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On-line Computer Facility
and Operating System COSACS
at the ANL Fast Neutron Generator

by

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	5
I. INTRODUCTION.	5
II. THE ON-LINE COMPUTER FACILITY.	7
A. General Description.	7
B. External I/O Channels	8
III. THE OPERATING SYSTEM COSACS	9
A. Design Background	9
B. Structure and Composition of COSACS.	11
1. Basic Outline	11
2. System Dynamics	12
3. The EXECUTIVE	12
4. Data Flow, Control Routine.	15
5. UTILITY Routines.	15
C. Support Software	16
IV. SUMMARY	16
APPENDIXES	
A. Summary of Command Codes in COSACS.	17
B. Summary of COSACS Subroutines.	18
C. Summary of Support Software	22

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.	Schematic of On-line/Off-line Computer System	6
2.	Core Map and Operation Scheme of COSACS	12

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
I.	Instruction Set for Standard Experiment Control.	11
II.	Subroutines Used in COSACS.	15
C.1.	Support Program Command Code Input Table.	23

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ABSTRACT

An on-line/off-line computer system has been installed at the ANL fast neutron generator (FNG) for on-line data acquisition and storage, and for off-line data reduction and evaluation. An operating system called COSACS has been written specifically for the installation. The present report describes all available hardware and software, but emphasizes those aspects of both that were tailored for this application. The various physical-data channels, both input and output, are discussed with regard to transfer rates, bit formats, and interrupt control. The general relationship and areas of compatibility of COSACS with standard compilers and assemblers is discussed. A complete tabulation is given of operations available under COSACS, together with their input/output formats.

I. INTRODUCTION

An on-line/off-line computer system was installed at the ANL fast neutron generator (FNG) facility for on-line data acquisition and storage, and for off-line data reduction and evaluation. The system consists of two medium-sized computers (System Engineering Laboratories Model 840MP, 16K, 24 bits), supported by a complement of peripherals. A block diagram of the total system is shown in Fig. 1. One of the computers is dedicated to on-line data acquisition and storage; the second computer is intended mainly for off-line data reduction and evaluation. However, a fast bidirectional data channel is available between both computers to facilitate the direct transfer of data for reduction and evaluation as well as fast data dumps to the peripheral units of the off-line system. Independent data-output peripherals (paper tape and disk) are available at the on-line computer.

An operating system, COSACS (Computer Operating System for the Acquisition and Experimental Control of Spectral Data), residing in the on-line computer, provides experimental control and directs data-flow operations. There is a sufficient overlap of the utility functions of COSACS and the standard

840MP off-line operating system to ensure simplicity in the preparation and assembly of COSACS user programs, and in the off-line retrieval and scanning of data stored under COSACS control.

Fig. 1. Schematic of On-line/Off-line Computer System. ANL Neg. No. 116-1551.

Although the various experiments encountered in the FNG program may require a large variety of input/output (I/O) operations and data-storage procedures, the necessary experimental control is similar in most of these experiments. In addition, the resulting data are of a spectral nature in most of the applications. These unifying parameters permit the operating system to employ a standardized set of utility subroutines for I/O operations and data handling that can be called into action by the experimenter's individual data-handling routines.

Basically, COSACS is a core-resident operating system (O.S.). However, bulkier utility routines may be stored on the disk and called in when needed. In the final composition of COSACS, a compromise in the allocation of core space retained a reasonable degree of user convenience and also reserved adequate core for fast storage of experimental data.

II. THE ON-LINE COMPUTER FACILITY

A. General Description

As mentioned in Sec. I above, the total computer system at the FNG site consists of two physically separate sections: the on-line computer with its associated peripherals, and the off-line computer with its peripherals. However, this discussion will be restricted mainly to the on-line computer. The off-line facilities will be viewed as additional I/O devices peripheral to the on-line computer.

The nucleus of the system is a 24-bit-word computer with a 16K core memory and a cycle time of 1.75 μ sec. The computer has the usual complement of hardwired instructions and 14 levels of priority interrupt. The immediate peripheral complement of the on-line computer consists of a magnetic disk, a CRT display, a standard ASR-33 teletype keyboard, and a fast paper-tape punch and read system.

The magnetic disk provides a 10^6 full-word auxiliary-storage area on 10 parallel surfaces with movable heads. Each head spans 100 tracks, which in turn are subdivided into 16 sectors of 64 words each. A minimum of one sector can be read or written on a single request. The maximum latency time can be as high as 145 msec. However, if the program limits the storage area to blocks of 10,240 words each (maximum available without moving a head), the maximum latency time is reduced to 25 msec. There is control circuitry for direct memory access from the disk that bypasses the normal CPU program once it has been activated. This device, called the BTC (Block Transfer Control), can transfer large blocks of data in either direction between the disk and the core memory. Before the operation is started, it is necessary to initialize the BTC with the corresponding areas of transfer on this disk and in the core, but once initialized, the transfer is relatively fast (19.4 μ sec/word) and is performed independently of the current program executed by the CPU.

