THE SCIENTIFIC COMPUTING NETWORK

II. THE C.S.I.R.O. SUBSIDIARY SYSTEMS

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THE SCIENTIFIC COMPUTING NETWORK

II. The C.S.I.R.O. Subsidiary Systems

1. Introduction

As the basis of a scientific computing network, C.S.I.R.O. is to install four medium sized subsidiary computing systems in addition to the large single system to be located at Canberra. The latter was described in an earlier memorandum (No.1). The present memorandum deals with the four subsidiaries. Three of these will be virtually identical, but the fourth will differ principally by the array of peripheral units to which it will be connected. It will also be connected directly to the 3600 processor with respect to which it will function as a controlled 'satellite'.

Each subsidiary system will consist of a recently announced Control Data 3200 computer, and a group of peripheral units which will allow use of both paper tape and punched card data media and which will efficiently handle programs expressed in a language such as FORTRAN.

The three independently operating subsidiaries will be located at the following places:

(i) Adelaide - in the new Civil Engineering Annexe of the University of Adelaide.

(ii) Melbourne - at the C.S.I.R.O. Division of Chemical Physics building currently being constructed close to Monash University at Clayton.

(iii) Sydney - at the C.S.I.R.O. National Standards Laboratory in the grounds of the University of Sydney.

A description of the Control Data 3200, indicating its versatility, speed and expansibility, is given in sections 2 and 4. Section 3 gives an itemized list of the actual equipment to be installed at the various sites, and sections 5 and 6 give details

of peripheral units to be provided.

2. The Control Data 3200 System

(a) General

The Control Data 3200 computing system is a high speed, medium size, computing and data processing system intended for operating in close association with a 3600 system which its logical structure, instruction repertoire and components, both internal and peripheral, closely resemble. It is, however, a powerful computing system in its own right (see the attachment published by Control Data Corporation for other details).

Its basic word length is 24 bits, plus four bits representing the parity state of each of the four 6-bit characters of which the 24 bit word is composed.

The instruction repertoire includes codes for operating upon 48-bit data in the same format as that used in the 3600 for both fixed and floating point data. Also included are character-oriented instructions which make the 3200 highly suitable for symbol manipulation and logical operations. In addition it is provided with an interrupt system, similar to that in the 3600, which makes it suitable for real-time and multiprogram uses. Incorporation of a special rapid-access store assists in its use for these types of operation.

The 3200 is also designed to handle peripheral units which are also used on the 3600 and interface units are available which allow it to be used as on on-line 'satellite', or peripheral, of the 3600. The subsidiary at Canberra is to be connected in this manner.

(b) Storage

The main store of the 3200 consists of a ferrite core matrix. The cycle time of 1.25 and access time of 0.75 microseconds is the same as that for the 3600 and allows of very high speed of operation on 24 or fewer data bits and a sufficiently high speed, at

economical equipment cost, on 48 or more data bits. This store may be extended to the 32768 24-bit (plus 4 parity bits) allowed for in the instruction code, but may be extended beyond this under certain conditions. (The subsidiaries to be installed will initially be provided with 8192 words of main store.)

In addition to the main store there is a rapid access store of 64 24-bit words which are randomly accessible by program control. Although certain of these are reserved for specific quantities and are available only for readout, others are available for both reading and writing for such purposes as storing incidental values, programmed index values and frequently needed quantities. The access time of this store is 0.25 microsec.

(c) Modes of Storage Transfers

In addition to the normal 24-bit, or full word, mode of transferring data to and from main store there are eleven other modes, many of which are associated with the character oriented operations available on the 3200.

Two of these are transfers of address values, one corresponding to the least significant 15 bits of a word being the word address part of a single 24-bit instruction, and one corresponding to the 17 least significant bits of a word being the address of a particular 6-bit character of which the store may hold up to 131072, packed 4 to a word.

Of the remaining modes, four correspond to each of four 6-bit character positions in a word, three correspond to transfer of 12-bit bytes of the three possible pairs of adjacent 6-bit characters of a word, and two correspond to 18-bit bytes of the two possible groups of three adjacent 6-bit characters of a word.

(d) Address Modification

Instructions are generally subject to modification in either, or both, of two ways. Firstly, by indirect addressing, in which the address component of an instruction initially contains the

address to which reference is made for the effective address of the operand, secondly, in the usual way, by addition of the content of any one of three 15-bit indexing registers.

(e) Character Handling

In addition to the usual single-word arithmetical, normal logical, incrementing, decrementing, conditional and unconditional jump instructions, others are provided which facilitate character-type of data processing.

In such operations each 24-bit word is considered as a string of four 6-bit characters, each with its associated parity bit thus making a 28-bit word. Any character transferred is always accompanied by its parity bit.

Instructions which handle characters are able to address any character in the main store by extension of the address portion of the instruction by an additional two bits, making 17 bits, the ascending order of the addresses of the characters within a word being from 'most' to 'least' significant 6-bits and from the highest to lowest word address. These instructions allow of transfers of characters to and from store, the remaining characters of an accessed word remaining unaffected.

Most instructions each occupy a 24-bit datum word, but a few occupy two words. Such special instructions allow for automatic searching for a particular character within a stated block of data in the store and for moving a block of stated length from one place in store to another.

(f) Decimal Arithmetic

Associated with the set of character handling operations is the facility for operations upon binary-coded decimal data held as strings of 6-bit characters in store and packed as 12 4-bit characters when brought into the arithmetical registers. These operations are, however, subject to special conditions as indicated below in section 2(i).

(g) Input and Output

Input and output operations can be carried out in four different ways, by character or word blocks of stated length, or by single characters or words. However, as in the case of the 3600, any such operation must be preceded by a 'selecting' operation which connects the required input or output device.

Up to eight simultaneously operating bidirectional data channels can be provided to each of which up to eight devices, making a total of 64 units, may be connected. Some of these units, such as magnetic tape controllers, may further control a number of devices such as magnetic tape transports, and real-time control and indicating devices.

(h) Interrupt System

The interrupt system provides for automatic and/or programmed detection of certain internal and external conditions. Prior to the execution of an instruction, the presence of any of these conditions causes the normal sequence of control to be broken, and a special sequence of actions performed to deal with the condition causing the interruption prior to returning to the point at which the break occurred.

Among the conditions which cause interruption are the internal conditions such as arithmetic overflow, including the fraction and exponent in floating-point operations, division fault etc., certain conditions which may occur when searching or moving data internally, and conditions associated with the peripheral input and output devices.

Another important condition causing interruption is the appearance, during a run, of certain types of instruction.

(i) Extended Precision, etc.

The instruction repertoire allows for a number of operations on data of extended precision and special formats:

i. 48-bit binary integers,

ii. 37-bit floating point numbers with an additional 11-bit exponent,

iii. Binary coded decimal character strings of up to 12 decimal digits.

