAK	LEV-REF	28		-54.545	-62.636	-0.0	-81.818	

AVG IN COUNTS
STANDARD DEVIATION IN COUNTS
DIVISION REFERENCE IN PERCENT OF FULL SCALE COUNTS AT 100 PERCENT USED
CALIBRATION REFERENCE PERCENT USED TO DETERMINE SCALE FACTOR
ZERO DIFFERENCE IN PERCENT OF FULL SCALE
OVERSCALE EQUIVALENT IS *****

TABLE 3

WIDE-BAND DATA DC CALIBRATION PRINTOUT

MT004T 6'S

CHANGE AMPLIFIER CALIBRATION ANALYSIS

JG0 2906
21.40.37
05/10/49KE-P LP-5 9 MAY 1960
U11103 F3 TAPE R-3 CALIB
FULL SCALE RE-DEFINED AS STEP AMPLITUDE AT BEGINNING OF EACH HALF-CYCLE

	SAMPLE 1 STEP 1	SAMPLE 2 STEP 1	SAMPLE 3 STEP 1	SAMPLE 4 STEP 1	SAMPLE 1 STEP 2	SAMPLE 2 STEP 2	SAMPLE 3 STEP 2	SAMPLE 4 STEP 2	TOTAL STEP 1	TOTAL STEP 2
DATA TIME (SECONDS)	02950.00	02975.00	03000.00	03025.00	03050.00	03075.00	03100.00	03125.00		
NUMBER OF USABLE PULSES	10	21	10	10	30	30	30	30	73	120
NUMBER OF UNUSABLE PULSES	14	9	12	14	0	0	0	0	47	0
AVERAGE AMPLITUDE (VOLTS PEAK-TO-PEAK)	0.3446165	0.3702276	0.3001490	0.344018	10.05315	10.08335	10.11130	10.09786	0.3602656	10.08096
AVERAGE OF ALL DATA POINTS OVER SAMPLE (VOLTS)	-0.030971	-0.020901	-0.030003	-0.031594	0.2775208	-0.112866	-0.054767	-0.070152		
PEAK AMPLE 2 SIGMA DEVIATION (PERCENT OF FULL SCALE)	0.3447065	0.4097556	0.3523686	0.3719175	1.205855	3.042788	1.224975	1.333806	0.3767193	1.411200
ABSOLUTE MAXIMUM DEVIATION FROM BEST FIT CURVE (PCT. OF F.S.)	0.3689201	0.3053977	0.410615	0.2524706	0.4790379	0.4483745	0.4463496	0.4548752	0.4169615	0.4568752
2 SIGMA DEVIATION FROM BEST FIT CURVE (PCT. OF F.S.)	0.1434557	0.1290658	0.1332175	0.1120651	0.1539089	0.1749566	0.1750642	0.1864625	0.1302143	0.1751477
PULSE AVERAGE SLOPE (PERCENT OF SAMPLE AMPLE/FULL)	0.179101	0.304463	0.091014	0.075525	0.954629	3.079114	3.630032	3.651619	3.059380	3.055385
PULSE SLOPE 2 SIGMA DEVIATION (PERCENT OF FULL SCALE / FULL)	0.1140499	0.1624518	0.1723746	0.1281350	0.7958366	0.8089019	0.898216	0.8429516	0.1452884	0.6260153
STEP 1 PERCENT OF STEP 2	1.444 PERCENT									
RESIDUAL NOISE & SIGMA DEV. PERCENT	0.23906 PERCENT OF FULL SCALE									
FULL SCALE IS DEFINED AS 70.4 STEP 2 OF THE AVERAGE CYCLE AMPLITUDE.										
ALL SYSTEM CALIBRATION MADE UNDER 05102107 003										

INLET RANGE 200.000 6'S SCALE FACTOR 0.0701104 6'S / COUNT

TABLE 4

WIDE-BAND DATA AC CALIBRATION PRINTOUT

charge and a square wave voltage into different points of the system at 200 Hz. These data were analyzed at AGC-Sacramento by the Instrumentation Section. If problem areas were uncovered, joint action was initiated between the Instrumentation groups of AGC-Sacramento and NRDS to effect appropriate corrective action. Tables 3 and 4 show a typical dc and ac calibration printout. These calibration procedures proved to be effective and should be made part of an NRDS procedure for NERVA testing.

2. Data Listing Procedure and Documentation

Tabulated data and computations are available from listing tapes that are used for SPEAR analysis. The first set of listings that was prepared for SPEAR was the DN3S data (thinned data) which are engineering-unit listings at essentially one sample per second when data was set at 10 frames per second. Approximately 500 calculations were also available. The data log identified the channels and calculations symbols.

Table 5 shows a page of a typical thinned data listing. Each listing of 15 variables is a pass identified by a four-character alphanumeric identification. The passes are segregated into groups according to the use of the data required by each group. That is, there are six groups of engineers that make up the SPEAR team and the data are placed into sets for each group. The sets of passes are then assembled into books.

To facilitate rapid location of desired data listing, three sets of tabulations are compiled into a single volume. This volume includes (1) the variables or parameters that are in each pass, (2) a parameter versus pass listing which identifies the pass for each variable, and (3) the passes that will be assembled in each book.

The procedure that was followed for producing pass listings was as follows. A set of computer pass listing identification cards was selected for a given test run. These cards are placed in the sequential

PAGE 10

PAGE ZERO

A17

TYPICAL LISTING OF NARROW-BAND DATA

order in which the pass listings are required and are presented to NTO Data Control. This deck of cards provides complete requirements for thin data listings. The SPEAR Director was responsible for specifying the listings to be included and the order of the listings.

At the start of a test a precalibration is made. This data is sent to NTO Data Control and a calibration listing in counts is made. The calibration listing also includes several previous calibrations prior to the test. Based on this data, appropriate data calibrations can be selected. After the test, another verification calibration is made for final changes that may be required prior to processing the data. In addition, an engineering-unit calibration listing is prepared for engineering use.

An events listing is prepared for 160 events that are recorded. At each time when any of the 160 events are activated or closed, a 1 or 0 is recorded for that event, with the status of the other events also being recorded. Table 6 shows a page of an events listing.

Four copies of the thin-data pass lists are made. One set is retained by NTO Data Control. One set is assigned to the SPEAR Measurement Group and is available to SPEAR members but is controlled. One set of the data is given to each SPEAR group leader. This set can be disassembled from its books and used at his discretion. The fourth set of data is available to any SPEAR member but the books containing the passes cannot be disassembled. The SPEAR Measurement Group's set of listings is ultimately sent to NRO Sacramento. One set is retained in the SPEAR library at NTO. The thin data is available 24 to 48 hours after completion of the test, and special requests will be available at approximately 72 hours after the test.

As in all analyses conducted by SPEAR members, all anomalies or discrepancies uncovered by evaluation of the listings are reported on the Discrepancy Reporting Form and given to the SPEAR Measurement Group for appropriate corrective action.

DIGITAL EVENTS
FIVE EVENTS

PASS EV02

FILE 43. 11.

