15090

Proposal

for

SOLOMON II COMPUTER

SPN-15114

4 November 1963

Presented to

UNITED STATES WEATHER BUREAU
General Circulation Research Laboratory
615 Pennsylvania Ave., N.W.
Washington, D.C.

by

WESTINGHOUSE ELECTRIC CORPORATION
625 K. Street
Washington 6, D.C.

TABLE OF CONTENTS

1. INTRODUCTION

2. TECHNICAL SUMMARY

3. MANAGEMENT

4. RELATED EXPERIENCE, FACILITIES, AND PERSONNEL

LIST OF ILLUSTRATIONS

1. INTRODUCTION

Every computer is brought into being to serve a selected class of requirements. The Westinghouse SOLOMON II Computer discussed on these pages was specifically designed as a general purpose scientific computing system for those requirements that are now or will become computer limited. In by-passing sequential computer limitations, SOLOMON is the first computer system to depart from conventional computer organization in a practical manner and, as such, is a break through in the state-of-the-art from which may be formed a new generation of computers.

The second of this series, the SOLOMON II, is especially adapted to provide the computing throughput necessary for otherwise unobtainable scientific calculations; an increase of many orders of magnitude in speed over sequential machines is achieved through parallel organization, using state-of-the-art integrated circuit components. At once, feasible speed, size, versatility, and cost are obtained though the capability is massive.

Based upon a workable concept of parallel logic organization, the SOLOMON II is a new departure from which a new progression in computer power may be obtained to pace the needs of the scientific community. Yet, in its present configuration, the Westinghouse SOLOMON II itself offers a considerable expansion in versatility and power by its modular nature.

In organization, the SOLOMON II embodies a decentralization of a large part of the arithmetic function into a linked network of identical processing elements. Simply, computing throughput may be increased in a planned, orderly growth by the addition of increments of processing elements as required.

The network, as formed, is programmed by a common central control in such a way as to simulate more directly the problem being solved. Thus is formed a system configuration which, though wholly digital, approaches the efficiency and the conceptual and operational simplicity of an analog system, yet retaining the flexibility and precision of an entirely digital, stored-program system.

In implementing the SOLOMON II, maximum use is made of integrated circuits to preclude system obsolescence because of component advance. Other advantages of integrated circuits are greatly increased system reliability and the ease of simplified maintenance.

In a very real sense, then, the SOLOMON II embodies the most desirable features possible in an advanced computer without relinquishing practicality. More significantly, in application to the needs of the Weather Bureau, SOLOMON II is ideally suited to mathematical model simulation of the dynamics of geophysical fluid systems of various scales.

For the present requirement, a 512-PE configuration of the SOLOMON is recommended for initial use.

Cost of the basic SOLOMON-Weather Bureau configuration and possible succeeding increments are shown in the cover letter.

2. TECHNICAL SUMMARY

2.1 INTRODUCTION

The family of Westinghouse SOLOMON Computers is a new approach in organizing conventional components to provide a large increase in computating speed over conventionally organized computers of comparable complexity. Due to this unique feature, an evaluation of its merits requires some knowledge of the organization and methods of utilization of a SOLOMON Computer.

At the end of this Section, a brief description of the Westinghouse SOLOMON II Computer is presented. Full details are contained in the "SOLOMON II Programmers' Reference Manual," a copy of which is transmitted with this document.

2.2 SOFTWARE

The software included with the SOLOMON II computer includes a FORTRAN IV Compiler for the General Purpose Unit (GPU), as well as an assembly system and library of the usual subroutines and a supervisory program.

The assembly system provides the programmer with the control necessary to efficiently use the computing power represented by the Network. The associative memory feature of the Network permits rapid compilation/assembly of programs for the GPU/Network Control Unit.

