COMPUTATION RESEARCH AT MSFC

May 25, 1967

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FOREWORD

Research Achievements Review No. 8, Volume II, was presented May 25, 1967. The paper that follows is a brief discussion of third generation computing at MSFC. This paper was prepared from the material presented at the review, which included the following talks:

1. Introduction to Computing at MSFC — by Helmut Hoelzer
2. History of Computers and Their Use at MSFC — by Charles P. Hubbard
3. The Third Generation Concept in Computing — by William Fortenberry
4. Application of the Third Generation Concept to MSFC Computation Problems — by Carl Prince
5. Technical Description of MSFC's Third Generation Computer System — by John C. Lynn
6. Implementation of Third Generation Computing at MSFC — by James T. Felder, Jr.
7. A Look at the Future in Computing at MSFC — by Helmut Kerner

THIRD GENERATION COMPUTING AT MSFC

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THIRD GENERATION COMPUTING AT MSFC

INTRODUCTION

The Univac 1108 third generation (3G) computer at MSFC (Fig. 1) will have the capability to handle multiple requests from the equipment shown in Figure 2. This time sharing ability will provide the entire Marshall Center with adequate means to process computer operations from almost any location.

The 55 teletypes that will be provided at remote locations offer rapid response to each individual user.

Letters and numerals can be displayed by the computer on the scope of 28 CRT (Cathode Ray Tube) stations, while 10 other CRT stations can provide computer generated pictures on their screen or allow the user to draw on the screen with a light pen. Thus the pictures can be altered by erasing lines and drawing other lines and picture segments on the screen.

FIGURE 1. 1108 COMPUTER

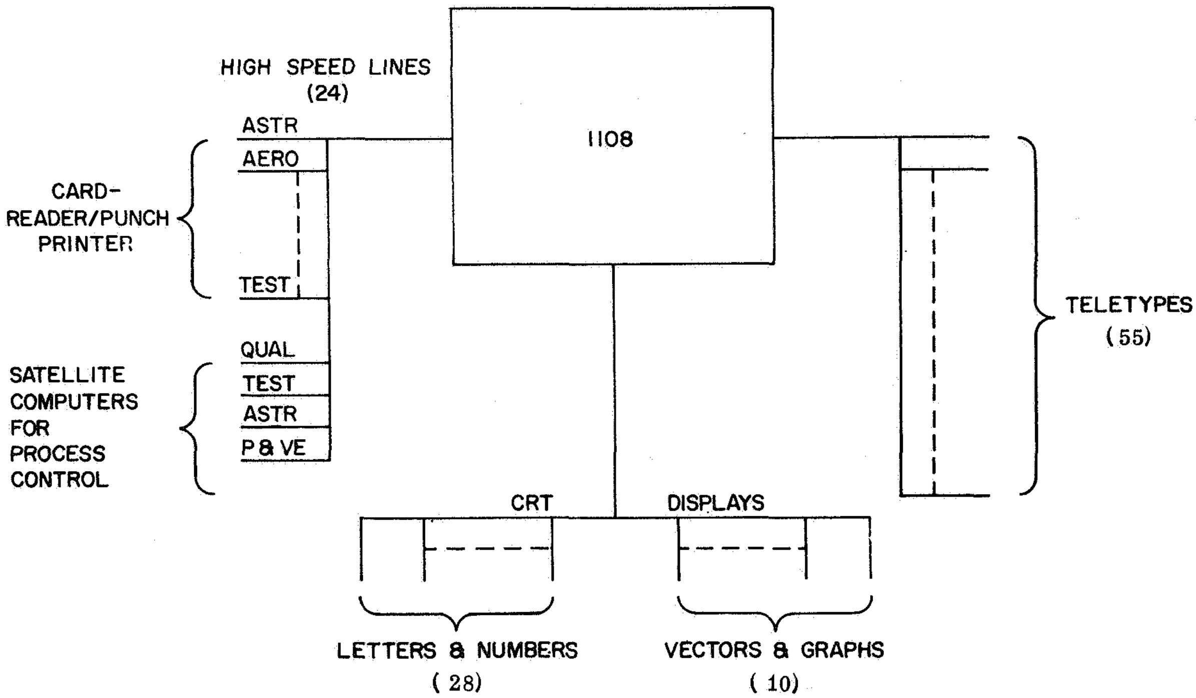

FIGURE 2. 1108 REMOTE STATIONS

A drawing of component or structure can be changed by adding or deleting items to assemble a new design concept.