[illegible]

A 19

TABLE 6

DIGITAL EVENTS LISTING PRINTOUT

3. Analog Data System

The analog data system consists of two major categories of data, analog magnetic tapes and analog data such as strip charts and oscillograms. Available for processing are 142 channels of analog tape data and wide-band data, and three different systems are available for recording data continuously on-line. The analog data systems are as follows. There are five Ampex analog tape recording systems; four consist of 32-track recorders and one a 14-track recorder. Two tracks from each recorder are reserved for time data so that 132 channels are available for recording wide-band data information. The frequency response of the analog tape recording system is rated from zero to 10,000 Hz. The recording systems include oscillograms and strip charts. The detailed description of the analog (and digital) system is given in RN-S-0510, Volume I of the XE-P Engine Final Report.

The allocation of channels for each analog recorder that is used for each test is described in the test as-run data log and also in the SPEAR Team Availability Listing.

Strip charts and oscillograms from each test were micro-filmed. For the early tests (XECF), ozalid (blue-line) copies were also made but since these were not used, the ozalid reproduction procedure was discontinued. Little use was made of strip charts and oscillograms for post-test analysis. These analog charts were utilized for time identification for significant events to be used for plotting purposes and the Measurement Group of the SPEAR team checked the oscillograms for data validity and for any transducer anomalies. One reason for the limited use of the strip charts and oscillograms was that engineering-unit plots were available from AGC Sacramento for most of the significant portions of the test and special request playback oscillograms were available on a 24-hr basis for any of the 132 channels available on the analog tapes. Since the special requests included time and/or amplitude expansion, this type of data was of greater demand than use of NTO oscillograms.

The duplicated analog tapes were shipped to AGC-Sacramento and to WANL-Pittsburgh. AGC did all of the wide-band data analysis to support SPEAR. The criterion that was established was to process all requests within a 72-hr period in increments of 24 hr. Prior to each test program, each of the wide-band data test equipments was subjected to a controlled test to verify that each equipment at AGC Sacramento was performing properly. The control tests included inputting three different frequencies at two different amplitudes, verifying the tape drives with a standard checkout tape, and a checkout of all equipments. A wide-band data requirements report was prepared prior to each test. This report contained the channels and measurement ranges required for each channel for each particular test. If test time or test information are required, these facts are so indicated. A typical index for a wide-band data request would include:

- a. Closed Loop (or Open Loop) Transfer Functions for TPCV and Drum Inputs

These described channels, measurement ranges, required transfer functions, required data, time history plots, and special instructions for data processing and data plots, and described conditions of the test. If necessary, filters were specified.

- b. TPCV Posttest Checkout

This defined channels to be used, specified procedures for data to be processed and analyzed.

- c. Vibration Analysis

Turbopump, engine, core channels description and identification of data for channel number, engineering-unit range and bandwidth are specified. Data plots (RMS, power spectral density, amplitude versus frequency or time), spectral data tabulation, and/or plots, and data summary.

Visirecords (oscillograms) were also specified for time, channels, range of data, and special instructions.

d. Performance Channels

Identified channels, type of data desired, and type of analysis required.

e. Strain Gage

Identified channels, specified RMS versus frequency, or time plots, and type of filter to use for each channel, and bandwidth for processing data.

An engineer was assigned the responsibility of preparing the requirements and following up to insure that the data were processed per schedule and that special requests were processed expeditiously.

The data were produced on reproducible masters for the listings and plots. Blue-lines were prepared and distributed to SPEAR, NTO, WANL, SNPO, and AGC. Usually, two books were prepared, one for transfer functions and one for the remaining wide-band data plots. AGC also processed WANL SPEAR requests for wide-band data. WANL prepared a formal transfer function report that was usually completed and distributed two to four weeks after the test. No formal report of vibration analysis was available during the XE-P tests.

4. Plotting Programs

The DN3 tapes were shipped to AGC Sacramento and WANL Pittsburgh approximately 30 to 36 hr after the test. Both AGC and WANL published a list of the plots that were available and the plots were requested according to a code letter that included several multiple plots for each code letter. AGC and

WANL prepared and checked out the programs for preparing the plots and corrections, additions, and modifications according to the needs of the SPEAR team.

At AGC-Sacramento a second list of plotting requests was available primarily for Control Section personnel. The Control Section personnel required many special requests such as very short time intervals, expanded ranges, and 100 s/s plots. These requests were processed by the AGC Test Area Division (who also processed the wide-band data) using an IBM 360/40 computer and Cal Comp plotters. The larger bulk of the plots was processed with the IBM 360/65 by the AGC Computing Sciences Division.

The procedure that was used for requesting plots was to have each of the SPEAR group leaders review the Test Diagnostic Center (TDC) plots and the chronology that was formally prepared for required time slices. A special form was available for requesting plots that required time slices, plot code letters, and special instructions. These time slices were called in to AGC and WANL so that the preprocessing and computer preparation could be initiated prior to receipt of DN3 tapes. In addition to digital plots (described at AGC by Code D57111), AGC had steady state (E57105) and best estimate (E57104) computer programs. The steady-state program listed the system performance and computed parameters for each steady-state hold. The best estimate program was a procedure for obtaining the best estimates by means of utilizing all the information available and making appropriate comparisons for discarding anomalous data. WANL published a similar set of documents for each EP defined as the Nuclear subsystem Data Reference Book. This reference book contained the equations, definitions, descriptions of the plots and presentation of the data. A classified volume was also published for classified data. AGC also issued a NERVA Turbopump Data Analysis Report. This report listed the pump, turbine, and bearing parameters every second for a specified time interval. The data were also plotted on multiplots as specified. AGC circular plot routine was available and applied to EP-10 data. The time schedule for all of these plot and analysis activities for AGC was to return the completed plots and analysis within a 24-hr period to SPEAR at NRDS. WANL, due to distance limitation, usually required 30 to 48 hr.

A number of limitations were observed during the XE-P program. Processing of data took 24 to 30 hr before DN3 tapes were completed at NRDS. The tapes were flown to AGC and WANL and processed at these facilities and the completed data returned to NRDS. It was not unreasonable that 72 hr may have elapsed before plot data were available to SPEAR personnel.

a. Obtain greater computer storage and memory capability so that the posttest processing can be minimized or eliminated.

b. Provide for disk accessibility for data so that data would be accessible by means other than direct computer memory.

c. Provide for more rapid methods of processing of data so that processing time can be minimized. This includes all tasks required, from collection of data to plotting, listing, displaying, and distributing the data.

d. Most of the plots that are required by the Test Control team and the SPEAR team can be made available via cathode ray tubes (CRT's). If data are tabulated on mass storage devices, plots of data would be available immediately after a test.

This factor of immediate accessibility of data is more important because the SPEAR team was often restricted as to the number of plots available. When plot requests exceeded 1000 to 1500 plots, restrictions were imposed as to quantities available. Often, SPEAR team personnel desired overview plots of a general portion of a test and then detailed plots over shorter time periods. These types of requests, although necessary and desirable, could account for an excessive number of plots. It is expected that these requirements can be satisfied in NERVA tests by using the CRT displays for exploratory investigation and using the hard-copy capability of CRT to obtain final copies.