Of these the first two forms are identical with equivalent forms in the 3600.

Although allocations in the instruction repertoire allowing for operations in these formats are made, they may be carried out at highest speeds (see section 3) using optional additional hardware in the central processor. When such hardware is not included the operations can be performed in a manner which, to the user, appears fully automatic. Its absence has no effect upon the method of programming and when one of these special operations is reached an interruption occurs which causes control to transfer to a subroutine which carries out the equivalent operation at some reduction in speed.

One special hardware unit allows 48-bit precision multiplication and division and two-word floating-point addition, subtraction, multiplication and division. Instructions for performing 48-bit addition and subtraction at high speed are always provided and do not require additional hardware. Another additional unit allows for fully automatic operations on binary coded decimal numbers (see (f) above.) (Some subsidiaries will be provided with the additional hardware for high-speed double precision and floating point operations, but none will be provided with the hardware for high-speed decimal operation.)

(j) Operation Speeds

Internal operation times for typical arithmetical functions, including access to instruction, operand and modification, are:

Single Precision (24 bit):	add/subtract	2.5	μs
	multiply	8.8 - 12.0	μs
	divide	11.9 - 12.2	μs
Double precision (48 bit):	add/subtract	3.8-4.4	μs
With additional hardware:			
Double precision (48 bit)	multiply	22.0	μs
	divide	24.0	μs
Floating point	add/subtract	12.0	μs
	multiply	29.0	μs
	divide	29.0	μs
Approximate operation times without additional hardware:			
Double precision (48 bit)	multiply (est)	120	μs
	divide (est)	120	μs
Floating point	add/subtract	123	μs
	multiply	141	μs
	divide	190	μs

It is anticipated that, on the average, ~~those~~ subsidiaries fitted with the double-precision and floating-point hardware will effectively operate at about twice the speed of those not so fitted.

(k) Peripheral Units

A wide range of peripheral units are available, including those suitable for use by a 3600, and allow for data media of 5, 7 and 8-channel paper tape, 80-column punched cards and 7-channel $\frac{1}{2}$ inch wide magnetic tape (in IBM compatible format), and output on similar media and by line printer, typewriter, plotter and CRT visual display. Details of peripherals to be supplied at the independently operating subsidiaries are given in sections 3 and 4.

3. The Particular Equipment Configurations

(a) Independently Operating Subsidiaries

In general, each subsidiary will consist of the following items :-

On-line:

1. A Control Data 3200 central processor with a core store of 8196 words of 24-bits (plus 4 parity bits) and two bidirectional input/output data channels, and with a separate operating console and input/output typewriter.
2. Two magnetic tape units with associated tape controller.
3. One 8-channel paper tape reader/punch unit (350 char/sec reading, 110 char/sec punching).
4. One 80 column punched card reader (1200 cds/min).
5. One line printer (300 l/min).
6. One incremental plotter (300 incr/sec).

Off-line

1. Two 8-channel paper-tape keyboard editing units.
2. One duplicating and printing 80-column keyboard card punch.) except where otherwise available.
3. One 80-column card verifier.)

The central processors at Melbourne and Sydney will be provided with the facilities for high-speed double-precision and floating point operations and off-line punched card equipment. The Canberra subsidiary will be provided with an additional pair of data channels and will operate within a wider environment.

Fig. 1 shows how the on-line peripheral units may be connected to the central processors at the independently operating subsidiaries.

(b) The Canberra Satellite

The satellite system at Canberra will form part of the 3600 system, will be physically connected to the 3600 processor and have

direct access to all its peripherals. To make such a wide variety and number of peripherals available, the 3200 at Canberra will be augmented by a pair of data channels making a total of four. It will not be provided with double-precision and floating-point hardware.

The number of on-line peripherals available to the Canberra 3200 are indicated in Table 1 to which must be added the following:

One card punch,
One disc-file system,
One high speed optical display unit,
One satellite coupler connecting directly to the 3600 processor through a 3600 data channel.

Details of these and other 3600 peripherals will be found in Memorandum No.1. Fig. 2 shows the probable connections between the satellite and all peripherals.

4. Expansibility

An important aspect of the initial installations will be their potential for a great degree of expansion, as and when required, by simple connection of additional units. Thus the store may be extended from 8192 to 32768 words, or more; simultaneous operation of peripherals may be extended from 2 to 8, by addition of further data channels, to each of which 8 units of equipment may be connected. In particular any unit may be a magnetic tape controller each of which may control up to 8 magnetic tapes, although only six separate input and/or output units and 2 magnetic tapes will be provided initially.

5. On-Line Peripherals

(a) Magnetic Tape Transports

Each separate subsidiary will be provided with two Control Data 604 magnetic tape transports. They are similar to the type 607 tape transports to be provided with the 3600 in that they record

at 200, 556 or 800 characters per inch but operate at rates of 15K, 41.7K or 60K characters per second respectively. However, tapes recorded on a 604 unit may be read on a 607 and vice versa. The writing densities are selected under program control.

The two magnetic tape transports to be provided are sufficient to provide for efficient compilation of FORTRAN programs.

(b) Paper Tape Reader/Punch

One inch wide 8-channel paper tape will be handled by a combined reader and punch unit. Reading will be carried out at a rate of 350 8-bit characters per second, and punching will be at a rate of 100 8-bit characters per second.

The reader will also be able to accept $\frac{7}{8}$ inch (7-hole) and 5/16th inch (5-hole) paper tape, selection being by simple hand adjustment.

(c) Punched Card Reader

Punched cards will be read at a rate of 1200 cards per minute, the same unit, the Control Data 405 card-reader, being supplied also to the 3600. However, no output card-punch will be provided since it is expected that, although source data and programs may frequently be provided on cards, output will be naturally restricted to printed data or, if required for a later run and not recorded on magnetic tape, will be output onto paper tape.

(d) Line Printer

For rapid output of results and for program listing and some diagnostic functions a Control Data 166-2 line printer will be provided. It will be fully buffered and will print 120 characters per line at a rate of 300 lines per minute using a set of 64 characters. Higher rates of printing may be possible for sets of less than 64 characters.

(e) Incremental Plotter

A somewhat unusual feature will be the provision of a chart plotter for which it is expected many uses will be found. It will

be an X-Y plotter of the moving pen-moving paper type and will have a precision of 0.01 inches in both directions and a plotting rate of 300 incremental points per second in both coordinates. The paper width is 12 inches and chart rolls up to 100 ft. long can be accommodated.

(f) Typewriter

An input-output typewriter will be provided for small volume output, directives to the operator and information concerning the state of current operations, and receipt from the operator of requests and controlling instructions.

6. Off-Line Peripherals

Off line equipment will be provided for data and program preparation where such equipment is not otherwise readily available.