The inherent capabilities of the CRT display interfaced to this system are somewhat more extensive than those usually found on similar systems. The 16-in. CRT can display on a 1023 x 1023 matrix with variable intensities and is hardwired for a full alphanumeric character set. It contains a device similar to the BTC of the disk (computer graphics processor or CGP), which permits the block transfer of data from the core memory to the display control, independent of the current computer program. In addition to these standard capabilities, this display is also able to recognize and execute a selection of specific instructions that can be interspersed at random in the data blocks being transferred. These instructions include line-texture control, character-set control, address-transfer control, and interrupt control. In effect, the display-control unit acts like an extension of the main computer.

The standard ASR-33 keyboard input to the computer is a common peripheral and therefore needs no further discussion. The fast paper-tape unit is a similarly common usage device with a speed of 300 characters/sec on the reader and 120 characters/sec on the punch.

In addition to these standard peripherals, the on-line computer is equipped with a fast-data and control channel to the off-line computer whereby all the peripherals attached to the off-line computer can become on-line peripherals to the on-line computer. These peripherals include a line printer, card punch, card reader, two magnetic-tape drives, and another magnetic disk.

The fast-data channel connecting the two computers is called the CCL (computer-to-computer link). This link is bidirectional and has a parallel word-transfer rate in excess of 10^5 words/sec. It uses a total interrupt technique in that both computers are under interrupt control during the transfer. This is significant in that information loss due to "runoff" is prohibited and also permits foreground-background operation in both computers while the transfer is being made.

B. External I/O Channels

The on-line computer system communicates with the experimental system via two identical devices known as data terminals 1 and 2 with two different device codes (20 and 21). Each of these data terminals is a multipurpose unit capable of servicing any number of external devices such as analog-to-digital converters, scalars, and relays. It is capable of transferring full parallel-word information in either direction and is equipped with two levels of interrupt. The mode of interrupt operation is that the external device activates the interrupt to the computer when a word is transferred from the device to the data-terminal register. The word will remain in this register until accepted by the computer.

Data terminal 1 services two analog-to-digital converters (ADC 1 and 2) and a set of six external control toggles. The ADC's each have a 12-bit capacity so that a single-word input to the computer will read both ADC's. However, before entering the computer, the 24 bits pass through a patchboard to permit the experimenter to substitute identifying levels in exchange for ADC bits. For example, one setup would allow 12 bits from ADC 1, eight bits from ADC 2, and four bits for detector identification. The six external control toggles permit the computer to set or reset control flip-flops with optional relay-closure outputs. These can be used to position samples, control beam gates, or pulse the beam itself, under computer control.

Data terminal 2 is interfaced to six multipurpose scalars, two of which are presetable. All the scalars have optional clear, start, and stop, which may be initiated from the computer, externally or from a preset count recognition. Each scalar has an external input, which may also be externally gated.

In addition, there is an internal pulser of 100 kHz, which may be switched to any input. In conjunction with the scaler circuits, an external real-time clock, which is normally routed to the input of scaler No. 6, is available for process timing. This scaler has been modified slightly to facilitate the "clocking process" of COSACS. Under normal circumstances, when the computer reads any particular scaler, the transfer automatically stops the scaler, and it must be restarted by an independent action. However, scaler No. 6 can be read, and the restarting action is automatic.

Both data terminals are capable of servicing additional external units. The present configuration may be expanded as the need develops.

III. THE OPERATING SYSTEM COSACS

A. Design Background

Apart from the programmatic requirements, which, of course, form the dominant influence in the O.S. design, there exists a background of constrictions in which the O.S. must function. These constrictions are really functional requirements, and stem from two major sources: the availability of computer hardware, and the mode of operation of the FNG facility. The availability of the hardware implies not only the quantity but also the reliability of the hardware.

For this O.S. design, the availability of hardware is determined by the computer system described in Sec. II. Obviously, not all of this system can be dedicated to on-line use continuously, since this would eventually cause a backup of other necessary data-reduction operations. However, the "on-line" system is indeed totally dedicated to on-line use and is not normally available for tasks such as compiling, assembling, or preparatory program checking. These must be performed on the "off-line" system, which contains identical peripherals except for the data terminals and display unit. (To check programs involving the display unit, there exists a third computer system with an identical display, which is available on a "use-if-free" basis.) The regular "off-line" system is available on a first-priority basis for on-line operations at the FNG facility, and there are utility routines incorporated in COSACS that can handle a continuous flow of data via the CCL. COSACS generally restricts its use of the "off-line" system to (1) dumping large blocks of data to the magnetic-tape units and (2) occasional transfers of selected data for plotting, card punching, or line printing.