Most of the 24 high speed lines will connect general purpose remote stations comprised of card readers and printers to the 1108 computer in the Computation Laboratory. A few of the 24 high speed lines will be transmission paths to connect satellite computers to the 1108. The satellite computers in other laboratories may be located up to a distance of one mile from the 1108 in the Computation Laboratory. These satellite computers can possibly be used to control large operations such as the static firing of an engine or the automatic checkout of a complete stage. Each of the 24 high speed lines has the capability to transmit 50,000 bits per second, an ample electronic transmission capability.

COMPUTER OPERATIONS

This operation of the 3G computer is made possible by multiprogramming, multiprocessing, internal and external interrupt capability initiated from either the main 1108 location or the remote sites, and the ability to do all peripheral work (reading cards, printing, storage on tapes) directly from almost any location. The hardware is modular, thus the components, such as memory banks, processors, input-output channels, and peripheral communication devices can be added to the system to increase its power. The engineer's thinking and the machine's computing process can now become one continuous, integrated operation.

Multiprogramming. Multiprogramming is the sharing of a processor when a computer handles several programs in sequential operations. The processor has the ability to address all of the computer's memory through a switching mechanism, and thus can address all of the programs residing there. Many programs can reside in the computer's memory because of its vast size, but are located in different locations; thus the central processor can act upon programs sharing the same memory whenever there is a pause in processing one program. The processor can operate physically on only one program at a time, causing the program to initiate some input or output function during which time a pause in the sequence is required. At this point a switch takes place and the processor moves from the operating program to another program residing in core and initiates some action on the new program. Except for the time needed for switching, the processor is in use 100% of the time.

Multiprocessing. Multiprocessing is the employment of two or more processors that can address the entire computer's memory simultaneously. Several processors provide the capability to independently and simultaneously handle several programs. More programs than the number of processors can be operating, because when some programs are performing input-output functions, the processors have searched memory and found other programs upon which to operate. The 1108 computer at Marshall will have three processors, therefore more than three programs can be operated on by the processors at any given time.

Time Sharing. Time quantums can be allocated to each program when several processors are handling a number of programs. The time quantums are allocated from the total amount of time available in the CPU (Central Processor Unit).

Interrupt System. When an interrupt occurs, the computer allows the program to complete a specific machine function, then moves to a precoded solution to solve the interrupt.

Types of Interrupts:

1. Program dependent types of interrupts (divide by zero in math equation).

2. Nonprogram dependent interrupt

3. Input-Output functions

4. Diagnostic problems (an error occurs in a memory bank and requires the attention of the "EXEC" to mark that memory bank off line automatically).

Storage. The main memory of the second generation computer now in use at MSFC has 32,000 words core storage capability. The 3G computer will have 262,000 words core storage capability. The total of 1 1/2 billion characters of storage can be expanded several orders of magnitude by adding more huge Fastrand drums with the practical limitation being the amount of facility space. The word size for both computers is 36 bits. The validity of results is assured by carrying one extra bit that serves as a check on the information (parity check). There is parity checking on all storage references; and continuous overlapping and interleaving operations are being run. Overlapping means that a reference to main storage is occurring while the processor is decoding the previous instruction. Interleaving is the simultaneous searching of odd and even banks of storage. The total 262,000-word main storage is in banks of 65,000 words that are divided into odd and even sections of 32,000 words each (interleaving on one bank is possible). Since three processors share or compete for memory, the multiprocessor-adapter assures that no processor will be more than one memory cycle behind any other processor in access to a memory bank. The input-output controllers (large multiplexers) will handle 24 high speed data channels that will allow additional input-output devices to join the systems.

Memory Protect Features.

1. Read Protected — Only the author can call up the data.

2. Write Protected (Memory Protect Feature) — A lockout capability prevents the data from being destroyed or overwritten so that several users can share the same data.

Types of Problems.

1. Compute Bound — requires little input and a great deal of manipulating and computation by the processor in the central unit, thus wasting the external communication power of the computer. Typical problems of this unit are (1) to find the Eigenvalues of a large matrix, (2) solving simultaneously a large system of equations, and (3) solving for certain key points along a long trajectory.