(a) Paper Tape Data Preparation

All subsidiaries will be provided with two AWA Typetronic units possessing one or two one-inch wide 8-channel paper-tape readers and one 8-channel punch each and will be identical to those provided at Canberra (see memorandum No.1.) They may be used for, i) recording programs and subject data onto paper tape via a 44-key double-case keyboard similar to that of a standard typewriter while simultaneously providing a page-printed copy of the data recorded, and ii) copying a tape (a) without printing, at 30 8-bit characters per second, or (b) printing, at a rate of 10 characters per second, a record of the data held on a tape.

Tapes may be edited for corrections, insertions and deletions by use of suitable key controls and, when two readers are provided on the same unit, tapes may be edited and merged onto a single output tape using the key controls and/or by controlling codes read from the input tapes.

(b) Punched Card Data Preparation

It is intended that all subsidiaries will have punched card data-preparation equipment available. Equipment will be specifically

supplied initially at Melbourne and Sydney only, and will consist of one card punch and one verifier identical to those provided at Canberra (see Memorandum No.1).

7. Character and Code Sets

The character and code set for punched card use will be the same throughout the system, i.e. the standard FORTRAN set used by IBM. The set to be used on paper tape will likewise be the same throughout the system and is being designed to cover the ALGOL set and include, as subsets, the COBOL and FORTRAN characters. Details of the character code sets will be the subject of a later memorandum.

8. The Programming and Operating System

The operation of each separate subsidiary will be controlled by a monitor routine, SCOPE 32, designed to accept, translate and perform a sequence of programs and data provided on punched cards and/or punched paper tape. It will at the outset be possible to provide for programs stated in the three languages as follows:

(i) FORTRAN 32 (being a subset of FORTRAN 63) used on the 3600), and

(ii) COMPACT (being a subset of COBOL and retaining all the format and utility of that language), and

(iii) COMPASS 32 (an assembly language comparable with COMPASS 36 used on the 3600).

(i) It is expected that most programs will be presented in FORTRAN, in which case, complete compatibility between subsidiaries and central systems can be assured. Details concerning this language and its use will be made available at a later date, during instruction courses and by distribution of suitable documentation to be provided by Control Data Corporation.

(ii) Although the version of FORTRAN provided allows for CHARACTER-type variables it is likely that COMPACT will be most

suited to those data-file operations which occasionally occur in scientific types of computation. COMPACT makes great and efficient use of the binary-coded decimal operations in the 3200 instruction code whereas, FORTRAN makes greatest use of the single and double word binary mode operations.

(iii) The assembly language, COMPASS 32, is of the mnemonic letter group type. Although its format is the same as that of COMPASS and some codes are identical for the same operation in both languages, there is considerable difference in detail due to the diversity of instructions between the 3600 and the 3200. However, it is expected that, in due course, an addition will be made to the SCOPE system on the 3600 to allow assembly codes from subsidiaries to be directly acceptable by the central system.

Although the initial monitor system for the 3200 will deal with a serial job flow, it is expected that, in view of its register store and interrupt features, the operating system will be extended to allow it to deal with programs and real-time control operations on a multiprogram basis.

Usually it is not possible to use more than one procedure-oriented language in a program although it is normally possible to supply subroutines in the assembly language. A feature of the 3200 monitor will be the facility for the programmer to use all three of the above languages in the same program, a feature which may be of considerable importance.

9. User's Organization

At present a user's organization specifically for the 3200 does not exist since this line of equipment has only recently been announced by Control Data Corporation. However, much of the CO-OP library, to which the network has access through its central facility, is obtainable in FORTRAN and may readily be made available for use on a 3200 subject to the reduced environment being suitable.

As the 3200 type of equipment becomes more widely adopted by a larger number of users (other than in the present network) a satisfactory user's organization oriented toward the 3200 system will no doubt be established.

T. Pearcey

28/11/63

Table 1. Equipment Configurations for the C.S.I.R.O. Subsidiaries

Site	Central Processor			On-line peripherals						Off-line Peripherals		
	Store words	Fl. pt and dl.pr. hardware	No. I/O Channels	Magnetic tape units	Card reader	8-channel paper tape reader	8-channel paper tape punch	Line printer	Plotter	Paper tape	Cards+ pu	Cards+ ve
Adelaide	8192	No	2	2 (604)	1 (405)	1	1	1(166-2)	1(165-2)	2	x	x
Melbourne	8192	Yes	2	2 (604)	1 (405)	1	1	1(166-2)	1(165-2)	2	1	1
Sydney	8192	Yes	2	2 (604)	1 (405)	1	1	1(166-2)	1(165-2)	2	1	1
Canberra	8192	No	4	10(607)*	10(405)*	3*	3*	1(166-2)* 2(501)*	1(165-2)* 1(165-3)*	8*	3*	3*

* indicates shared by 3200 and 3600.

Notes:
1. 604 mag. tape units operate at character transfer rates of 15K, 41.7K and 60K characters/sec.
   607 " " " " " " " " " 30K, 83.4K and 120K " "
2. 405 card readers operate at 1200 cards/min.
3. 165-2 plotters use 12 inch wide paper rolls.
   165-3 " " 30 inch " " "
4. 166-2 printers have line capacity of 120 characters and line rates of 300 lines per min. or greater.
   166-3 " " " " " 130 " " " " " 1000 lines per min.
5. All subsidiaries will be provided with separate operating console and I/O typewriter.
6. Of the three paper-tape readers at Canberra, one will operate at 350 ch/sec and two at 1000 ch/sec. All three paper-tape punches will operate at 110 ch/sec.
7. Numbers enclosed within parentheses represent Control Data reference numbers for equipment types.

+ pu = punch, ve = verifier.