A description of the assembler system is contained in the SOLOMON Project Technical Memorandum No. 24, "Assembly System," also transmitted herewith. Several examples of programs coded in assembler language are contained in SOLOMON Project Technical Memorandum No. 22, "Programming Considerations and Examples." These examples include subroutines for double precision addition and multiplication in the Network Processing Unit, as well as programs of particular interest to the Weather Bureau. These

programs are intended for illustration purposes and are not necessarily the most optimum programs possible.

Currently being specified is a SOLOMON II Simulator for use on the Computer in the computing center of the Westinghouse Defense and Space Center, located near Washington. To be available about 6 months before delivery of the first SOLOMON II, this functional simulator will accept SOLOMON II assembly language for a small size network and will be used for training and program checkout. Because of the tremendous random access memory and speed advantage of SOLOMON over any conventional computer, full scale simulation is manifestly impossible. A nominal amount of time will be available for customer program checkout prior to computer delivery.

2.3 SUMMARY OF THIS PROPOSAL

Section 3 of this proposal describes the required computer environment, the customer personnel training program to be conducted in Baltimore (on the Weather Bureau Installation) and the continued software support available as well as the growth potential for this computer.

Section 4 describes the Westinghouse experience, personnel, and facilities which ensure the delivery and performance as specified.

2.4 SOLOMON II PHYSICAL CHARACTERISTICS

An attached document, in addition to the three previously referred to, SOLOMON Project Technical Memorandum No. 25, "SOLOMON II Physical Characteristics," describes the functions of each of the major subunits of the SOLOMON II.

The benefits of a parallel organized computer are reflected not only in speed of computation but in the design, manufacture, checkout, maintenance, and spare parts. A large portion of the hardware consists of large numbers of identical circuit boards. The considerable effort expended in optimizing the circuitboard design is justified in the considerable economies and simplifications in manufacture, check-out, and maintenance.

2.5 PROGRAMMING CONSIDERATIONS AND EXAMPLES

The document, "Programming Considerations and Examples," is of particular interest and should be studied to obtain a detailed understanding of the programming of the Network and Network Control Unit as well as of the potential of such features as mode control, geometric control, routing, variable geometry, broadcast inputs, and the associative memory feature inherent in SOLOMON organization. (The General Purpose Unit is conventionally organized and utilized. It has an ADD time of 2 microseconds (fixed or floating) and a multiply time of 5 microseconds (fixed or floating). Study of that report and of the programs it contains there will demonstrate the straightforward nature of network programming.

The potential of mode control for specifying irregular boundaries is noted there, as well as the optional use of the Broadcast Register to account for special computations at the north and south poles.

Numerical experimentation most natural to SOLOMON indicates that the relaxation method is frequently more efficient than the Liebmann technique, while clearly, it is never less efficient than the Richardson technique.

Considerable detail of the programming of the computational part of the solution of the primitive equations is given including execution times for these portions of the study. The Weather Bureau is in receipt of SOLOMON Project Technical Memorandum No. 14. "Preliminary Numerical Weather Application Study." In that report a SOLOMON I Program for a simplified Barotropic Model was presented. The same problem, reprogrammed for SOLOMON II, is contained in "Programming Considerations and Examples".

In view of the above remarks on the convergence of the relaxation technique, one can estimate relative execution times for this program on the basis of an equal number of iterations for SOLOMON II and a reference conventional computer. The result is that SOLOMON II is about 2000 times faster than the IBM 7090 for the computation of this problem. This advantage derives from the inherent speed of the Processing Element arithmetic (add = 2.2

microseconds, mul = 13 microseconds) as well as from the parallel (1024 Processing Elements) organization of the computer.

This Section concludes, as stated earlier, with the Introduction from the "SOLOMON II Programmers Reference Manual" which furnishes a brief description of the Westinghouse SOLOMON II Computer. For futher details, this manual should be consulted.

2.6 WESTINGHOUSE SOLOMON II COMPUTER

Figure 2-1 is a block diagram of the Westinghouse SOLOMON II Computer. Westinghouse SOLOMON II is divided into two systems, the Network Processor and the General Purpose System. The Network Processor consists of the Network Program Memory, the Network Control Unit (NCU), the Network Sequencer Unit, and the Network. The Network Processor can function alone and is so available.