2. Input-Output (IO) Bound — requires large amount of IO and little operation by the processor, thus wasting the computing power of the system while the tapes and printers are functioning to receive the data and make a reply. Typical problems of this kind are (1) to furnish personnel reports, (2) to compile contract status reports, (3) to inventory catalogues of data, and (4) to run the payroll.

3. Consolidating Volumes of Data — requires storage capability with up to 1 1/2 billion characters available on Fastran drums for

compiling files of data for engineering requirements. These problems include (1) design and development of a large project, (2) changes to specifications, and (3) data storehouses.

Capabilities. The third generation computer can respond as quickly as the engineer can change the design and data on the CRT screen or review plans and diagrams presented by the computer. To exploit such rapid communications between the engineer and computer requires program-oriented languages that make extensive use of new pictorial and graphical methods for stating the problem and presenting the results. Standard programs on call from memory devices in the computer can be used to solve the problem when the computer has sufficient information, possibly in pictorial form and in equations, and has converted these data to a form to be processed by conventional problem solving programs.

Some computer operations make use of pictorial or graphical means for the statement of the problem and the presentation of the results. They can be separated into two main areas of application (Fig. 3).

1. TOPOLOGICAL
   - A. ELECTRONIC CIRCUIT ANALYSIS
   - B. PERT
2. GEOMETRICAL
   - A. STRUCTURAL AND STRESS ANALYSIS
   - B. VIBRATION STUDIES
   - C. HEAT-TRANSFER STUDIES
   - D. AERODYNAMICS APPLICATIONS
   - E. ENGINEERING DRAWING RETRIEVAL AND/OR MODIFICATION

FIGURE 3. COMPUTER GRAPHICS APPLICATIONS

One group of problems requires providing topological relationships between objects to solve applications involving electronic circuit design and analysis, design of feedback control systems on a block level, PERT systems, and structured data that can be presented in a flow or organizational chart. The other group of problems can be solved by the computer by receiving the data in geometrical form. This type of applications includes structural and stress analyses of space vehicles, vibration studies, heat transfer studies, and aerodynamic applications. In the future, engineering drawings can be modified by drawing on the screen with a light pen and automatically receiving a copy of the revised drawing.

PROBLEM-ORIENTED LANGUAGES

TOPOLOGICAL PROBLEM STATEMENTS

1. Circuits

Circuit analysis problems are stated topologically. The engineer has a choice of block, such as amplifiers or resistors, etc. When the interconnections of the system are defined by the use of the light pen, the computer can evaluate the circuit. Given certain input signals, the response at any point specified by the light pen can be obtained and displayed on the screen.

Likewise, the same process can be followed with feedback control systems of electric or electromechanical systems. In this case the blocks would represent transfer functions. With the light pen the user could interconnect the different blocks and specify the type of block, e.g., a differentiator, adder, and integrator. Then, by using the verbal features of the teletypewriter, functions within the block can be defined by writing the equation. The computer then processes the data and draws and types the results to prepare enough information for the engineer to make decisions.

Figure 4 shows a sample circuit an engineer might design. When needed, the using engineer can change the constants of the transfer function or the equations themselves from the teletypewriter. An iteration of the procedure to find a solution will take only minutes as opposed to at least a day on today's system.

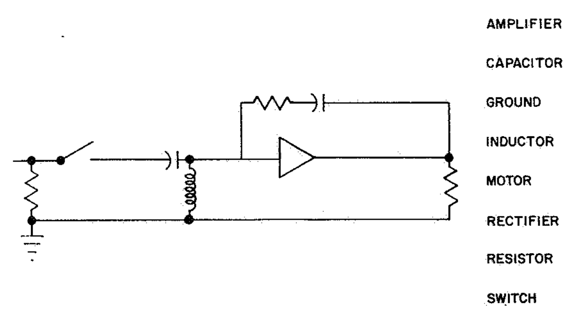

FIGURE 4. ELECTRONIC CIRCUIT DESIGN AND ANALYSIS

2. Marves

Another example of this programming system that was developed at Marshall is MARVES (Marshall

Vehicle Engineering System), a language for computation of trajectories. Each of its 100 modules represents a physical effect or a mathematical method. Most trajectory problems can be constructed with these building blocks. Since the using engineer can not be expected to have a working knowledge of all 100 and more different blocks, some type of retrieval system is needed to assist him in the composition of his program. This service can be requested by typing MARVES on one of the teletypewriters. The computer will respond by offering the first level of options via display on a CRT console (Fig. 5) to the user, who takes his choice by merely pointing with his light pen. Depending on his choice, the computer will offer the next lower level of options and so forth until the problem is completely specified. Whenever the user does not vote for any option, the computer will take a standard route. Finally the computer will list all modules selected, which the user can modify or exchange later.