Inherent long-term reliability characteristics of each peripheral unit in a computer system have a definite influence on the design of an O.S. Experience has shown that even a well-maintained magnetic-disk system has a much higher failure probability per unit time than the paper-tape system or the teletype. This is characteristic of all disk systems and is the result of

the large difference in the electrical and mechanical tolerance demands between the various types of units. Similar comparisons can be made with large display systems.

As a result of this uneven unit reliability, COSACS is designed to avoid total dependence on units that have a higher than normal probability of breakdown. Specifically, COSACS contains a basic core-resident section that permits all necessary operations, with restricted ease of handling when the disk system is disabled. However, nonresident utility routines with extended capabilities and handling ease may be placed on disk or paper tape and called in at execution time by the COSACS "EXECUTIVE" or any data-flow control program using the COSACS disk read-and-write routine.

Another influence on the design of the O.S. stems from the range in the technical proficiency of the personnel actually using the system. The FNG is normally scheduled for operation 24 hours a day, 6 days a week. The usual duration for any particular set of experiments is one to two weeks, during which a sequence of FNG beam exposures is performed with various energies, samples, geometries, and other experimental parameters. The FNG is operated in three shifts by technicians who are not normally trained in computer techniques but are required to perform some operations on the computer, especially during the two night shifts. In response to this working environment, the COSACS executive control language is of a mnemonic nature and the control input is from the typewriter.

Most sets of experiments that are run at the FNG site go through several characteristic phases. The first phase is a major setup procedure during which the experimenter personally interacts with the computer. In this phase, some data are usually collected in order to adjust threshold settings and timing as well as to check various experimental parameters such as count rates, background contributions, or broad spectral characteristics. For this phase, an extended set of operations by the computer is needed.

In the second phase, the experiments are monitored and controlled by the FNG operators. The primary duty of these operators is to tend to needs of the FNG and to provide the experimenter with a particle beam whose energy and current correspond to a schedule previously determined by the experimenter. Beyond those duties, the FNG operators perform any necessary manipulation of the targets, samples, or detectors. They may also be required to start initial test runs on the computer, display the accumulated data, extract certain fiducial points from the data, feed these points back into the main runs according to the preset schedule of the experimenter, and possibly monitor the displayed data for gross characteristics. During a particular run, the FNG operators may find it necessary to interrupt the data accumulation temporarily for FNG preventive or remedial maintenance. This again requires interaction with the computer by stopping and restarting, but without clearing any previous data. At the termination of each run, the accumulated data have to be transferred from the core storage to an intermediate storage. Each of

these computer interactions with the FNG operator must be performed in such a way that the operator is not required to be familiar with the internal computer logic, but he must know what is being accomplished by each action. It is also extremely helpful to the experimenter if a chronological record is kept of each action performed during his absence. Since all external interactions with the O.S. are directed through the teletype, this record is available on the teletype output sheet.

Corresponding to these two phases of a typical experiment, two sets of instructions were provided in COSACS. The first set is used in the first phase extensively by the experimenter, who has a more detailed knowledge of the experiment and of specific storage locations in the computer. This set includes instructions for transferring data for temporary storage retrieval or display, core operations, tests of special functions, and coding support. The set of instructions exclusively used in the second phase avoids using specific storage locations and parameter input. These are shown in Table I.

TABLE I. Instruction Set for Standard Experiment Control

Input Code Word	Operation
TEST	Data area is cleared. Input of new data is started.
RUN Comment line	Start of a run. The comment line serves for recording run number, experimental parameters etc. Operation is as for TEST.
STOP	End of a run. The output of data is initiated, parameters are updated, etc.
WAIT	Operations are halted, time of interruption is recorded, and partial output of parameters is initiated. Further instructions are awaited.
CONT	Data input is resumed. Start time of the continuation is recorded.
STORE Input values	Input of parameters relevant to the experiment and data recording.
SCA	Copy of present scaler readings to the typewriter (simultaneous).
DISP1 ... 4	Specific data displays.

B. Structure and Composition of COSACS

1. Basic Outline

COSACS consists of three major parts: the EXECUTIVE routines, the DATA FLOW CONTROL routines, and the UTILITY routines.

The EXECUTIVE provides the software interface between the user and the remaining parts of COSACS. In effect, they interpret user messages entered on the teletype and initiate the appropriate subroutines for the corresponding action.

The DATA FLOW CONTROL routines are those routines that actually call the experimental data into the computer and store them according to the individual format requirements of the experimenter.

CORE MAP OF COSACS

OPERATION SCHEME OF COSACS

Fig. 2. Core Map and Operation Scheme of COSACS. ANL Neg. No. 116-1738.