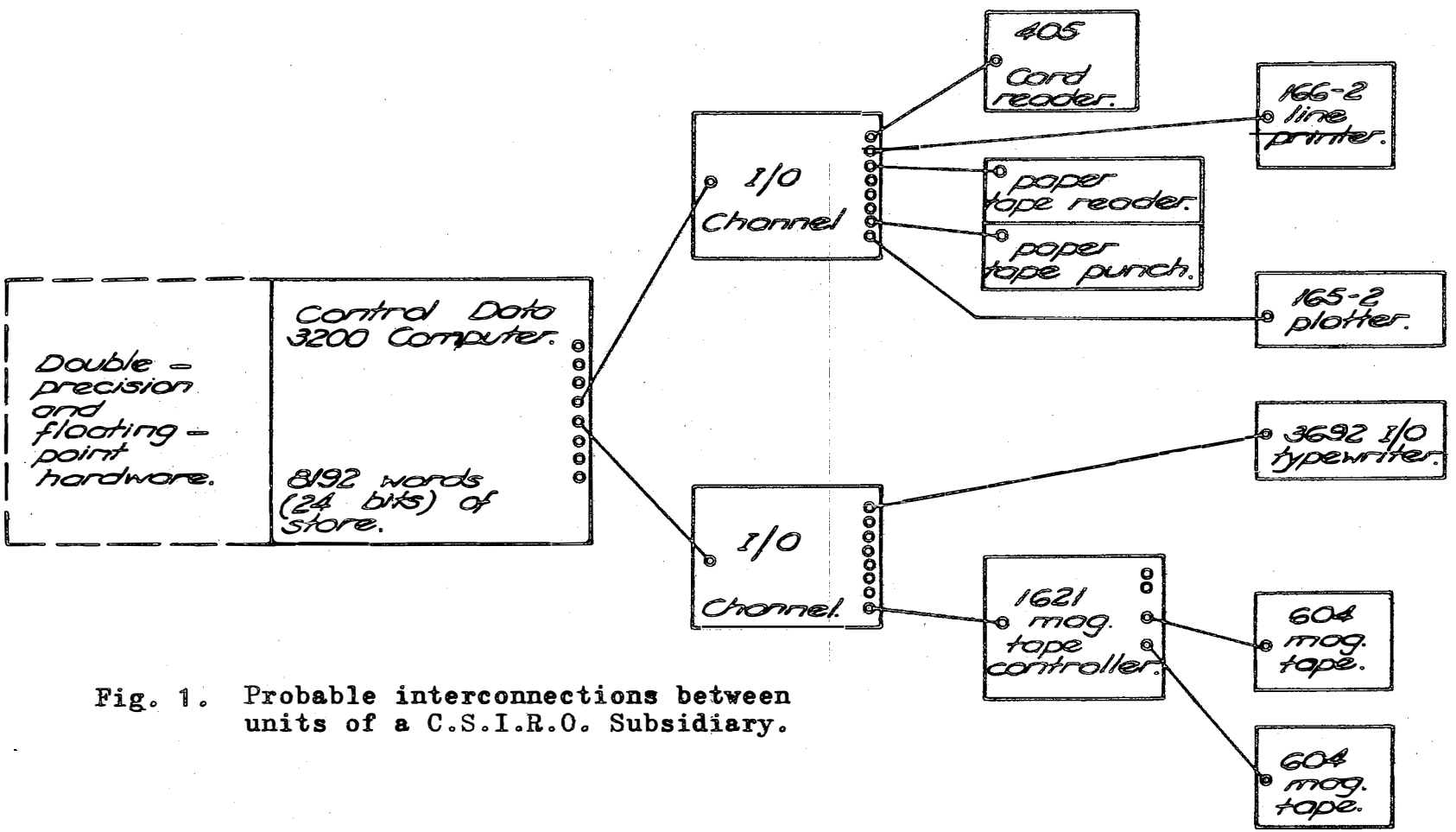


Fig. 1. Probable interconnections between units of a