GEOMETRICAL PROBLEM STATEMENTS

1. Lifting Body

The geometrical form input to the computer could present new techniques for conducting aerodynamic studies of a lifting body. Given a group of basic building blocks consisting of cones, cylinders, spheres, and different two-dimensional features such as triangles, through a movement of the light pen the designer could move the two-dimensional representation of the cone and connect it to the two-dimensional representation of the cylinder and half of a sphere, etc., and a composite picture would appear. Fins for the flight stage can be added later. Thus the designer can define a geometrical body and thereby implicitly define his design problem by using a simple language of pictures supported by numerical parameters.

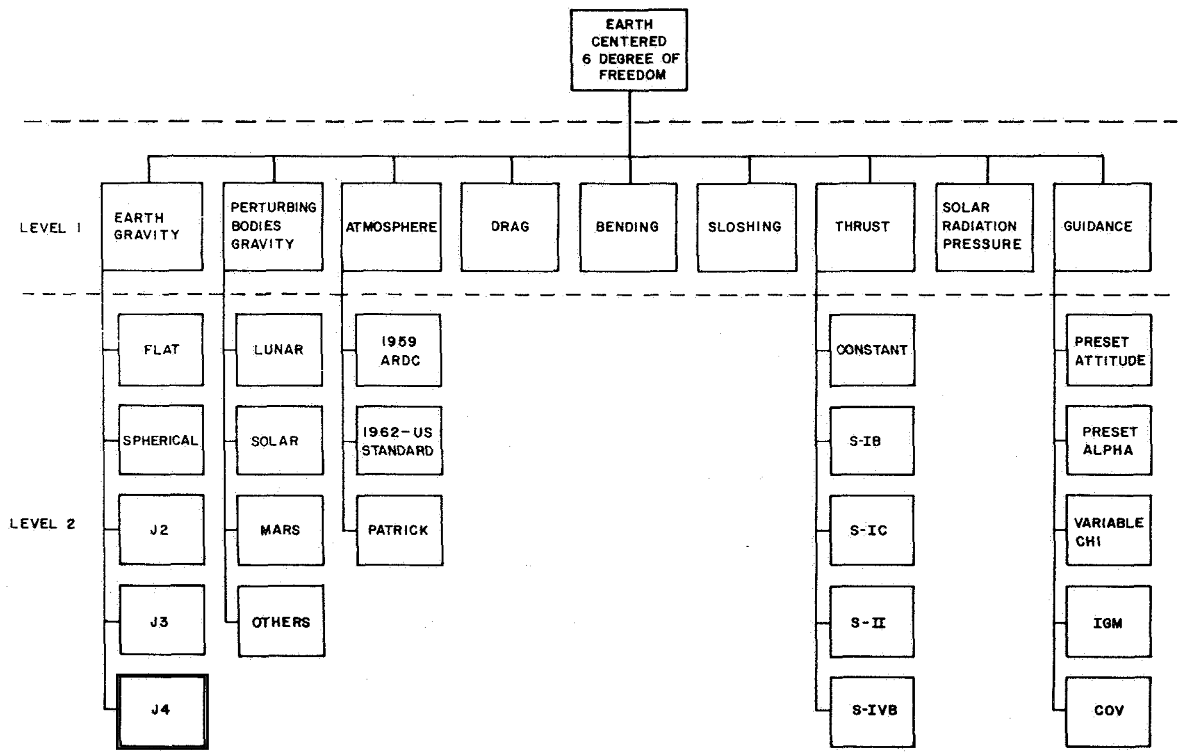

FIGURE 5. EXAMPLE OF LEVEL 1 AND LEVEL 2 OPTIONS AVAILABLE FOR THE 6-DEGREE-OF-FREEDOM EARTH CENTERED TRAJECTORY PROBLEM

To completely define the concept, the engineer stipulates the geometrical aspects of the design to include the thrust required for the vehicle. The computer than makes an evaluation. As a result, drag, lift, and the center of this lifting force can be obtained and displayed on the screen. Whenever the engineer specifies the material property, the center of gravity can be computed (Fig. 6). This is a typical example of a problem-oriented pictorial language.