The UTILITY routines constitute the actual "task library" available to the EXECUTIVE. However, they are separated from the EXECUTIVE routines so that they can also be available to the DATA FLOW CONTROL routines.

Figure 2 shows the interrelation of the three major parts of COSACS and their position in the core.

2. System Dynamics

Superimposed upon the three major parts of COSACS is the priority-interrupt system, which is normally activated during run time. The highest-priority interrupt is assigned to the typewriter input so that the user always has the prerogative to change the course of the experiment at any time. The next highest priority is assigned to data terminal No. 1. This assignment was made so that experiments that must contend with extremely low count rates can still be programmed for a live display without losing any data. All other peripherals have a priority assignment that

is arbitrary most of the time. The entire priority assignment, however, can be changed to any particular pattern by reconfiguring a patchboard. The use of the priority interrupt permits the EXECUTIVE to make decisions based upon immediate program needs rather than upon a fixed sequential set of instructions. The EXECUTIVE does this by always returning to a waiting loop after each individual operation and activating all interrupt levels. Since the teletype input has the highest priority, any instruction typed in will always receive the immediate attention of the EXECUTIVE. However, in the absence of typewriter input, data terminal No. 1 input will always be serviced first.

3. The EXECUTIVE

The EXECUTIVE comprises a number of software units. A short description of these units and their operation is given below.

The Thumb-In Program Loader was derived from the SEL 840 thumb-in loader and is located at locations 0-14. It usually resides intact in the core, but is occasionally destroyed and must be manually restored. A

"no operation" instruction (NOP) is placed at position 0 because this position is occasionally cleared in an FNG shutoff or other power surge. Loading the program with a zero in the first location requires only actuating the START switch a second time. The loading procedure is terminated by a branch to the entry of COSACS.

The Parameter Table contains several locations to be loaded with values specific for certain experiments. The first-word addresses (FWA's) and word counts (WC's) for up to four special displays have to be stored at locations '47-'56. (The use of ' before a number indicates it is an octal number.) At locations '20 and '21, the clock interrupt time is stored. At '75, the FWA for nonresident programs loaded from paper tapes should be stored. At '76 and '77, the FWA and WC for special typewriter input, originating with the command STORE, must be loaded.

The Priority Interrupt Locations are from '100 to '117. As previously explained, the highest priority was assigned to the typewriter. The typewriter input will also cause an interrupt on the standard interrupt level '116. This permits the use of the identical programs on the on-line as well as the off-line computer system. The next highest priority was assigned to the input interrupt from the data terminal. This order ensures the capability of live displays, etc.

Entry into COSACS is from '120. The priority of the typewriter input from keyboard is enabled here. The exit from ENTRY goes to the WAIT subroutine, in which the computer stays until an interrupt from the typewriter provides an exit. This interrupt directs the program counter to the command code input, decode, and routing routine.

In the Command Code Input, Decode, and Routing Routine of COSACS, all interrupt levels are reset and the interrupt time is recorded. The instruction code is entered from the typewriter using the subroutine CODE. The code is compared with a list of code words. If the code is not found in this list, an error message occurs on the typewriter. If the code is found in the code library, the computer will branch according to a parallel-ordered routing library.

The Command Code Library contains all the command codes incorporated in the system; they are summarized in Appendix A. The codes are obtained from the last two octal digits of the ASR-33 teletype character codes. These truncated characters are stored sequentially in a word. For example, the typewriter input DISP (ASR 33 codes: D = '304, I = '311, S = '323, and P = '320) corresponds to the octal command-code data word '04112320. Code words of less than four characters are right-adjusted and filled with zeros.

The Command Routing List contains the branch addresses for the corresponding instruction codes. If the instruction code was found at the nth place in the instruction-code library, the computer will branch to the address

given at the n th place in the routing list. Thus, extending the present instruction capability requires placing a card DATA 'X₁X₂X₃X₄X₅X₆X₇X₈ (where X stands for an octal digit) in the code library at the i th place and a card DAC ENR or DAC \$ENR at the i th place in the routing list at assembly time. Here ENR may be an existing location in COSACS, the entry location of an addition to COSACS, or the location at which such an entry location is stored (indirect addressing). \$ENR would be an added subroutine whose entry location is inserted into the program counter.

The Input Format of Command Codes and Parameters to COSACS is via the typewriter. The first word is a command code, as listed in Appendix A. The input of a code word is completed by a blank or a carriage return (CR). If the code word is found in the library, the typewriter is ready for any necessary parameter input. These parameters may be separated by one or more b's or one CR. Decimal values require a D in front of each single parameter. A parameter input may be canceled by an ↑ input if executed before a "b" or a CR. During the parameter input, all nonnumbers except D, +, -, b, CR, and / cause an error message. After this message, the computer is ready to take the correct parameter.