C.S.I.R.O. Subsidiary.

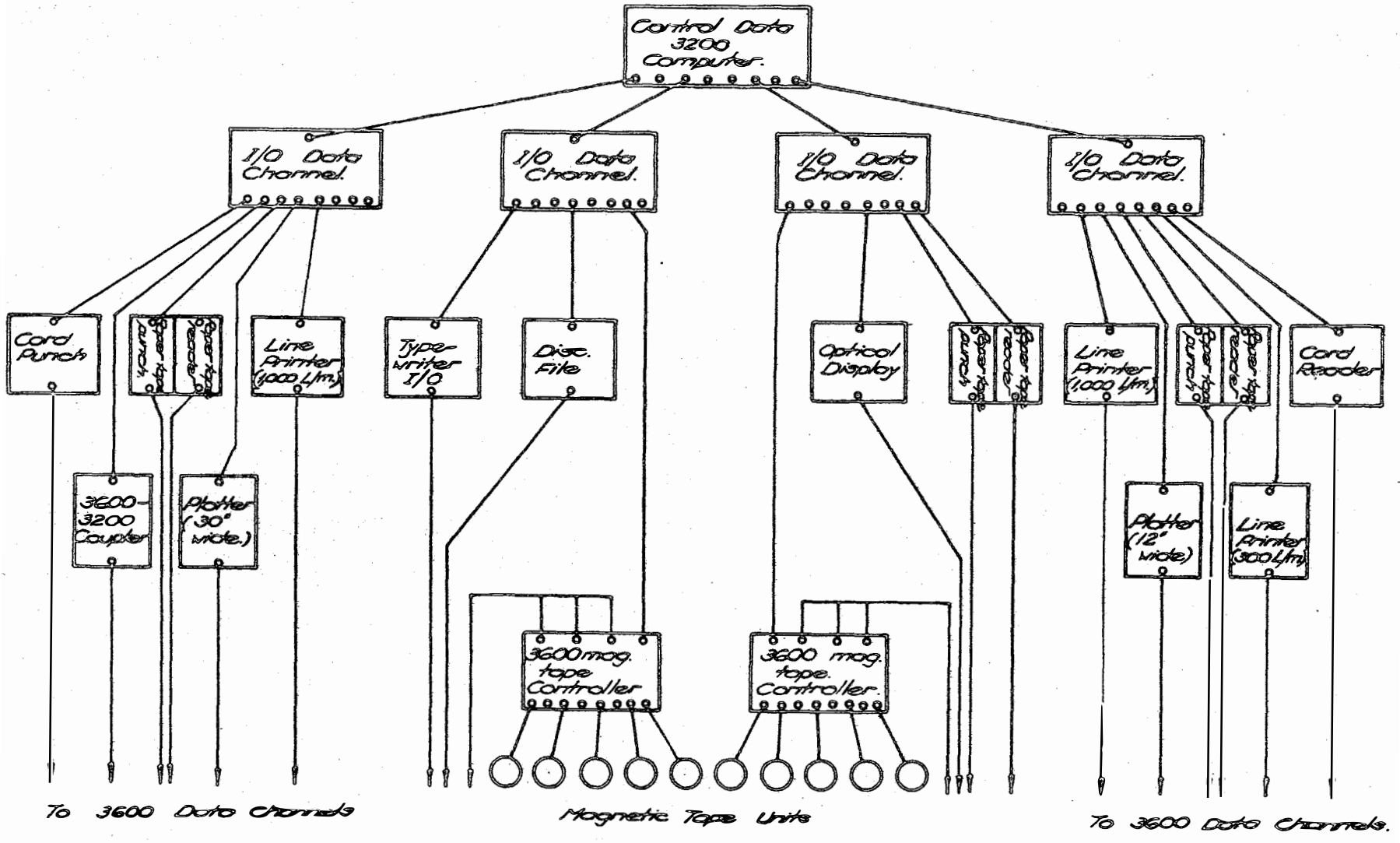
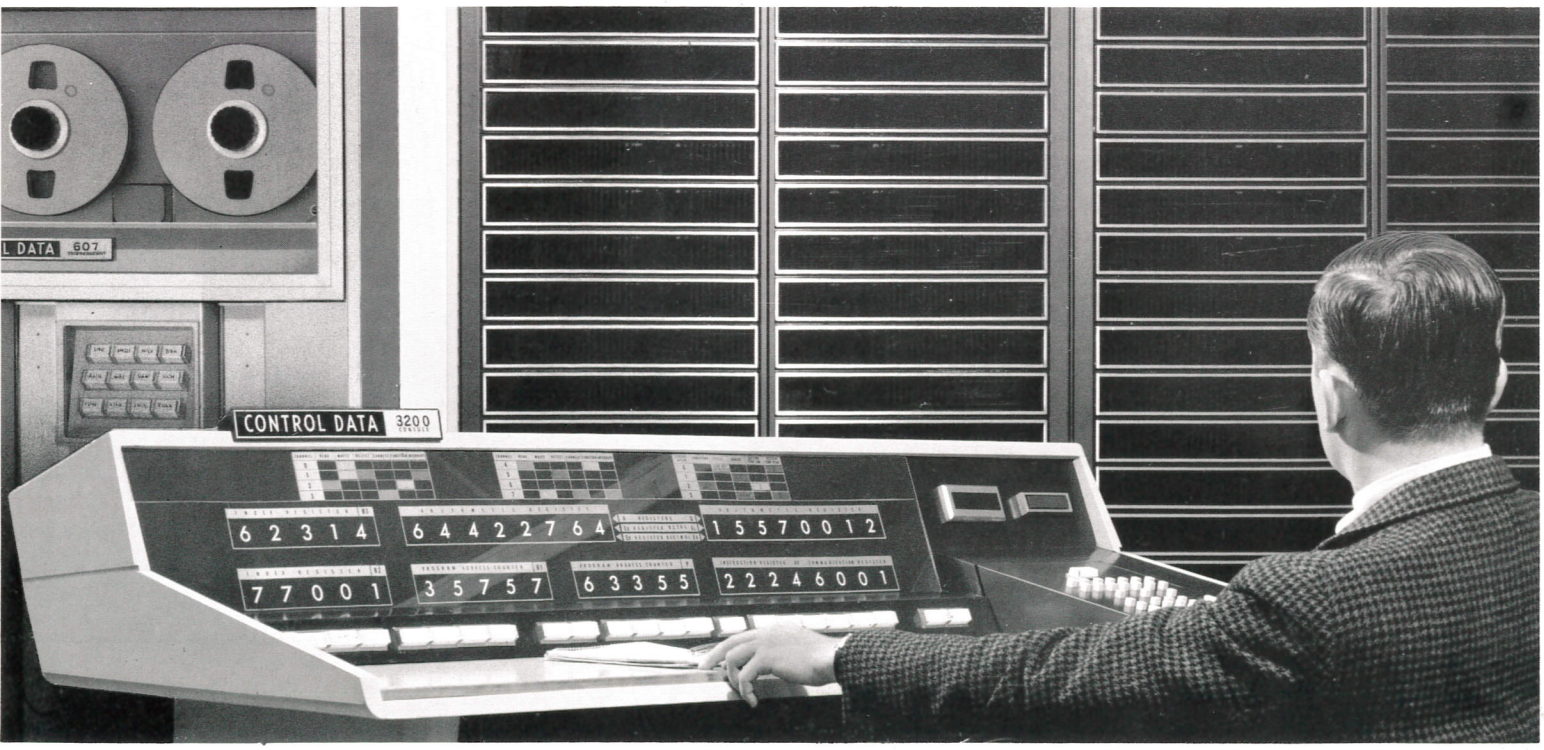