At the conclusion of the test, a special TDC plotting tape was prepared. Depending on the number of channels, number of plots, and time segments, the plotting tape for approximately 25 plots per time segment using about 100 channels of data for two to three time frames took about 1 hr for preparing the plotting tape and 3 to 5 hr for preparing the plots on the Cal Comp plotter at NRDS. Priority was assigned to the sequence in which the plots were to be prepared so that after 1 hr, 10 to 15 summary plots would be available to SPEAR personnel for evaluation and selecting time segments for plots to be prepared at AGC and WANL. Other individuals were able to obtain a "quick-look" of the test performance to search for any anomalies or problem areas that may influence the testing schedule. The real-time system became a very efficient and effective procedure and is being considered as the prime data source for NERVA. There will be no need to have redundant data systems in NERVA for the same data. Also, experience with TDC indicates that this is probably the most economical method and probably the only method to meet short turn-around time between tests that appears to be a requirement for NERVA.

When the TDC plots were completed, the Cal Comp equipment at NRDS was available for special request plots. Although the number that could be produced was limited due to the slowness of the units, several hundred plots were prepared at NRDS for each EP. At the end of the XE-Prime program each set of plots was given an identification to avoid duplication in requesting plots. Two plots were run simultaneously to speed up the process, although it is desirable that a faster procedure for reproducing plots be considered at NRDS for NERVA data.

Pretest processing was entered about the channel engineering data collecting program. Data relating to all the channels from wiring and patching to the transducers, data, and controls were collected by a control data and reports were generated on a regular or as-needed basis. Section III describes the channel engineering program.

III. CHANNEL ENGINEERING

Channel Engineering is a method that combines all data relating to engine and facility channels to include information concerning transducers, data setup mode, range, and accuracy, wiring and patching information, and routine reports to document these types of information.

The procedure used is to establish a data base for all data and measurement system information at NRDS. The following data were inputted into the system:

A. MRL - MEASUREMENT REQUIREMENT LIST

This is a set of engine data requirements supplied by ANSC and updated as required. ANSC coordinated these requirements with WANL and SNPO.

B. RDR - RECORDER AND DISPLAY REQUIREMENTS

This document was prepared to identify each engine and facility channel with respect to the mode of display that is contemplated for each channel.

C. EWL - ENGINEERING WIRE LIST

The wiring information is supplied by ANSC and is updated as necessary to support this activity.

D. CC/A - CHANNEL CHANGE AUTHORIZATION

This is the final data document that is inputted. It records continuously the changes that are authorized after the start of the test program.

Measurement information is inputted in the following forms for the data base:

a. Transducer Inventory

Transducer information, such as range, setup, vendor, and pertinent data, is prepared for each channel on a monthly basis.

b. Signal Conditioning Mode Card

The applicable mode card and pertinent data relating to each channel is inputted and updated on a monthly basis.

c. Engineering and Measurement Change Request

All approved engineering changes are inputted continually as they pertain to the measurement system.

d. Measurement and Transducer Design Criteria Sheets

These are maintained for input into the data bank as applicable.

These data are made part of a data base consisting of over 5000 channels in the form of a series of data tapes. In some cases, separate data tapes are prepared for special reports. From the data a series of reports is prepared on a routine schedule or are available as needed. The following reports are prepared:

a. Datalog

A list of all engine and facility channels describing all information regarding the measurement system to support each test. A datalog

was issued prior to each test with a supplement prepared to cover changes that were made immediately before the test.

b. Master Channel Listing

This listing includes a channel list to define the basic channel inventory. This listing is prepared as required. It was prepared approximately once or twice a year during XE-P tests.

c. Termination and Cable Listing

This listing was prepared from a special tape and issued weekly. It included a channel map with end-to-end wiring description.

d. Patch List

A detailed description to define the patching sequence of each channel. A patch list was issued approximately every other EP during the XE-P tests.

e. Transducer Inventory - issued monthly.

f. Tag Number List - issued bimonthly.

g. Mode and Inventory - issued monthly.

There were two data base tapes that were available for generating tapes. The ETS-1 Master Data Base contained all the information to support the 5000 channels. In addition, an XE-P Data Base was maintained to refer to the specific XE-P tests only.

The procedures and controls governing and updating the channel engineering programs are described in NTO-G-0095, "NERVA Test Operations Guide for Channel Engineering Program Operations," dated 26 June 1969. This guide covers the T&C unit list, channel map, and power distribution tabulation.

APPENDIX B

COMPARISON OF VARIOUS COMPUTER SYSTEMS

To aid in the comparison and evaluation of the various manufacturers' computer systems, lists of equipment needed for complete systems of various capacities were made and the approximate costs per month for a 1-year lease, including maintenance charges, were listed.* These system configurations are shown in the following tables. The systems, as listed, were designed to be representative of what might be used to meet the requirements outlined in this report but do not represent optimum systems.

To make comparisons of the various systems as meaningful as possible, the following guidelines were used to determine what equipment would be included:

1. The systems designed for the larger (12,000-hour) Sacramento workload were to include three remote entry (card read/line print) terminals and 36 typewriter or CRT terminals. The smaller (8,000-hour workload) systems were to have two remote entry and 12 typewriter terminals.
2. A single on-line mass storage device of about 200 million characters was to be included in each of the systems.
3. The systems would contain eight tape drives each.

*The enclosed costs are for a 1 year lease, including maintenance.

SYSTEM B-1
IBM 360/195

<u>Quantity</u>	<u>Number</u>	<u>Description</u>	<u>Approx. Cost/Mo.</u>
EQUIPMENT AT THE CENTRAL SITE:			
1	2160	System Console	\$ 7200
1	2195	Processing Unit - 2 Million Bytes	127800
1	2180-86	Power and Dist. System	4000
2	2860/2	Selector Channel - (4)	5990
1	2870/1	Multiplexor Channel w/ Selector Sub-Channel	2595
1	2803-2	Tape Controller	1175
8	2420-V	Tape Drives	4313
2	2314	Dir. Access Storage - 16 Disk Drives Total	9940
1	2821-3	Card/Print Controller	1319
1	1403	Printer w/Train	2925
1	2501	Card Reader	338
1	1442	Card Punch	365
2	2702	Data Adaptor	2030
6	2701	Data Adaptor Unit	6306
TOTAL COST			\$ 176,296

EQUIPMENT AT EACH REMOTE STATION:			
2	2712	Remote Multiplexor	Est. \$ 2000
20	2741	Typewriter Terminals	2270
1	2848	Display Control	1000
16	2260	CRT Terminals	816
3	2780	R.J.E. Terminals	3093
1	2030-C	Processing Unit (8192 Bytes)	1275
1	7915	1051 Attachment	75
1	2501	Card Reader	338
1	1442 N2	Card Punch	365
1	2821-3	Card/Print Controller	1200
1	7945	Third Printer	500
3	3615	1100 LPM Printer	75
3	1403	1100 LPM Printer	2625
2	2401-02	Tape Units (60 KB)	970
1	2803-001	Tape Control	650
REMOTES - TOTAL COST PER LOCATION			\$ 17,252

Therefore, the total computing equipment cost for a central site plus two remote terminal locations would be \$210.8K per month, plus sales tax (\$10.5K/mo.). In addition, there would be communications lines and interfacing equipment costs.