Instructions and their functions are grouped in Appendix A according to the I/O unit or operational class.

A major part of the EXECUTIVE provides for the initiation of the appropriate subroutines according to the given instructions and the proper return to the main control program. Appendix B contains a more detailed description of these subroutine capabilities.

Nonresidents are linked to the main program by the instruction LOAD TAPE or LOAD DISC. The former causes loading of a program from paper tape and requires no additional parameters; the latter loads from the disk. The name of the nonresident is required in the latter case.

The nonresident program must be a completely independent ASSEMBLER or FORTRAN routine. A special entry arrangement is used: The first word is the entry point at which the return point will be stored. This address is identical with the FWA of the parameters (not the parameter addresses as usual). The FWA for the nonresident is taken from location '75 if the nonresident is loaded from a paper tape. If the nonresident is stored on the disk, the head number and the FWA are merged in the data word contained in the disk data-word library. The most significant octal digit contains the head number; the next four octal digits contain the FWA. For example, a nonresident stored at head 4 of the disk nonresident library (track 1 only), which will be stored at address '5000 in core, has the data word '45000000. If the nonresident is loaded from the disk, the core contents will be preserved on track 0, head 0, and restored after the operation with the nonresident is finished.

4. Data Flow, Control Routine

These subroutines vary from experiment to experiment and are generally provided by the experimenter. In some cases, the particular experimental control and data format will correspond to some standard DATA FLOW CONTROL set or a set previously used, with changes only in the dimensions of stored quantities. However, in the event the experimental control calls for specialized formatting or sequencing of data, the experimenter is required to provide his own DATA FLOW CONTROL routine. In programming this set of routines, the experimenter can make liberal use of the UTILITY routines, especially the standard output routines which are already part of COSACS. In actuality, then, the part that must be provided by the experimenter is only the input and storage loop, usually not more than 40g-100g assembly language instructions. The DATA FLOW CONTROL routines are linked to the EXECUTIVE with the general instructions such as TEST, STOP, WAIT, and RUN, or special instructions that may be added by the experimenter to the instruction code library. The address linking is performed at assembly time. Extensive use of the subroutines and utilities provided with COSACS may be made, and FORTRAN subroutines may also be used. However, I/O functions in FORTRAN format must be excluded.

5. UTILITY Routines

These routines contain all the I/O handlers, some spectral arithmetic, test routines, and code support routines. Some of these routines are used exclusively in COSACS. Most of the I/O handlers, however, are useful for data retrieval or display in off-line data-evaluation programs; therefore all these routines are FORTRAN compatible. In addition to the resident utility routines, nonresident routines may be placed on the disk or paper tape and brought into core under COSACS control during run time. The stored data or programs in the core area where the nonresident will reside will be preserved on a special library on the disk while the nonresident is functional. Table II

TABLE II. Subroutines Used in COSACS

Name	Function	Name	Function
RETN	COSACS return control	TIME	Time (clock)
CODE	COSACS command code	SCAL	Scaler reading
WAIT	Wait loop	COSC	Scaler control
TPIN	Typewriter input (parameter set)	FLFL	Flip-flop switch control
TNIN	Typewriter input (single value)	RDSCAL	Scaler reading (all six scalers)
REFL	Typewriter input (one character)	CRLF	Carriage return and line feed
SUM	Sum of the contents of consecutive channels	CHKS	Checksum message
SIFT	Shift spectra to new location	INER	Input-error message
SETC	Set constant contents into determined number of channels	CODER	Code-error message
ADDS	Add/subtract spectra	CCLC	CCL error message
DISK	Disk handler	MESG	Message output
PAPT	Paper-tape handler	COPY	Copy paper tape to typewriter
CCLN	CCCL handler	FPA	Argument transfer
HOME	Initiate disk	RES	Accumulator rescue
DISPL	Display (FORTRAN entry)	BELL	Bell initiated
DISP	Display	MOZART	CCL I/O
GRAP	Display (CGP entry)	KLEE 1	CCL I/O
OVER	Display (overflow entry)	KLEE 2	CCL I/O
TYPE	Typewriter output handler	SKIP	Skip paper tape
INT	Integration	DUMP	Dump disk to magnetic tape

lists each currently available subroutine under its call name and a corresponding semidescriptive title. A more complete description is given in Appendix B.

C. Support Software

There exists a large amount of software that, to varying degrees, is compatible with and complimentary to COSACS, even though not a part of it. This classification actually includes such major programs as the FORTRAN compiler and library and the 840 Assembler; however, there are a number of programs written specifically for the support of COSACS. These programs fall into two categories: those that aid the COSACS user in preparing programs for on-line use with COSACS, and those that aid the user in transposing COSACS data from one form to another for off-line processing. Appendix C presents information needed for the application of these programs and describes the programs individually.