All significant arithmetic capability of the Network Processor is in the Network. The Network Control Unit's arithmetic capability is limited to addition, subtraction, Boolean operations, and index modifications and tests. These capabilities are provided in the NCU primarily to allow for flexible means of modifying any portion of the 40-bit instruction words.

The separate Memory, Control Unit, and Arithmetic Unit shown in figure 2-1 comprise a general purpose computer capable of communicating with the Network Processor through a common memory. Normally, the NCU communicates only with the Network Program Memory and the Control Unit of the General Purpose Computer only with the General Purpose Memory. However, each control unit is capable of addressing the other unit's memory if so desired.

The Input/Output unit can be activated by both systems. The data channels transmit data between the General Purpose or Network Program Memories and conventional peripheral devices such as magnetic tape units, printers, card reader and punch, typewriter, drum or disc file, etc.

The Network contains more than 90 percent of all the logic of the Network Processor. The individual Processing Element (PE) is designed to provide

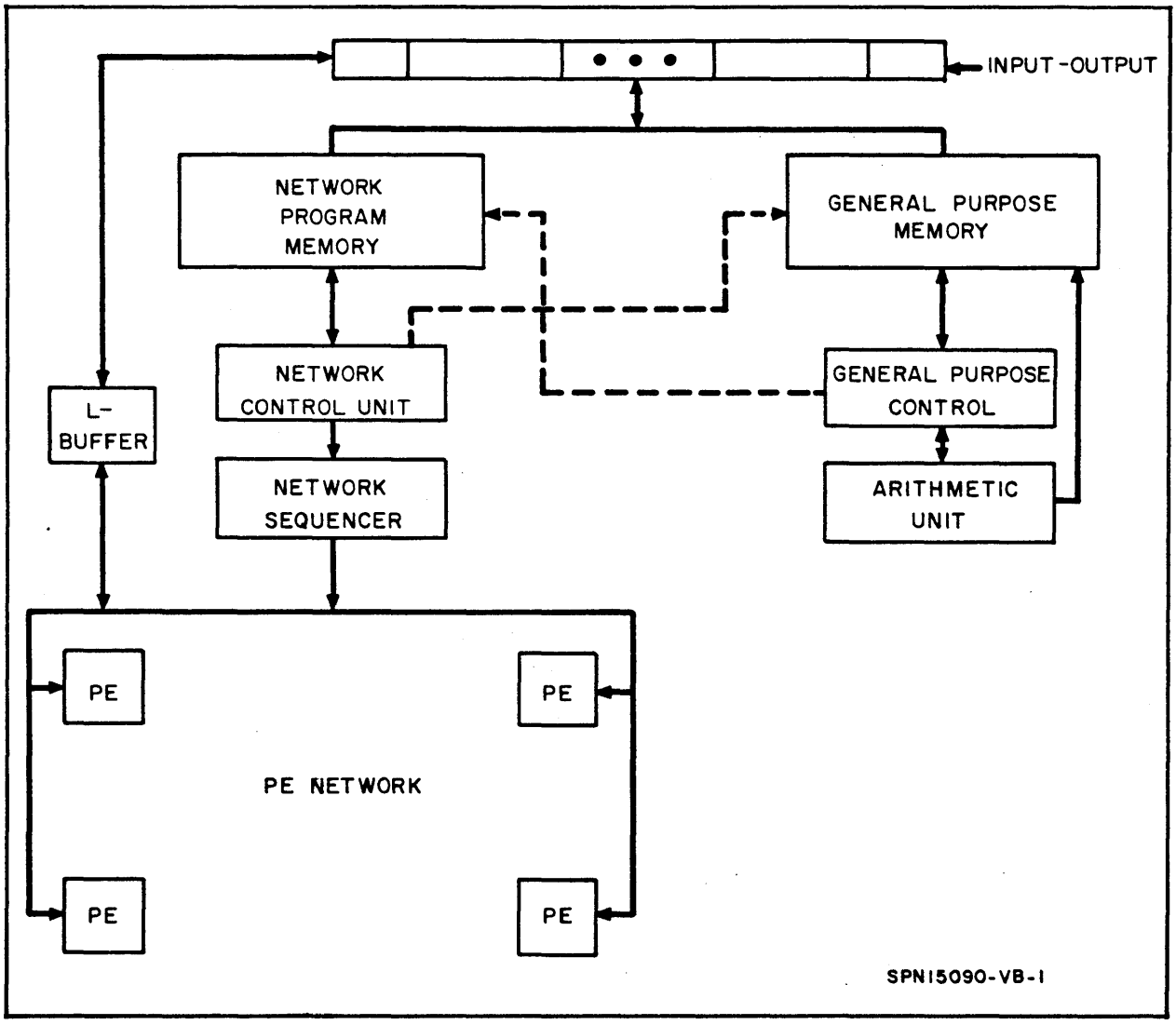

Figure 2-1. General Block Diagram of Westinghouse SOLOMON II Computer

fast operation with logical simplicity. The Network is composed of multiples of 256 PE's, nominally 1024, arranged normally in a 32 x 32 array with each PE capable of communicating with its four nearest neighbors as well as with a broadcast input. Each PE has 2048 20-bit words of core memory expandable to 8192 words. Figure 2-2 depicts the Network.

Typical execution times are:

Add	2.2 μsec
Multiply	13.0 μsec
Divide	50.0 μsec

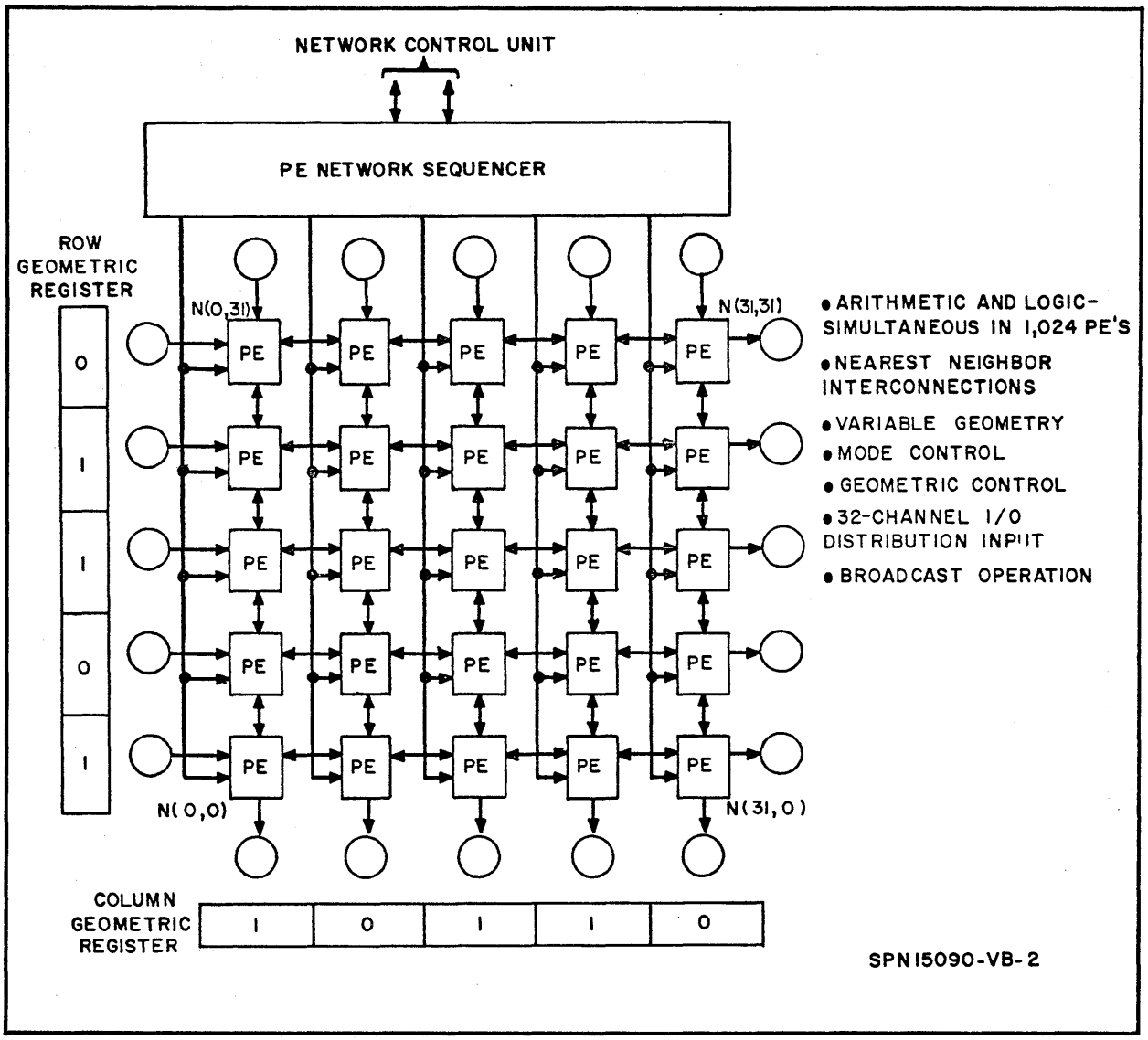

Figure 2-2. The Processing Element Network

The General Purpose System is connected to the PE system only through the common memory and through certain interrupt features. Otherwise, it is a conventional single address, 40-bit word length computer.

Typical execution times are:

Index	1 μsec
Add	2 μsec
Multiply	5 μsec

3. MANAGEMENT

3.1 PHYSICAL PLANNING INFORMATION

The SOLOMON II Computing System requires 1700 square feet of floor space in an air-conditioned room with the following temperature and humidity specifications:

	High	Low
Temperature	85°F	50°F
Humidity	90 percent	10 percent

The ac input power requirement is 30 KW at 220-volts 3-phase.

Westinghouse anticipates that the Weather Bureau's present facilities should require only minor changes prior to installing a SOLOMON II System.

3.2 WESTINGHOUSE TRAINING CAPABILITIES

The wide variety of products and services furnished by Westinghouse provides the basis for a highly versatile training staff. This training organization founded in 1950, has provided courses of instruction to more than 8,000 students representing all branches of the U.S. Government, industrial organizations, and foreign countries.

3.2.1 The Team Approach

Westinghouse is convinced that the key to success in technical training lies in the capabilities of the people engaged in the project.

The Westinghouse training team consists primarily of personnel from the Technical Training Section and the Computer Engineering Section. We believe that the Westinghouse "team approach" to technical training, utilizing the the combined talent and experience of departments within the Westinghouse structure, offers a demonstrated capability in technical training.

3.2.2 Related Training Experience

Specific instructional experience has been gained in each of the following training programs conducted in support of computer systems:

AN/SPA-22 A shipborne computer system which aids Air Controllers in performing the tracking and control functions in air interceptions.

ULCER The Underwater Launch Current and Energy Recorder Mk 15 is a computer system which analyzes all components of ships motion and sea environmental conditions. Based on these parameters, the probability of successful launch is computed and predicted.

AUTOPLOT A shipborne digital computer system which accepts inputs from a wide variety of navigational aids to give precise position information.

AN/UYK-1 A solid state, binary, parallel machine with a stored program repertoire to facilitate both numeric computation and alphanumeric manipulation. The computer is organized as a 15-bit word machine; however, it can be programmed to operate with word lengths which are multiples of 15 bits.

AN/USQ-20 A general purpose solid state digital computer.

General training experience, accumulated over a period of 13 years, has developed a practical understanding of the procedures and techniques, for presenting in a simplified manner the most difficult areas of computer system operation and programming. This background of experience is offered to evaluate the training needs in support of the Solomon II Computer System.