SYSTEM B-2
IBM 360/75 - 1024K-Byte Core

<u>Quantity</u>	<u>Number</u>	<u>Description</u>	<u>Approx. Cost/Month</u>
1	2075	Processing Unit	\$ 23280
4	2065	Processor Storage - 1024K	36980
1	1052	Console	66
1	2860	Selector Channel (2)	3090
1	2870	Multiplexor Channel w/Selector Sub	2195
1	2314	8-Drive Disk Unit	5390
8	2316	Disk Packs	160
1	2803-2	Tape Controller	1175
2	2401-II	Tape Drive - 60K char/sec - 7-Track	990
6	2420-V	Tape Drive - 120K char/sec - 9-Track	3235
1	2821-3	Card/Print Controller	1319
2	1403	1100 LPM Printer and Print Train	1950
1	2501	Card Reader	338
1	1442	Card Punch	365
1	2701	Transmission Control Unit	950
2	2780	Remote Batch Entry Terminals	2002
12	2260	Visual Display Terminals	1610
TOTAL EQUIPMENT			\$ 85095
5% Sales Tax			4255
TOTAL			\$ 89350

SYSTEM B-3
IBM 360/85 - 2048-BYTE CORE

<u>Quantity</u>	<u>Number</u>	<u>Description</u>	<u>Approx. Cost/Month</u>
1	2085	Central Processor	\$ 42680
8	2365	Storage - 2048K Bytes Total	73960
1	2860	Selector Channel (2)	3090
1	2870	Multiplexor Channel w/Selector Sub-Channel	2195
1	5450	Operators Console	750
1	2314	Disk Unit and 8 2316 Packs	5550
1	2803-2	Tape Controller	1175
6	2420-V	Tape Drives	3235
2	2401-II	Tape Drives - 60K char/sec - 7-Track	990
1	2821-3	Card/Print Controller	1319
3	1403	Printer w/Train	2925
1	2501	Card Reader	338
1	1442	Card PUNCH	365
1	2701	Transmission Control Unit	1051
3	2780	Remote Batch Entry Terminal	3003
1	2702	Data Adapter	1015
12	2741	Typewriter Terminal	1362
1	2848	Display Control	1000
24	2260	CRT Terminal	1224
TOTAL EQUIPMENT			\$ 14,227
5% Sales Tax			7361
TOTAL			\$ 15,588

SYSTEM B-4

CDC 6500 - 131-K-WORD CORE

<u>Quantity</u>	<u>Number</u>	<u>Description</u>	<u>Approx. Cost/Month</u>
1	6513	Central Computer - 131K Core	\$64000
1	6612	Console Display	1200
4	6681	Data Channel Converter	1300
1	6638	Disk System	9400
1	3447	Card Reader Controller	235
1	405	Card Reader	420
1	3446	Card Punch Controller	475
1	415	Card Punch	310
1	3555-1	Line Printer Controller	625
2	512	Line Printer and Train	2150
1	3229	Mag. Tape Controller	630
8	604	Mag. Tape Transports	5040
1	3234	Disk Storage Controller	540
3	853	Disk Drives +3 Disk Packs	1110
2	200 UT	Remote Batch Entry Terminals	2390
1	6671	Data Set Controllers	1200
1	3290-4	Display Controller	440
12	211-4	CRT Display Terminals	1344
TOTAL EQUIPMENT			\$ 92,929
5% Sales Tax			4,646
TOTAL			\$97,575

SYSTEM B-5
CDC 6600 - 131K-WORD CORE

<u>Quantity</u>	<u>Number</u>	<u>Description</u>	<u>Approx. Cost/Month</u>
1	6613	Central Computer - 131 K Core	\$89500
1	6612	Console Display	1200
1	6638	Disk System	9400
6	6681	Data Channel Converter	1950
1	3447	Card Reader Controller	235
1	405	Card Reader	420
1	3446	Card Punch Controller	475
1	415	Card Punch	310
3	3555-1	Line Printer Controller	1875
3	512	Line Printer w/Train	3225
1	3423	Mag. Tape Controller (2x8)	1450
8	607	Mag. Tape Transports	7360
1	3234	Disk Storage Controller	540
3	853	Disk Drive and Pack	1110
3	200 UT	Remote Batch Entry Terminal	3585
1	6671	Data Set Controller	1200
1	6676	Data Set Controller	2000
36	211-4	CRT Terminal	4032
TOTAL EQUIPMENT			\$ 129,867
5% Sales Tax			6,493
TOTAL			\$136,360

SYSTEM B-6

UNIVAC 1106 DUAL PROCESSOR - 262K-WORD CORE

		<u>Purchase</u>	<u>Maintenance</u>	<u>Rental</u>
3011-20	1106 CPU (2)	\$ 566460	\$ 2330	\$11800
F0680-99	Channel expansion	21000	60	485
4009-99	Display console (2)	65250	500	1500
F1053-99	MP Reature (2)	17400	-	400
7005-56	262K Ovrtp core	823500	1490	17155
0954-99	MMA (4)	226200	200	5200
CPU sub total		\$ 1719810	\$ 4580	\$36540
5012-00	432/1782 Control	82515	260	1885
6015-00	1782 Drum	117210	260	2680
HS Drum subsystem sub total		\$ 199725	\$ 520	\$ 4565
0961-02	MSA	23760	55	495
F1321-02	MSA expansion	18960	45	395
F1323-00	Function buffer expansion (2)	3840	20	80
5024-02	8414 Control unit (2)	52800	180	1100
F1371-00	Dual access feature (8)	17280	40	360
8414-98	Disc storage unit (8)	207840	550	4330
F1214-00	Disc Pack (8)	5200	-	160
Disc system sub total		\$ 329680	\$ 890	\$ 6920
0961-02	MSA	23760	55	495
5017-00	Uniservo 12/16 CTL	23925	100	550
0862-04	Uniservo 16 (8)	254040	880	5840
Tape system sub total		\$ 301725	\$ 1035	\$ 6885
5011-00	Printer CTI	30015	200	685
0750-00	Printer	43500	305	945
H.S. Printer sub total		\$ 73515	\$ 505	\$ 1630
3030-02	9300 Processor	27825	160	635
7007-08	8K storage	24390	47	555
F0864-00	Print exp	3140	10	74
0711-00	Card reader	6630	63	152
F1097-00	M/S read feature	1145	5	26
0603-04	Punch	6630	63	152
F0869-01	MVX channel	3380	5	79
9300 system total		\$ 73140	\$ 353	\$ 1673
F1095-02	ICCU for above	8920	45	205
F0900-06	CTMC	24700	135	570
F1048-00	CTMVI-LS (3)	10440	45	240
F0991-00	CTMVI-HS (4)	18280	80	420
Communications controller sub total		\$ 53420	\$ 260	\$ 1230

SYSTEM B-6 (continued)