IV. SUMMARY

The system described in this report (both hardware and software) has been assembled from numerous sources. For the most part, the hardware is of standard commercial design. However, there is an appreciable fraction that was designed specifically for this system in response to specific user needs.

The software was written specifically to meet the needs of the experimenter. These areas of specialized design could have possibly been covered by commercial units with some loss of operating efficiency. However, these same areas are highly susceptible to modification and expansion within a changing experimental program. Since most commercial modules (especially the software) are difficult to modify due to their "black-box" effect, it was felt that, in the long run, "in-house" designing would more than pay for itself.

APPENDIX A

Summary of Command Codes in COSACS

Unit	Code	Parameters	Function
Disk	RDD	FWA, 1st head, 1st track, total heads, total tracks	Read disk
	WTD	Same	Write disk
	CPD	Same	Clear part of disk
	CLRD	FWA (1024 dummy)	Clear all data disk
	HOME	None	Zero track
Paper Tape	READ	FWA	Read program tape
	PUN	FWA, WC	Punch program tape
	OUT	FWA, WC	Punch data tape
	INP	FWA	Read data tape
	SKIP	None	Skip paper tape
Typewriter	TYPP	FWA, WC	Type out octal channel and octal contents
	TYPD	FWA, WC	Type out decimal data
	TYPI	FWA (Exit with ,)	Type input (D for decimal)
Core	SFT	FWA, WC, FWA destination	Shift array in core
	CLRM	FWA, WC	Clear memory
	SETC	FWA, WC, value	Set constant value in array
	ADD	FWA, WC, FWA-B, FWA-C	Add 2 arrays. $C = A + B$
	SUB	Same	Difference of 2 arrays. $C = A - B$
	SUM	FWA, WC	Sum of consecutive channels
	INT	Channel 1, Channel 2	Integral, background subtracted
Computer- to- computer Link (CCL)	CCI	FWA, WC, control	CCL input
	CCO	Same	CCL output
	SWB	None	Switch to BACH
	SWG	None	Switch to GOYA
	RMG	None	Rewind magnetic tape (in GOYA)
	RMB	None	Rewind magnetic tape (in BACH)
	PLOT	None	Plot
	DUMP	1st track, total tracks	Dump disk
Display	DISP	FWA, WC	Display
	DPAR	FWA vector	Display parameter input
Tests, Code	FLFL	(Re)Set control	Set or reset control bit output
	SCN	Control	Start, stop, or clear scalars
	BELL	None (Exit with)	Bell
	COPY	None	Copy tape to typewriter
	CODE	Input word	Type out numerical code
	MESG	Word (3 characters in 1 step)	Type out numerical code
Experimental Test	P	None	Repeat last display
	T	None	Test (clear and take data)
	C	None	Continue (add more data)
Experimental Operation	TEST	None	Test (clear and take data)
	RUN	One comment line	Run (clear and take data)
	STOP	None	Stop of run
	WAIT	None	Wait
	CONT	None	Continue to take data
	STORE	Input values	Store experimental parameters
	SCA	None	Copy scalars to typewriter
	DISP1	None	Display 1
	DISP2	None	Display 2
	DISP3	None	Display 3
	DISP4	None	Display 4
Link Nonresident	LOAD TAPE	None	Load nonresident from tape
	LOAD DISC NAME		Load nonresident from disk

APPENDIX B

Summary of COSACS Subroutines

The following tabulation groups currently available subroutines of COSACS into general categories according to their application. In describing these subroutines, we felt that complete detailing of their use such as calling sequences, memory-space requirements, and hardware requirements was not in keeping with the objective of this report. Therefore, these details, although readily available in the complete console documentation, will be omitted here for the sake of brevity, and only a brief description of the character of the subroutines will be given. In the input parameters of each subroutine, the mnemonic FWA reads "first-word address" and refers to the core address of the first word in a block of words to be stored or accessed. Corresponding, the mnemonic WC reads "word count" and refers to the number of words to be handled.

1. Subroutines Used for Transferring Blocks of Data from One Unit to Another

<u>PAPT</u>	This program is the COSACS paper-tape handler which performs both input and output of program sections or data from and to the paper-tape punch and reader. This output can be used for input of data in COSACS paper-tape format in FORTRAN programs. The input parameters call for (1) the FWA, (2) the address where the WC can be found, and (3) the address where routing control is stored.
<u>DISK,</u>
<u>HOME</u>	These programs constitute the magnetic-disk handler for COSACS. They permit one to read or write on the disk in increments of 1024 words. The input parameters call for an FWA, a head and track number, and also a WC in terms of head increments and track increments. An address is also required where the control code for reading or writing can be found. The program HOME positions the heads at zero track and resets the track position counter in the DISK subroutine. Both of these subroutines are usable in FORTRAN and the assembler.
<u>DISP</u>	This program provides the display of one-dimensional spectra on the CRT. There are two versions of this program; one is a point display, the other a histogram display. The input parameters call for (1) the number of channels to be displayed, (2) the FWA of the data, and (3) the FWA of the vector assembly space (essentially a scratch-pad area). Amplitude control and channel-marker control are available from the console switches.
<u>TYPE</u>	This program is the COSACS typewriter handler and is used to output on the typewriter either sections of programs in octal or blocks or data in decimal. The input parameters require the FWA, the WC, and the address of the control word that determines the format.