Fig. 2 Probable Interconnections between Equipment Units at the Satellite at Canberra.

3200

CONTROL DATA® 3200 Computer System / Scientific Applications

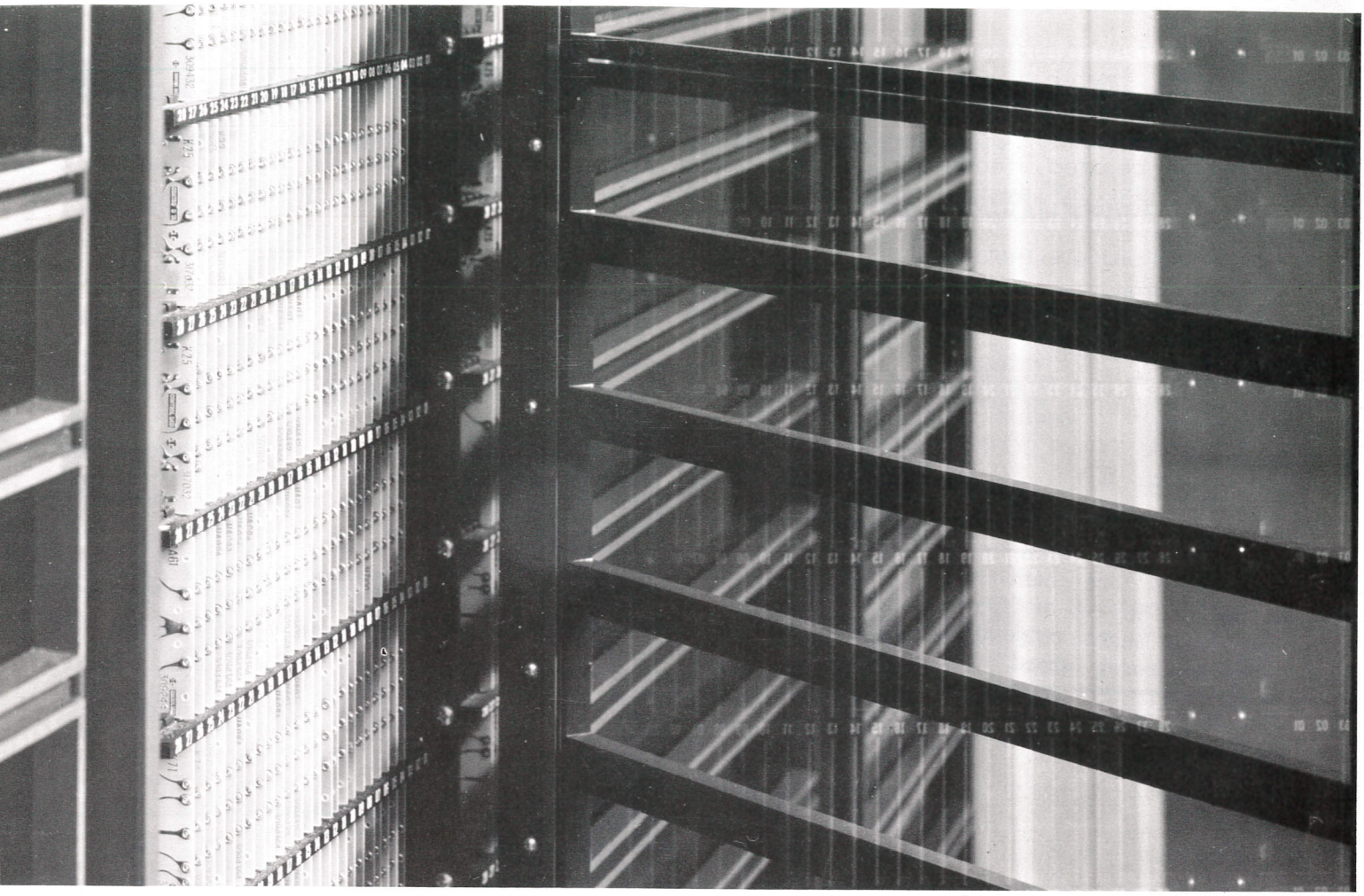


3200

Control Data Corporation continues to keep pace with the broadest requirements of scientific computer users by introducing the CONTROL DATA® 3200 Computer System. Specifically designed to meet current needs at low cost, the 3200 maintains in its hardware and programming structure the potential for system growth against problem growth. Of particular interest to the scientist are features of the 3200 which are distinctly scientific. Among them:

- fast and precise arithmetic capability
- specialized hardware for high-speed calculations
- convenient and efficient software systems, including FORTRAN 32, SCOPE 32 monitor, COMPASS 32 assembler
- modular system configuration to supply precise equipment to precise requirements

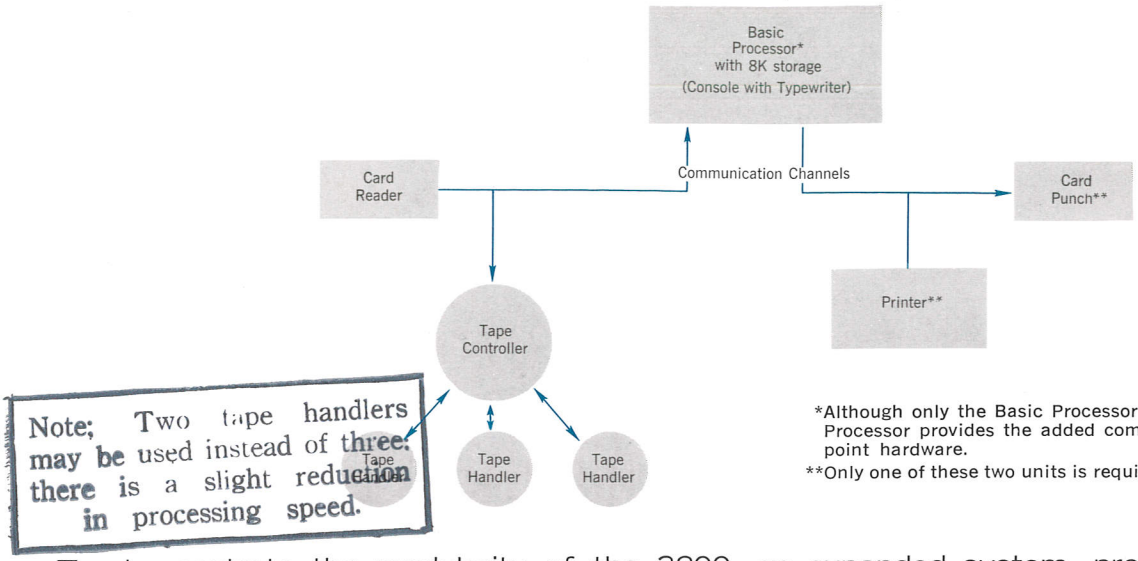
Within these pages, you will find the way to orient your computing system requirements to your scientific problems. The CONTROL DATA 3200 may be fitted precisely to the problem, giving you the most efficient and advanced medium-scale computer system at the cost level you choose.




CONTROL DATA
3200
COMPUTER
62314
77001
64422764
35757
63355
15570012
22246001

TYPICAL 3200 CONFIGURATIONS FOR SCIENTIFIC APPLICATIONS

To provide the 3200 Computer user with an insight into the various equipment configurations which can be used effectively for scientific applications, the following diagrams are presented. The minimum 3200 system required for using FORTRAN 32, COMPASS 32, and SCOPE 32 is:

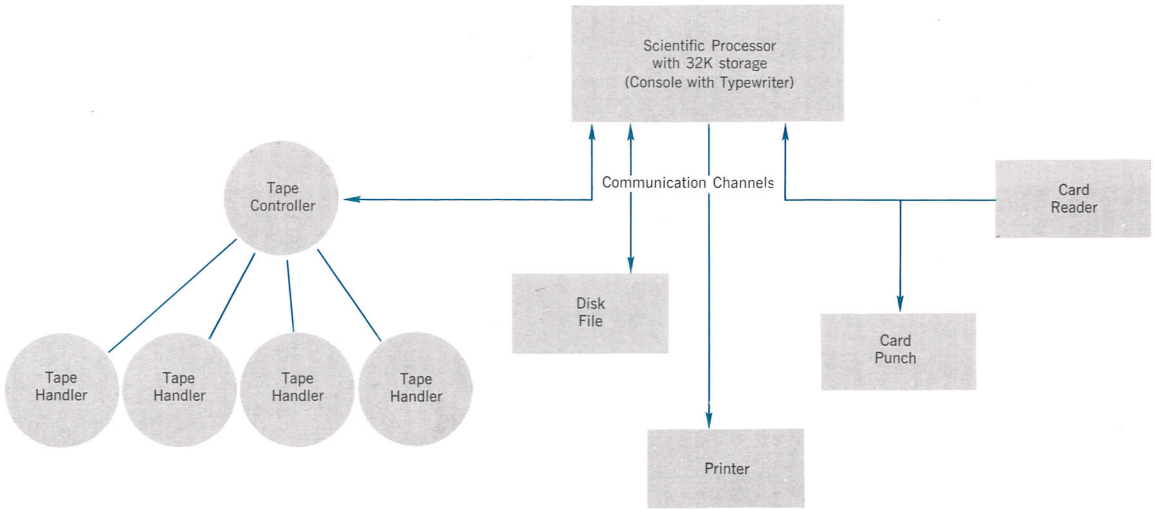


Note; Two tape handlers may be used instead of three; there is a slight reduction in processing speed.