3541-99	DCT-500 (6)	\$ 17280	\$ 120	\$ 360
1355-00	Keyboard (6)	2310	12	48
DCT 500 sub total		\$ 19590	\$ 132	\$ 408
3536-98	Uniscope 100 (6)	20700	150	420
F1242-03	A/N Keyboard (6)	2550	-	90
F1245-01	Synch interface (6)	2880	-	90
Uniscope sub totals		\$ 26130	\$ 150	\$ 600
3030-00	9200 Processor	12810	68	294
F0869-00	MUX Channel	2175	5	53
F0868-01	132 print position	7730	21	179
F1130-00	Form adjustment	410	-	10
7007-93	8K storage	16665	32	383
0711-00	Card reader	4970	32	116
F1097-00	M/S read feature	1145	5	26
0603-04	Card punch	6630	63	152
F1000-00	LTC-1	4570	15	105
F1098-99	LRC	740	3	17
F1005-98	LT synch check	2375	10	55
F1002-04	C1 data phase	565	2	13
remote 9200 (each)		\$ 607785	\$ 256	\$ 1403
2 remote 9200		\$ 121570	\$ 512	\$ 2806
Class I equip totals		\$ 2733918	\$ 8117	\$58983
Class II equip totals (9000 series)		194710	865	4479
TOTAL		\$2928628	\$ 8982	\$63462

One year lease \$8,982 + 63,462 = \$72,444

Five Yr. Lease, declining payments

	MAINT	RENTAL 1186	RENTAL 9000
Year 1:	8982	+ 50135.55	+ 4255.05 = 63372.60
2:	8982	+ 47186.40	+ 4031.10 = 60199.50
3:	8982	+ 44237.25	+ 3807.15 = 57026.40
4:	8982	+ 41288.10	+ 3583.20 = 53853.30
5:	8982	+ 38338.95	+ 3359.25 = 50680.20

Outright sale price: \$29,286.28

SYSTEM B-6 (continued)

Additional cost for 1557/1558 Graphic display

1557-00	Control unit	\$ 69000	\$ 150	\$ 1725
1558-00	Graphic display	57000	340	1425
F1123-00	Light pen	3000	15	75
		<hr/>		
		\$ 126300	\$ 505	\$ 3225
F0991-00	CTMVI-HS	4570	20	105

Outright purchase: \$130870

One year lease: 525 maint + 3330 equip = 3855 /mo

Five year lease:

Year 1: 525 Maint + 2830.50 equip = 3355.50 /mo
 2: 525 Maint + 2664.00 equip = 3189.00 /mo
 3: 525 Maint + 2497.50 equip = 3022.50 /mo
 4: 525 Maint + 2331.00 equip = 2856.00 /mo
 5: 525 Maint + 2164.50 equip = 2689.50 /mo

SYSTEM B-7

UNIVAC - 1106 MP + 1106

<u>Quantity</u>	<u>Number</u>	<u>Description</u>	<u>Approx. . Cost/Month</u>
3	3011-20	Central Processor	\$ 21195
3	4009-99	Display Console	3000
1	7005-56	Storage - 262K	18645
1	7005-57	Storage - 196K	13985
2	F1053-94	Multiprocessor Capability	400
1	F0680-99	Channel Expansion	545
4	0954-99	M.M.A.	5400
1	F0833-00	M.M.A. Interface - to 196K	60
1	F0833-01	M.M.A. Interface - to 262K	60
2	5012-00	Drum Controller	4290
2	6015-00	FH1782 Drum	5880
1	5024-02	Disk File Controller	640
1	8414-96	Disk File - 8 Drive (inc. 8 packs)	5040
2	5008-12	Tape Controller - 7 or 9-track	3200
10	0859-00	Uniservo VIII-C Tape Units - 8 9 tr, 2 7 tr	8720
2	5011-00	Printer Control	1770
2	0758-00	Printer	2500
2	9300	Subsystem - For I/O Use - Includes Multiplexor Channel 600 CPM 600 LPM 80 CPM Punch	4052
1	0955-04	S.P.I.	475
1	0955-05	S.P.I.	420
3	9200	Remote Batch Entry Terminals	4977
1	F0900-06	CTMC	705
8	F0903-02	CTM-HS	800
2	F1095-02	1106/900 ICCU	500
5	8538-00	Terminal Multiplexor	175
36	3536-98	Uniscope 100	3780
36	F1242-01	Keyboard	360
TOTAL EQUIPMENT			\$111,574
5% Sales Tax			5,579
TOTAL			\$117,153

SYSTEM B-8
UNIVAC - 1108 MP

<u>Quantity</u>	<u>Number</u>	<u>Description</u>	<u>Approx. Cost/Month</u>
2	3011-95	Central Processor	\$ 33450
2	4009-99	Display Console	2000
1	7005-70	Storage - 262K	44255
2	F1053-94	Multiprocessor Capability	400
1	F0680-99	Channel Expansion	545
4	0954-99	M.M.A.	5400
1	F0833-00	M.M.A. Interface - to 196K	60
1	F0833-01	M.M.A. Interface - to 262K	60
1	F1095-02	1106/9000 ICCU	250
1	5012-00	Drum Controller	2145
1	6015-00	FH 1782 Drum	2940
1	5024-02	Disk File Controller	640
1	8414-96	Disk File - 8 Drive (inc. 8 Packs)	5040
1	5008-12	Tape Controller	1600
9	0859-00	Uniservo VIII-C Tape Units - 7 9 tr, 2 7-tr	7845
1	5011-00	Printer Control	885
1	F0751-00	Printer Control Expansion	630
2	0758-00	Printer	2500
1	9300	Subsystem - for I/O use - includes Mux Channel 600 CPM Read - 600 LPM Print and 80 CPM Punch	2026
3	9200	Remote Batch Entry Terminals	4977
1	F0900-06	CTMC	705
8	F0903-02	CTM-HS	800
5	8539-00	Terminal Multiplexor	175
36	3536-98	Uniscope 100	3780
36	F1242-01	Keyboard	360
TOTAL EQUIPMENT			\$123,468
5% Sales Tax			6,173
TOTAL			\$129,641

NTO CONFIGURATION B-9

UNIVAC 1106 - 131K-WORD CORE

<u>Quantity</u>	<u>Part No.</u>	<u>Description</u>	<u>Cost/Mo.</u>
1	3011-20	Central Processor	\$ 7,065
1	F0680-99	I/O Channel Expansion	545
1	4009-99	Display Console	1,000
1	7005-57	Storage - 131K Words	9,325
1	1095-02	1106/9000 ICCU	250
1	5012-00	Drum Controller	2,145
1	6015-00	FH 1782 Drum	2,940
1	5024-02	Disk File Controller	640
1	8414-96	Disk File - 8 Drives + 8 Packs	5,040
1	0961-02	Multi-subsystem Adaptor	600
1	5008-12	Tape Controller	1,550
8	0859-00	Uniservo VIII-C Tape Units	6,970
1	9300	Subsystem - For I/O Use; Includes Multiplexor Channel, 600 Card/Min. Reader, 600 Line/Min. Printer, and 80 Card/Min. Punch	1,930
TOTAL EQUIPMENT			\$40,000

System B-10

NRDS DATA STREAM ESTIMATED PRICES

NOTE: Subject to confirmation and adjustment to meet
customer data format and rate requirements