SKIP This program causes the paper-tape reader to skip one channel. It is necessary that the data be written in a COSACS output format.

2. Subroutines That Perform Arithmetic and Geometric Operations on Spectra or Blocks of Data in the Core

SUM This program can be used to sum the contents of consecutive addresses in the core. The input parameters call for the FWA, the address of the WC, and the address where the result will be stored. There are two different versions of this program. They differ in that, with one, it is possible to accommodate negative numbers, but the capacity of the result address is reduced by a factor of two. The result in both cases is a double-precision number.

ADDS This program can be used to add or subtract two spectra. The input parameter calls for the FWA's, the word count of the first spectrum, and the address of the control word that determines whether to add or subtract.

SIFT This program can be used to shift spectra within the core. The input parameters call for two FWA's (original spectrum and result spectrum) and the address of the WC.

SETC This program can be used to set to a constant value the contents of all channels in a spectrum. The input parameters call for the FWA, the address of the WC, and the address of the constant.

INT This program can be used to integrate between points on a spectrum. Input parameters call for the two channel limits and the address where the result is to be stored.

3. Subroutines That Communicate with External Scalers or Flip-flops

SCAL This program causes any specified scaler to be read. The input parameters call for the address containing the scaler number and the FWA for the result, which occupies two words.

TIME This program causes Scaler No. 6 (this is reserved for the clock) to be read. The input parameter calls for the FWA of the result.

RDSCAL This program reads and restarts all six scalers. The input parameter calls for the FWA of the results.

COSC This program transmits a specified control code to all scalers. Any scaler whose control parameters are switched to the transmitted code will respond accordingly. Possible control options on each scaler include stop, clear, and start. Input parameters call for the address of the control number.

FLFL This program transmits a code to six flip-flops, which will ensure any desired configuration of set and reset. The driver output of these flip-flops can be used for experimental control such as sample movement and beam stops. The input parameter calls for the address of the control code.

4. Subroutines That Provide Process Control from the Typewriter Input

TPIN This program is used to insert formal parameters into a working COSACS program by typewriter at run time. The input parameters call for the FWA and the address of the WC.

TNIN This program is used to insert from the typewriter numerical values into the A register (either decimal or octal). It is used as a subroutine for the more general routine TPIN. There are no input parameters, since the result stays in the A register and the operation is terminated by a blank, /, or ↑.

REFL This is a basic typewriter single-character input subroutine with a reflecting output to the typewriter. This is used by COSACS on all keyboard input operations. A check is made for the / character in order to jump out of any current operation.

CODE This subroutine, when called for, inputs an instruction from the typewriter terminated by a blank or CR. The truncated instruction word formed from the last four characters is in the A accumulator.

5. Subroutines That Provide Control Response to the Typewriter Output

CRLF This program produces a carriage return and a line feed to the typewriter.

BELL This program produces a continuous bell sound from the typewriter for an audio signal to personnel.

MESG This program causes the typewriter to print any message that has been previously stored at some fixed area in the memory. The input parameters call for the FWA of the message and a WC. The message is coded in ASCII, three characters per word.

COPY This program copies a message from the paper-tape reader of the teletype to the teletype printer. There are no input parameters. This instruction can be used to pass sequenced messages to operating personnel.

CHKS This program prints CHKS ERR on the typewriter.

INER This program prints INP ERR on the typewriter.

CODER This program prints COD ERR on the typewriter.

CCL This program prints ERR IN CCL on the typewriter.

6. Subroutines That Perform Internal "Housekeeping" Tasks

WAIT This program transfers the control to a waiting loop and resets all the interrupts except for the typewriter.

RETN This program is used after a typewriter-directed operation has been finished. Priority interrupts are cleared and reset. The CRT of the display unit is switched off, and control is transferred to the entry of COSACS and from there to the WAIT loop.

FPA,
RES These two programs enable one to pass the argument addresses from the calling routine to the called subroutine. The FPA subroutine calls for the FWA and the WC of the arguments. The RES subroutine preserves the contents of the registers.