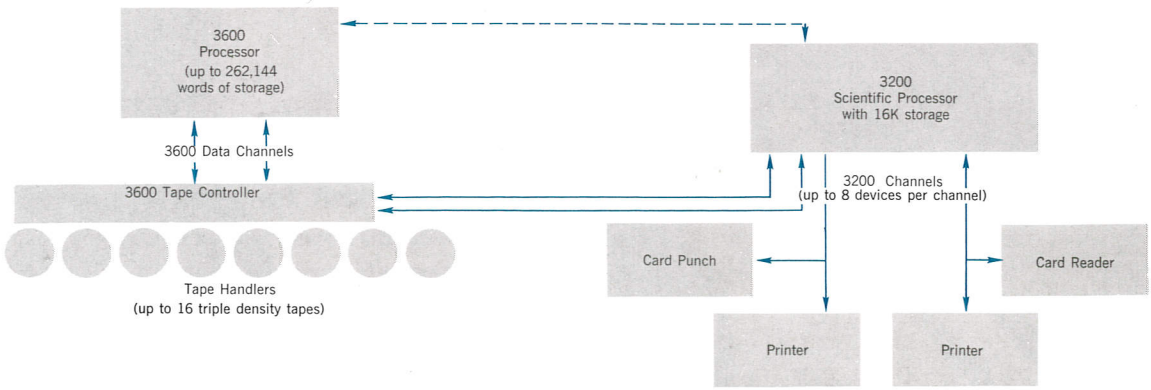
*Although only the Basic Processor is required, the Scientific Processor provides the added computation speed of floating point hardware.

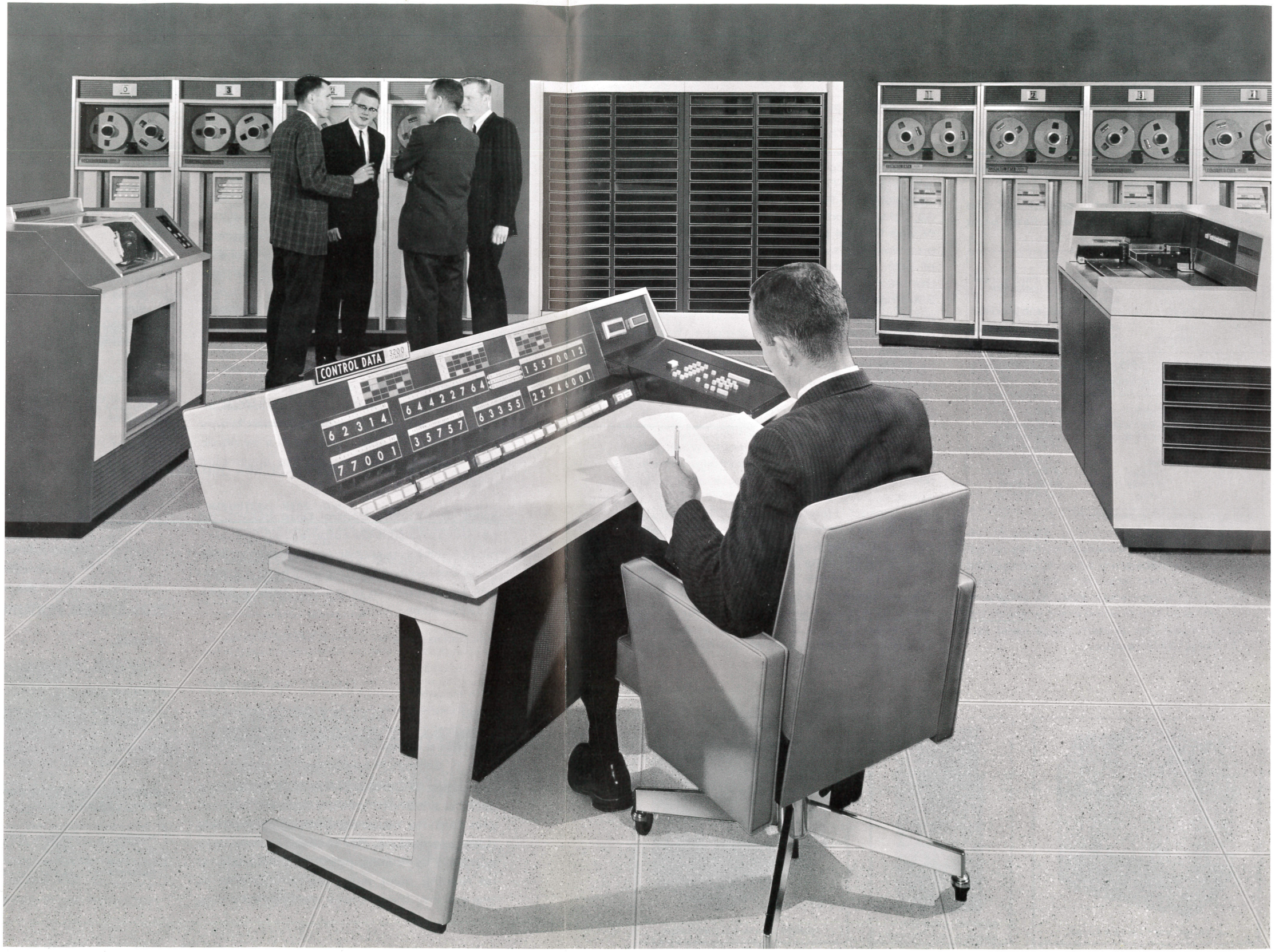
**Only one of these two units is required for a minimum system.

To demonstrate the modularity of the 3200, an expanded system, providing a complete computing facility for medium to large programs, is shown below:



For large installations the 3200 may be used as a satellite to the **Control Data** 3600. The configuration for such a system (shown below) allows for magnetic tapes to be shared; thus making the 3600 completely tape oriented.

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The CONTROL DATA® 3200 Computer System . . . Characterized for Scientific Applications

THE 3200 SCIENTIFIC PROCESSOR

The **Control Data** 3200 Computer System features a Scientific Processor, one of four distinct central processing units conceived for multi-purpose operation.

The standard arithmetic section of the Basic Processor provides these fixed point operations:

Precision	Operation	Result	
24-bit	Add	24-bit sum	with overflow detection
	Substract	24-bit difference	
	Multiply	48-bit product	
	Divide	24-bit quotient; 24-bit remainder	
48-bit	Add	48-bit sum	with overflow detection
	Subtract	48-bit difference	

In addition, the 3200 Scientific Processor adds the following capabilities:

Fixed/Floating	Operation	Result
Fixed	48-bit multiply	96-bit product
	48-bit divide	48-bit quotient; 48-bit remainder
Floating*	Add	48-bit sum
	Subtract	48-bit difference
	Multiply	48-bit product
	Divide	48-bit quotient

*36-bit mantissa; exponent range: 10 ± 307

For those scientific users who require at the start only the Basic Processor, tedious recoding will not be necessary when floating point hardware is added later. An instruction trap is built into the processor allowing programs to be written using floating point instructions whether or not the system being used has the floating point feature.