6-11-70

Number of Items	Description	Product No.	Option I and Option IV	Option II
1	Satellite Coupler	1718	10,600	NR
1	Buffered Data Channel	1706	8,480	8,480
1	Computer -4K	1704	30,740	30,740
1	Interrupt Data Channel	1705	4,240	4,240
5	Storage Increment - 4K	1708	42,400	42,400
1	Buffered I/O Interface	1797	9,010	9,010
1	DCB Terminator	1750	9,540	9,540
1	Tape Controller	QSE	35,000	35,000
2	Mag Tape - High Speed	657-4	93,280	93,280
1	Sampling I/O	1572	2,650	2,650
1	Paper Tape Reader	1721	4,770	4,770
1	Teletypewriter	1711	4,240	4,240
1	Papertape Punch	1723	5,410	5,410
1	TDI/ADI	704B	9,300	9,300
1	PIOC	QSE	51,500	51,500
1	ESM	QSE	40,000	40,000
1	EPM	QSE	63,000	63,000
1	TDB		NC	NC
1	Telemetry Equip. Controller	QSE	25,000	25,000
1	BCD to Binary Conver.	QSE	5,000	5,000
1	PDF (Parallel Data Form)	QSE	20,000	20,000
1	ADP	QSE	13,300	13,300
1	FM Subsystem to be defined		NI	NI
1	DAC's and Analog Patch System to be defined		NI	NI
	Estimated Cost of MUX and ADC		10,000	10,000
1	Card Read Punch Controller	1728	NR	9,010
1	Card Reader and Punch	430	NR	19,080
1	Line Printer and Controller	1742	NR	40,810
1	Data Set Controller	1747	NR	17,490
	TOTAL		<u>\$497,460</u>	<u>\$578,250</u>

NI = Not Included

NR = Not Required

OPTION IV - 62 ystem Located NRDS

Number of Items	Description	Product No.	Purchase Price	Basic Monthly Lease Price				Monthly Maintenance
				1-year	3-year	4-year	5-year	
1	Central Computer 7 Peripheral Processors 9 I/O Channels 32K - 60-bit word memory	6215-7	\$589,580	\$14,380	\$13,661	\$13,373	\$12,942	\$2,478
1	Memory Increment Increases memory to 49K.- 60-bit word memory	10177-1	302,100	6,660	6,330	6,195	5,995	648
4	Data Channel Converters	6681	59,360	1,200	1,140	1,120	1,080	156
1	Console Display	6612	50,880	1,085	1,035	1,010	980	173
1	Data Set Controller	6671	44,520	1,100	1,045	1,025	990	157
1	Mass Storage Controller Two Channel Connections Single Sector Buffer	3553-2	39,220	770	735	720	695	152
1	Data File 419 million characters	821-1	148,400	2,750	2,615	2,565	2,480	525
1	Card Read Controller	3447	12,720	190	185	180	175	60
1	Card Reader 1200 CPM	405	24,910	370	355	345	335	71
1	Card Punch Controller	3446	24,380	430	410	400	390	71
1	Card Punch 250 CPM	415	20,140	260	250	245	235	65
1	Line Printer Controller	3555-1	28,620	605	575	565	545	49
1	Line Printer - 1200 LPM	512-1	47,700	780	745	730	705	243
1	Train Cartridge	595-1	3,180	105	100	98	95	T&M
6	Remote Display/Entry Terminals Alphanumeric	214	37,500	840	810	780	750	264
			(Budget)	1,000	1,000	1,000	1,000	250
6	TTY Units (obtain from mfg.)							
3	Graphic Subsystems	241-1	213,060	4,710	4,485	4,395	4,245	1,119
3	Memory Expansion to 8K for 241-1	248-1	20,670	495	480	465	450	81
1	Tape Controller Single Channel - controls up to 8 - Model 657 or 659 (intermixed) Tape Units, provides code conversion, 200, 556, 800, 1600 BPI	3518-3	46,640	855	815	800	770	195
2	Mag Tape Transports - 7-track 800 BPI 75 in./sec	657-2	58,300	860	820	800	780	250
2	Mag Tape Transports - 9-track 1600 BPI - 75 in./sec	659-2	52,470	920	880	860	830	238
Subtotal			\$1,824,350	\$40,365	\$38,471	\$37,761	\$36,467	\$7,245
DATA STREAM			497,460				15,000 est.	
TOTAL 6200 SYSTEM			<u>\$2,321,810</u>				\$51,467	

SYSTEM B-11

APPENDIX C

PROPOSED DIGITAL CONTROL REQUIREMENTS

A preliminary sizing of the flight control computer system has been made. This provides a basis for commonality and modularity in the systems required for ETS-1, Test Cell C, and the ANSC Laboratory.

1. Acquisition of data from 500 to 700 channels.
2. Conversion of input data to usable units and averaging as required.
3. Examination of input data for critical malfunctions and action where appropriate.
4. Verification that previous control action is being accomplished.
5. Calculation of control action required.
6. Examination of control action required for reasonableness and action where appropriate.
7. Conversion of control action to output units.
8. Output of control action required.
9. Verification of the validity of input data to detect possible transducer malfunction.
10. Examine component data for trends indicating the possibility of long term failure.
11. As necessary, change algorithms to compensate for inaccurate or incorrect data, etc.
12. Prepare data for telemetry.
13. Output telemetry.

<u>Item</u>	<u>Input Rate Samples/sec</u>	<u>Output Rate Samples/sec</u>	<u>Program Steps Steps/sec</u>	<u>Memory</u>
Acquisition of data	15,650	0	2,500	1,650
Conversion of data to usable units and averaging	0	0	360,000	4,000
Examination of the input data for critical malfunction (Worst case corrective action)	0	0	31,250 (250,000) *	7,500
Verification of previous control action	0	0	12,500	100
Calculation of control action (Worst case corrective action)	0	0	212,500 (31,250) *	9,000
Transmission of control signals	0	2,500	25,000	100
Verification of each input signal	0	0	13,250	13,000
Trend detection	0	0	5,500	41,000
Telemetry system	NOT DEFINED			
Executive system			102,000	16,000 2,000/processor
TOTAL		Best case	764,500	92,350 + 2,000/processor
		Worst case	1,045,750	
*Additional Program Steps				

SUMMARY OF PROGRAM STEPS AND
MEMORY REQUIREMENTS FOR EPIC CONTROLS COMPUTER SYSTEM
WITH MAXIMUM SAMPLING RATE OF 50 SAMPLES/SEC

TABLE C-1

These tasks are expected to be started on a time basis, at present expected to be in the order of every 0.01 sec. Note that the entire process as can be accomplished over several time frames.

Table C-1 is a summary of the total requirements.

1. Acquisition of Data

550 A/D channels are estimated to be acquired as follows:

250 channels at 50 samples/second or 12,500 samples/second
150 channels at 20 samples/second or 3,000 samples/second
150 channels at 1 samples/second or 150 samples/second

This is an effective data rate of 16,000 samples/second. To start the input operation will require 50 program steps (PS) at the beginning of each frame. In addition 1650 words of memory will be required to keep three frames of data at all times.

2. Conversion of Data to Useable Engineering Units

This task will require 10 program steps/conversion and 4,000 words of memory to store the conversion tables. After the data has been converted approximately 40 average/reject channels will be calculated every frame. The calculation of an average/reject channel will require 100 PS.

3. Examination of the Input Data for Critical Malfunctions

Approximately 25 PS will be required to detect any one of 25 possible critical malfunctions every frame of input data (50 frames/second). Some 2500 words of memory will be required for storage of data used to detect the critical malfunctions. When a malfunction has been detected, an additional 200 PS each frame of data will be required for corrective action and 5000 words of memory for storage of data to be used in the corrective action.