7. Subroutines That Utilize the Computer-to-Computer Link

CCLN This program is the master subroutine in the on-line system for data transfer via the CCL, handling both the input and output of data. The corresponding slave routines in the off-line system are MOZART for the "input" and KLEE 1 and 2 for the "output." The input parameters call for a code word that satisfies MOZART, KLEE 1, and KLEE 2 input parameters.

MOZART This program resides in the off-line system and communicates directly with the CCL in the transfer of blocks of data from the on-line computer to the off-line computer. The input parameters call for (1) the name of the array, (2) a five-character code for unit control, and (3) the WC.

KLEE 1
KLEE 2 These two programs, which reside in the off-line system, are linked closely together and correspond directly to MOZART, except that they deal only with the transfer of data from the off-line system to the on-line system. Input parameters are similar to those of MOZART.

APPENDIX C

Summary of Support Software

A large volume of auxiliary software available to the COSACS user was written specifically for the support of COSACS. Each program is stored on the standard operating system library at the off-line system, and can be called into core with the standard request such as LOAD BACH. The options and input parameters are specified in Table C.1.

BACH

This program resides in the off-line computer O.S. and provides the off-line software necessary for synchronizing the transfer of data to the off-line peripherals via the CCL. Once BACH has been activated, it is self-sustaining and all control is handled from the on-line typewriter. The peripherals available to BACH are the magnetic tape, the line printer, the card punch, and the plotter. The input parameters call for unit designation, format options, and WC. There are additional control options with the magnetic tape that permit searching and rewinding as well as writing. The plotter options under BACH are intended to provide only a fixed-survey type of plot, rather than a general-purpose plotting package.

GOYA

This program is analogous to BACH, except that it provides the off-line software for transferring data from the peripherals to the on-line system. The possible options include the magnetic tape and the card reader. The input parameters again call for unit designation, format, and WC. Additional search and rewind options are available to the magnetic-tape unit.

SWITCH BACH
and SWITCH GOYA

The interchange of the support routines SWITCH BACH and SWITCH GOYA can be initiated from the on-line computer with these routines.

PLOT

This is a multi-input plot program, which accepts data input via the CCL or from any input device on which data are stored in COSACS or BACH standard formats. The input may also be from the card reader in a format determined at run time. The input parameters provide a wide selection of options, such as number of points to be plotted, the length and scale of the axis, the type of plot symbol, and the interval space.

TABLE C.1 Support Program Command Code Input Table

JON/KON	Operation		
<u>CCO-JON/KON Input for BACH</u>			
<u>Magnetic Tape</u>			
	<u>Start</u>	<u>Exit</u>	
YY001	Start with new reel	Tape off	YY is the number of transfers for one file (01 = for CCO).
YY002	Start with new reel	Continue	
YY003	Continue with existing reel	Tape off	
YY004	Continue with existing reel	Continue	
YY005	Search for designated file, and continue	Tape off	
YY006	Search for designated file, and continue	Continue	
00015	Exit change from continue to tape off		
<u>Cards</u>			
XX016	Card punch	Format 1018	XX is the label preceding the cards or printout in Format 13
XX017	Card punch	Format 8110	
XX020	Card punch	Format 1017	
<u>Line Printer</u>			
XX022	Line printer	Format 2x, 8110	
XX023	Line printer	Format 2x, 10110	
XX024	Line printer	Format 2x, 1218	
<u>Plot</u>			
ST026	Plot 6 x 10 in , pen left	ST is start channel	
<u>CCI-JON/KON Input for GOYA</u>			
<u>Magnetic Tape</u>			
00003	Continue with existing reel	Tape off	ZZ is the number of the file to be read
00004	Continue with existing reel	Continue	
Z/005	Search for designated file, and read	Tape off	
ZZ006	Search for designated file, and read	Continue	
00015	Rewind tape		
<u>Cards</u>			
00016	Card reader	Format 1018	
00017	Card reader	Format 8110	
00020	Card reader	Format 1017	
<u>PLOT Input at Shared System</u>			
CON	INP .	Control input device, data input device	
NT	NCH	Number of spectra, number of channels	
FRAME	XL YL YO W SYMB	Length of X (inches), length of Y (inches), offset of Y (inches), letter size (mills), symbol	
NFWA . / FWA	LWA	Number of intervals, first-word address, last-word address	
<u>DUMP Input at Shared System</u>			
NREEL	Label for magnetic tape		

DUMP

This program dumps an entire disk of data from the on-line system to the off-line magnetic tape unformatted. The input options permit adding on to a previous dump and labeling of the dump. This dump to magnetic tape can be read under FORTRAN in an unformatted statement.

PUNC

This program produces an object paper tape after assembling or compiling a DATA FLOW CONTROL routine with COSACS on the off-line system. The output of PUNC will be accepted by the Thumb-In Program Loader in COSACS. Input parameters are the FWA and the WC.