3200 SCIENTIFIC PROGRAMMING SYSTEMS

FORTRAN 32 . . . This problem oriented language has been implemented for the scientific user who prefers coding in a familiar algebraic language. FORTRAN 32 goes beyond the capabilities of FORTRAN II and FORTRAN 62, being an extensive subset of FORTRAN IV and **Control Data** 3600 FORTRAN. This programming system takes full advantage of both the latest compiler techniques and the unique capabilities of the **Control Data** 3200 hardware. The ability to perform character operations provides a tremendous speed advantage for the compiler in that character searches through statements can be performed directly rather than by using a repeated loop of logical instructions.

One advantage of FORTRAN 32 is the provision for a variable length Identifier List. Previously, the maximum ID List length was fixed by the specifications of the compiler. Therefore, the compiler could indicate an ID List overflow even though a portion of memory was unused. However, the FORTRAN 32 compiler can determine how much memory is needed for the Monitor I/O drivers and how much is available for the FORTRAN program. Since this amount of memory is variable from program to program, the compiler can define a different length ID List for each. This ability of the compiler eliminates the possibility of a false ID List overflow indica-

CONTROL DATA 166 Line Printer

CONTROL DATA 607
Magnetic Tape Transport

CONTROL DATA 405 Card Reader

tion. In the same manner, additional memory automatically allows the extension of ID List allocation.

COMPASS 32 . . . is a comprehensive system which provides a convenient means (symbolic instructions) for writing machine language programs. Input to COMPASS 32 may be from punched cards, paper tape, or magnetic tape; the output is a machine code, relocatable binary object program. One of the features of COMPASS 32 is the ability to define several different types of data such as; 24-bit decimal and octal constants, 48-bit decimal integer, and floating point constants. Macros can be defined in the program; address literals are valid; and arithmetic expressions can be used in address fields. COMPASS 32 produces as output a relocatable binary object program and, optionally, a symbolic and machine code listing of the assembled program.

SCOPE 32 . . . The **Control Data** SCOPE 32 observes and controls automatically the compilation and/or execution of programs written in various source languages. There are several advantages to operating under a monitored system:

- job stacking – programs written in different languages can be compiled and/or executed without operation intervention.
- job accounting – each job, as it is processed, is logged separately which provides control over project time allocation and computer utilization.
- assignment of I/O functions and initiation of I/O activities.
- adjustment of system operation to system environment.
- allocation of memory.

Expanding a **Control Data** 3200 by adding optional arithmetic and/or additional memory presents no recoding problems. Floating point expressions, for example, are always compiled to floating point machine code. If no floating point arithmetic is available to the system, these codes are trapped during computation, and exits are made to floating point arithmetic subroutines.

CODING EXAMPLES

FORTRAN 32 statements to evaluate the standard deviation, X, for a set of 30 data points:

```
      N = 30
      SUMX = SUMXSQ = 0
      DØ 55 I = 1, N
      SUMX = SUMX + X(I)
55    SUMXSQ = SUMXSQ + X(I) **2
      X = SQRTF ((N*SUMXSQ – SUMX **2) / (N*(N-1)))
```

COMPASS 32 symbolic commands to evaluate $Z_i = B^2 - A*D_i$ in 48-bit floating point for 10 values of D:

```
START   ENI     9, 1      Set index register 1
        LDAQ    B         Load B
        FMU     B         Multiply by B
        STAQ    TEMP      Store B²
LØØP    LCAQ    A         Load Complement A
        FMU     D, 1      Multiply by Dᵢ
        FAD     TEMP      Add B²
        STAQ    Z, 1      Store Zᵢ
        IJD     LØØP, 1   Increment and Loop
```

3200 SYSTEM FEATURES

STORAGE

- 8,192, 16,384, or 32,768 words plus a 64 word Register File
- Total cycle time;
  main storage – 1.25 microseconds
  register file – 500 nanoseconds
- Effective cycle time (for overlapped, 2 module operation):
  main storage –.750 microseconds

SCIENTIFIC PROCESSOR ARITHMETIC EXECUTION TIMES (microseconds):

Notation	Precision	Add/Sub.	Multiply	Divide
Fixed Point	24-bits	2.5	8.8-12	11.9-12.1
Fixed Point	48-bits	3.8-4.4	22	24
Floating Point	48-bits*	12	29	29

*36-bit mantissa; exponent range: $10\pm^{307}$

LOGIC

- Parallel Mode
- Single Address
- Three Index Registers
- Indirect Addressing to any Depth
- Internal and External Program Interrupts
- Trapped Instructions
- Real-Time Clock
- Instruction Repertoire Includes:

Fixed and Floating Point Arithmetic
24 and 48-Bit Arithmetic
Decimal Arithmetic
Logical Operations
Masking Operations
Indexing
Inter-Register Transfers
Conditional and Unconditional Jumps and Stops
Buffered Storage Search by Word, Character, or Mask

INPUT-OUTPUT

- 1, 2, 4, 6, or 8 Bi-directional Communication Channels
- 6, 12, or 24-Bit Byte Transmission

Speed: up to one million characters/sec. (For special applications, input/output may take place directly with storage at a rate of one 24-bit word per storage cycle — 1.25 μs.

Peripheral Speeds:

Type	In	Out
Cards	1200/min.	250/min.
Mag. Tape*	15,000-120,000 chars./sec.	
Paper Tape	350 chars./sec.	110 chars./sec.
Plotter	- -	300 increments/sec.
Printer	- -	300-1000 lines/min.

*Forward and reverse read; 175 and 350 in./sec. search speed

PHYSICAL

- Solid State
- Diode Logic
- Transistor Amplifiers
- Magnetic Core Storage
- Less Than 250 Sq. Feet Floor Space Required
- Low Power Requirements

TYPICAL 3200 SCIENTIFIC APPLICATIONS

BIO-MEDICAL RESEARCH

Electrocardiographic Analysis
Neurological Experimentation
Physiological Research
Brain Wave Analysis

NUCLEAR RESEARCH

Nuclear and Thermonuclear Applications in Weapons Systems
Bubble Chamber Computations
Nuclear Reactor Simulation
Multi-parameter Analysis

MILITARY

Checkout of Vehicles and Weapons Systems
Damage Assessment and Evaluation
Command and Control Systems
Telemetry Data Acquisition
Weather Research

INDUSTRIAL RESEARCH

Distribution of Radioactive Materials on a Surface
Vibration and Motion Studies
Oil Production Analysis
Heat Transfer Studies
Information Retrieval
Crystallography
Radar Research

MATHEMATICAL ANALYSIS

Simultaneous Linear and Non-Linear Differential Equations
Correlation Coefficients and Analysis of Variance
Tables of Specialized Functions
Eigenvalues and Eigenvectors
Multiple Regression Analysis
Probability Analysis
Complex Polynomials
Fourier Analysis
Matrix Algebra
Curve Fitting

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