4. Verification of Previous Control Action

Every frame, the 25 critical control signals will require 10 PS to verify the action taken during the previous frame. Some 100 words of memory will be required. The verification will probably be to check for a large change in the control signal.

5. Calculation of Control Action

The evaluation of the control laws will be required every frame for each of the 25 control signals. The evaluation of the control laws will require 120 PS and 8000 words of memory to store the control law coefficients. Before the control action is transmitted to the actuators each control action will be checked against the previous action to determine if this is a reasonable action. Each check will require 50 PS and 200 words of memory. When an unreasonable control action is detected an additional 25 PS and 200 words of memory will be required to take corrective action.

6. Transmission of Control Signals

Transmission of 50 control signals 50 times a second will require 10 PS for each control signal to convert the signal to a suitable output form. This requires an output transfer of 2500 samples/second. Some 100 words of memory will be required for storage of the conversion factors. This will also require 50 D/A converters.

7. Verification of each Input Signal

Each input signal must be checked for validity to detect any possible transducer malfunction. This process will be accomplished once every second for all 550 inputs using 3000 words of memory. The detection of a possible error will require 15 PS. Corrective action routines will require 10,000 words of memory and an average of 5000 PS.

<u>Item</u>	<u>Input Rate Samples/sec</u>	<u>Output Rate Samples/sec</u>	<u>Program Steps Steps/sec</u>
Acquisition of data	20,650	0	5,000
Conversion of data to usable units and averaging	0	0	500,650
Examination of the input data for critical malfunction (Worst case corrective action)	0	0	625,000 (500,000) *
Verification of previous control action	0	0	25,000
Calculation of control action (Worst case corrective action)	0	0	212,500 (31,250) *
Transmission of control signals	0	2,500	25,000
Verification of each input signal	0	0	13,250
Trend detection	0	0	5,500
Telemetry system	NOT DEFINED		
Executive system			122,000
TOTAL		Best case	1,533,900
		Worst case	2,065,150

*Additional Program Steps

SUMMARY OF PROGRAM STEPS AND
MEMORY REQUIREMENTS FOR EPIC CONTROLS COMPUTER SYSTEM
WITH MAXIMUM SAMPLING RATE OF 100 SAMPLES/SEC

TABLE C-2

8. Trend Detection

All component data will be observed once every second for any trend indicating the possibility of a long term failure. Each of the input channels will require 10 PS for this action each second and 41,000 words of memory to store the trend information.

9. Telemetry System

The telemetry system requirements are not known at this time. However, there are two steps which will be required. First, the data will have to be converted to a form suitable for transmission. Second, the output operation will have to be started.

10. Executive System

An executive system to manage the entire processing system will be required. The executive system will be the link between the outside world (input of data, output of data, crew requests) and the calculation being performed. As the data is input it may be necessary to change the algorithms of particular functions to further compensate for inaccurate or incorrect data. This aspect of the executive program will require 8000 words of memory and 2000 PS/second.

Every time a frame of data is input, the executive program will have to verify that the algorithms are being scheduled correctly and that the algorithms for the previous frames were completed correctly. In addition to this the executive program will be required to monitor the communication line from the crew in order to respond to any requested action. Accomplishing these tasks should require 2000 PS every frame and 8000 words of memory.

In addition to the executive routine each processor will probably require 2000 words for the processor monitor.

In order to obtain an estimate of the effect a higher sampling rate would have on the computer sizing, the following assumptions were made:

(1) 100 of the 250, 50 sample/second, channels will be received at 100 samples/second.

(2) 20 of the 40 average/reject channels will be calculated 100 times per second.

(3) The 25 critical malfunctions and the 25 critical controls signals will be operated on 100 times per second.

(4) The executive system would require an additional 20,000 PS/second. Table indicates the effect that this higher sampling rate will have on the number of program steps per second required.

I. GENERAL DIGITAL CONTROL CONCEPTS

A. SPECIFICS FOR "R" SERIES TESTS

Development of NERVA engine flight digital control system concepts is planned for implementation during the "R" series tests to be conducted at Test Cell C. These digital control systems are planned to provide on line reactor and feed system controls, malfunction controls, test system checkout, supervisory system, controls data processing and system interfacing.

B. COMMONALITY FOR ANSC, ETS-1 AND TEST CELL C

Digital control systems are required to be implemented on common or similar digital computer hardware located at ANSC, ETS-1 and Test Cell C. Commonality of digital computer hardware is required for these three locations and is factored into the NERVA reactor test control computer requirements for TCC.

II. BASIC SYSTEM REQUIREMENTS

A. REACTOR CONTROL REQUIREMENTS

A demonstration of the control of the reactor thrust chamber temperature by means of a digitally-implemented state-variable feedback controller is required. Control inputs in response to changes in temperature demand will be applied to the control drum and support system control valve actuators.

The control laws will consist of linear combinations of the reactor state variables. The constants or feedback gains required to obtain the desired system response will be determined at several operating points and stored in the control digital computer to be multiplied by the state variables. The feedback gain vectors will be modified as functions of the reactor operating point, which is uniquely determined by thrust chamber pressure and temperature.

A two-dimensional table look-up of the feedback gains as functions of chamber pressure and temperature will be used to update the control law as the reactor operating point changes. Approximately 20 state variables are to be used for reactor control. These states will be derived from averages of 125 input variables from the reactor sampled at 50 sec. The two controller outputs will be updated 50 times per second and directed to the 18 control drums and the two redundant SSCV actuators, respectively.

Roughly 1000 program steps in the control digital computer will be necessary to multiply all the states by their feedback gains for the two control laws, and to look up the gains in the tables as functions of the operating point variables. Included in this task is the generation of the chamber temperature demand profile.

In addition to the stored program memory allocation, the storage of the feedback gains and the demand profiles will require approximately 4000 words of memory, assuming a division of the operating map into roughly 50 regions.

B. FEEDSYSTEM CONTROL

The facility propellant feedsystem controller will also be a state-variable feedback design. Digital-to-analog conversion will be required to input the control functions to the analog actuators of the feedsystem. The feedback states will be derived from 75 input channels at 50 samples per second. The control outputs are updated at the same rate, and are used to control reactor flow by means of the TPCV's and the entire impedance valve. Calculation of the control law will require about 400 program steps, and 2000 words of memory are required for storage of the feedback constants.

C. OPERATOR AND DATA SYSTEM INTERFACE

Inputs from operator consoles and output to same will be required for the conduction of reactor testing. These inputs will take the form of analog signals requiring A-D conversion in the case of manual trims and binary signals in the case of emergency shutdown and manual override. The outputs will be analog indication either on meters or strip chart recorders (requiring D/A conversion), or binary indicator lights detailing run phase, and error states. Events such as these and demand signals will be required to be recorded in the PAM/FM data system and therefore will require D/A conversion.

Fifty channels of input and 50 channels of output will be required at a sample rate of 10 per second. Two hundred program steps will be required to service this function.

D. MALFUNCTION CONTROLS

On-line malfunction controls are required to ensure reactor operation within its permissible operating limits. These malfunction controls provide detection in the event of component failures in either the reactor control system or feedsystem controls. After a given failure is detected specific control actions are required to permit continued operation of the reactor or to perform an emergency shutdown.