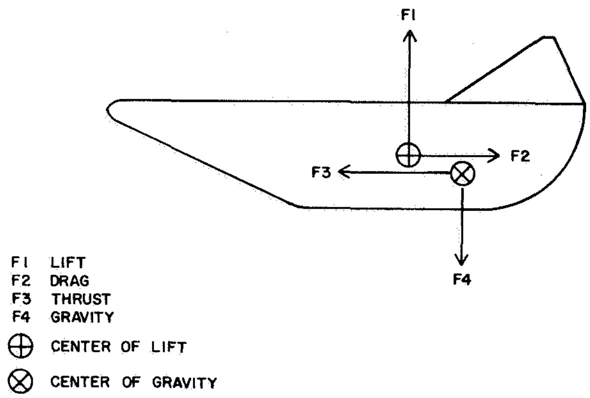

FIGURE 6. AERODYNAMIC STUDIES (LIFTING BODY)

2. Structures

It is quite obvious that a similar procedure can be used for the design of structures. The designer can shape, size, and position any of the basic building blocks, by use of the light pen. At any selected position in space the computer would then produce a three-dimensional (perspective) picture of the composite structure by connecting the basic building blocks (Fig. 7). The computer would also display two-dimensional projections and compute the commands for a numerically controlled manufacturing process.

INFORMATION RETRIEVAL SYSTEMS

A third interesting category of problem-oriented languages is information retrieval systems. A typical example at Marshall Space Flight Center is the technical library. Given a set of key words, the computer will print out a list of all journals or books in the library that deal with the subject matter.

Retrieval systems can be designed for particular organizations and programmed to prevent duplication in data storage and transmission. The design of such systems and access to the data depend upon many factors that are too complex to be discussed in this paper.

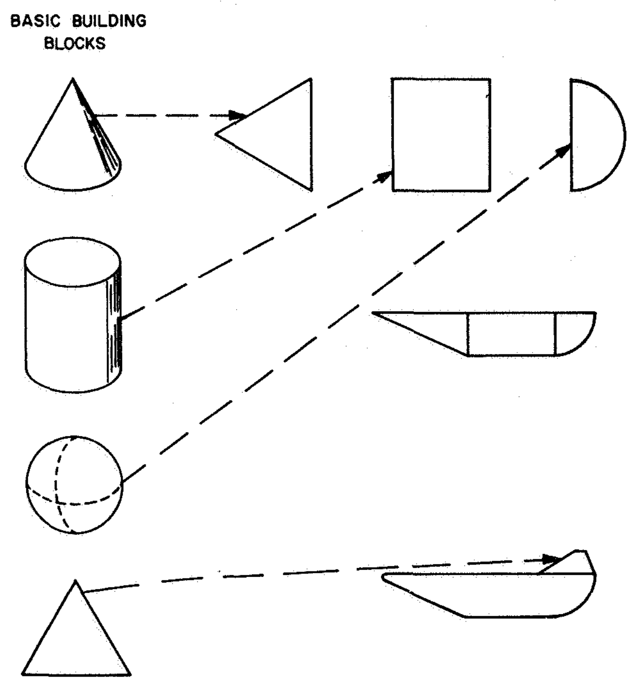

FIGURE 7. STRUCTURAL DESIGN

ONBOARD COMPUTER

A significant evolution is taking place in onboard computers. Previously the onboard computer performed only guidance and control operations. Today's Saturn computer uses only 20 to 30 percent of its time for the classic guidance and control problem. Looking toward Voyager and beyond, it appears that only a small percentage of computer time will be used for the guidance and control function; the main computer function will be data management and data compression. Further, it will be necessary to build a computer that will last at least three to four years for a manned Mars mission. In the case of a failure it should not break down totally (concept of the gracious degradation). Power must be much lower than the present kilowatts; it must be rather in the order of watts only.

It is believed that with the LSI technology that will be available in the early 1970's, it will be possible to build computers to meet such requirements and to find the proper computer organization for these applications. Years of work by mathematicians and computer designers will be necessary. The powerful third generation computer at MSFC will be intensively used for simulations of the onboard machines to obtain knowledge about the reliability of such a predicted new computer concept as to its accuracy and speed. Its executive system will be evaluated toward the features of self-organizing. The Computation Laboratory is presently organizing to begin to work toward these goals.