Proper operation of the reactor in the event of component failures is provided by means of 25 input and output channels with a sampling rate of 100 samples per second with allocation of 2250 program steps are estimated for malfunction control.

E. CHECKOUT

1. System Validity

In the period immediately prior to an experimental plan (generally R-1, R-2, and R-3 days), there is a requirement to exercise and validate the entire control system.

2. Simulation

In order to perform the required tasks of this section, some minimal amount of simulation must be made available. Such simulation will not, of necessity, include an entire model of the test article and facility but some critical subsystems will be simulated probably in a linear fashion with some assistance from analog hardware.

3. Operator Training

The control room operating team will require training or updating of existing operating skills in order to qualify for reactor testing. This activity will be best performed under the auspices of the digital computer system while operating in a simulation mode.

4. Data System Calibration

In order to facilitate the conversion of digitized data to engineering units in an expeditious manner, it will be necessary to analyze an impressed voltage calibration at some time prior to run day and make corrections to the transducer calibration data to account for the data system parameters. It is suggested that this voltage calibration include not only the current eleven step impressed voltage injected prior to signal conditioning but also some voltages injected at the input to the A-D to produce meaningful calculations in the design regions of reactor operations.

5. Checkout Requirements

The checkout activity is not a real-time function and therefore no time estimates are needed. It is, however, a function that will have to utilize some or all of the software components of the overall control system and therefore will require memory capacity in addition to that of the general system. However, no input or output channels in addition to those already specified will be required. Approximately 10,000 words of memory will be required for this function.

F. SUPERVISORY SYSTEM

1. Adaptation of the Control Law to Changes in the Plant

The controls laws, as initially implemented, result in a desired closed loop response of a nominal reactor system. The adaptive feature

of the digital-state variable feedback controller will provide for modifications to the feedback gains as functions of the corrosion history of the core. This will be implemented as an 'A' priority function of the deviation of the SSCV position at the design point, compared to the zero-corrosion position at first startup. The gain tables will be modified according to the predetermined algorithm as corrosion is detected through SSCV and control drum movement.

A relatively slow repetition rate is to be used for this task, with about 750 program steps being executed every 100 seconds. Total memory required is 1000 words.

2. State Variable Estimation

Several state variables that are to be used in the feedback controller design are not measurable. Examples of such variables are delayed neutron precursor concentrations, or power during the early phases of startup. In order to accomplish a complete state variable feedback design, it will be necessary to estimate such unmeasurable states.

Some alternative approaches to the solution of the estimation problem exist, and some variations may be investigated in the basic system to satisfy the estimator requirements. One workable approach is to develop optimal reduced-order linear models of the system at several reactor operating points. These models may be used to find linear observation filters to reconstruct the unknown states, or to derive minimum variance estimation algorithms such as the Kalman filter. The first case requires storage of the linear model coefficients as functions of chamber temperature and pressure, and solution of a system of differential equations of order equal to the number of unknown states, in real time. The second candidate for state variable estimation requires solution of a much larger system of equations.

In order to implement at least the simpler observer-filter approach, approximately 5000 words of memory are required for storage of the linear model parameters, and 1500 computer program steps will be necessary for solution of the observer differential equations.

The estimator must also have the ability to estimate states that are lost during the reactor run. The estimator then will expand to accommodate this case.

The estimation process will also include digital filtering of some of the measured states for the observation algorithms. Storage of the filtering weighting constants will require at least 1000 words of computer memory.

3. Computer Status

The digital control computer system must be self checking in order to protect against test article failure due to a failure of the computer. Through diagnostic programs and other means to be determined, the supervisory system determines if there has been an internal failure and attempts to correct for such failure. Corrective action will consist of, as a minimum, a hold on the control demands and a warning to indicate manual override is required and/or provisions to protect the integrity of the non-malfunctioning components of the system. In the case of a multiprocessing configuration, this action would be typified by closing the ports of common memory to the offending CPU so that valid data could not be overwritten. Ultimately, correction of internal malfunctions would consist of switching some other component in to take over the function of the malfunctioning component.

One thousand words of memory will be required for this function.

G. DATA PREPROCESSOR

Some 200 channels of A/D information at 50 samples per second will be required. Processing of this 10 KC data stream will consist of the following:

1. Conversion to Engineering Units

Each data point must be converted to engineering units by table look up (in the case of non-linear transducer calibrations such as thermocouples) and linear interpolation. This process will require 30 μ sec (assuming a basic machine cycle of 1 μ sec, which will be nominal for all hardware considered). Therefore, 6m sec will be utilized for the 200 channels. Three thousand words of memory will be required.

2. Averaging

Averages will be required on certain sets of channels and rejection will be employed iteratively until a "good" average is obtained. If 10 averages of 10 channels each are required and one iteration on each average is performed 400 μ sec will be used per average for a total of 4m sec. Two thousand words of memory will be required.

3. Engineering Calculations

Several engineering calculations will be required to make available for subsequent processing parameters which are not amenable to direct measurement. These calculations will include but will not be limited to the following.

- a. Hydrogen properties - 4 m sec required for 10 properties - 3K core
 - b. Chamber temperature) All other application programs
 -) require 2 m sec
 -) and ~ 1K core
Total core	9K
Monitors	6K
	15K Total

PREPROCESSOR EVENTS DURATION

Figure C-1

4. Processor Timing

Figure C-1 shows the time duration of preprocessing events for the assumed 50 samples per second duty cycle of 20 m sec.

H. SYSTEM INTERFACING

A/D and D/A conversion is required to interface digital computer system hardware with the analog computer CAM models used for analysis at ANSC and WANL. High-level analog voltages with a range of ± 100 volts which are used on these cam models interface with these conversion units.

Interfacing with the digital and analog actuators requires addressable buffers, which are special designed hardware for use at Test Cell C.

I. OPERATIONAL REQUIREMENTS

Apart from the functions and facilities necessary to satisfy the test requirements, there are other considerations of operational nature which will be reflected primarily in the peripherals attached to the digital control system. Some minimum set of peripheral devices will be essential to operating the machine, perhaps only a typewriter and slow-speed paper tape reader punch. However programming, assembling, debugging, and monitoring would be severely restricted without other devices to augment the operator-machine dialogue.

For example, it would be advantageous to make the assembler supplied with the system look like a one-pass assembler, although it will undoubtedly be a two-pass process. This could be easily done through the addition of a bulk storage device, such as a magnetic tape or a rotating memory.

Other peripheral applications of this nature will be considered in terms of cost-effectiveness.

III. ALTERNATE SYSTEM NUMBER 1

The requirements of this system are the same as Item II with the exception of the deletion of Item II.F, the supervisory system and a reduction in scope of Item II.E, the checkout system. This system is proposed merely to meet the exigencies of budgetary requirements and represents an alternate of reduced scope to support the R-1 reactor test.

IV. ALTERNATE SYSTEM NUMBER 2

The requirements of this system are the same as those stated in Item II with the abridgements of Item III and the further deletion of the feed-system control (Item II.B) with accompanying reduction of the data preprocessing requirement (Item II.G) in the number of channels.