3.2.3 Competence of Instructors

The Westinghouse personnel assigned to instruct Weather Bureau personnel will be senior people from the Training and Computer Section.

3.2.4 Training Facilities

The Westinghouse Technical Training Facility at Baltimore, Maryland is located in a building designed exclusively for training purposes. Each of 20 modern classrooms is equipped for the most up-to-date methods of technical training. Five completely equipped training laboratories are

located adjacent to the classrooms to provide "live" equipment support. The school site, on the Washington Boulevard, is convenient to the Baltimore-Washington Parkway, which facilitates attendance of students from the Washington, D. C. area.

The major purpose of our training effort is to develop and provide courses of instruction "tailored" to the needs of the customer. Westinghouse is fully prepared to furnish all required training for the SOLOMAN II Computer System either in our 22,000 square foot training facility or at a site selected by the Weather Bureau.

This page intentionally left blank

3.3 SOFTWARE CONSIDERATIONS

3.3.1 Software Package

Westinghouse is aware of the emphasis that the Weather Bureau places on the software associated with a computer. Accordingly, the SOLOMON II software package will consist of a powerful executive system that has access to:

a. A ASA standard FORTRAN IV compiler for the General Purpose Unit (GPU)

b. Assembler systems for the General Purpose Unit and the Network Control Unit

c. Library of the usual subroutines (sin, cos, etc.) including double precision routines.

d. Diagnostics for all units

e. A completely programmed primitive equation model for global circulation.

f. Additional example programs of interest to the Weather Bureau

The associative memory properties of SOLOMON provide a unique facility in the assembly and compiling of program; i. e., a major portion of compiling/ assembly time is spent in table look-up. By the associative property of SOLOMON, this table look-up can be performed on 1024 items in a matter of a few microseconds. This feature will significantly reduce compiling and assembly time.

3.3.2 Programming Support

Westinghouse will provide continued software support in the form of reference manuals, maintaining the software package, and programming aid to ensure efficient use of the SOLOMON II System.

3.3.3 Program Checkout

To ensure smooth intergration of the SOLOMON II System into the Weather Bureau's activities, Westinghouse will provide the Weather Bureau with pre-checkout time of their problems.

The initial phase of this activity will consist of assembling programs with the SOLOMON II Assemble System written for the computer available in the Westinghouse computer center. Subsequent phases will involve simulation of programs on a SOLOMON II simulation program. The final phase is the assembly and running of programs on the SOLOMON II System.

Westinghouse stands ready to negotiate with the Weather Bureau the exact details of the software package, the amount and schedule of precheckout time, and the amount of programming support. These services are contained in the rental or purchase price.

The location of the Defense and Space Center in relation to the Weather Bureau will place a minimum of inconvenience on personnel of both facilities.

3.4 EXPANSION AND FUTURE GROWTH

3.4.1 Direct Expandability

The SOLOMON system is unique in its ability to provide modular computing power increases. In SOLOMON, this capability is most directly provided through the inclusion of a PE Network of varying size. The basic PE modules contain 256 PE's arranged in an 8 by 32 rectangular array. The computing system can be provided with additional PE modules as required and they may be included in the system at any time without wiring changes and extensive reprogramming of the original array. Figure 3-1 indicates the relationship of effective PE Network computing speeds versus the number of PE's in the system. In addition, a general purpose (conventionally organized) arithmetic capability can be directly added into the SOLOMON system at any time to augment the computing capability of the PE Network. An ultimate extension of a basic SOLOMON system to 4096 PE's (128 by 32 or 64 by 64), several general purpose arithmetic and control systems, 128,000 words of central memory, and up to 32 independently controlled input-output trunks is possible. It should be noted that any combination of numbers of units mentioned above is permissible (i.e., 8 by 32 PE's with 128,000 words of memory but no general purpose units, etc.). This high degree of flexibility

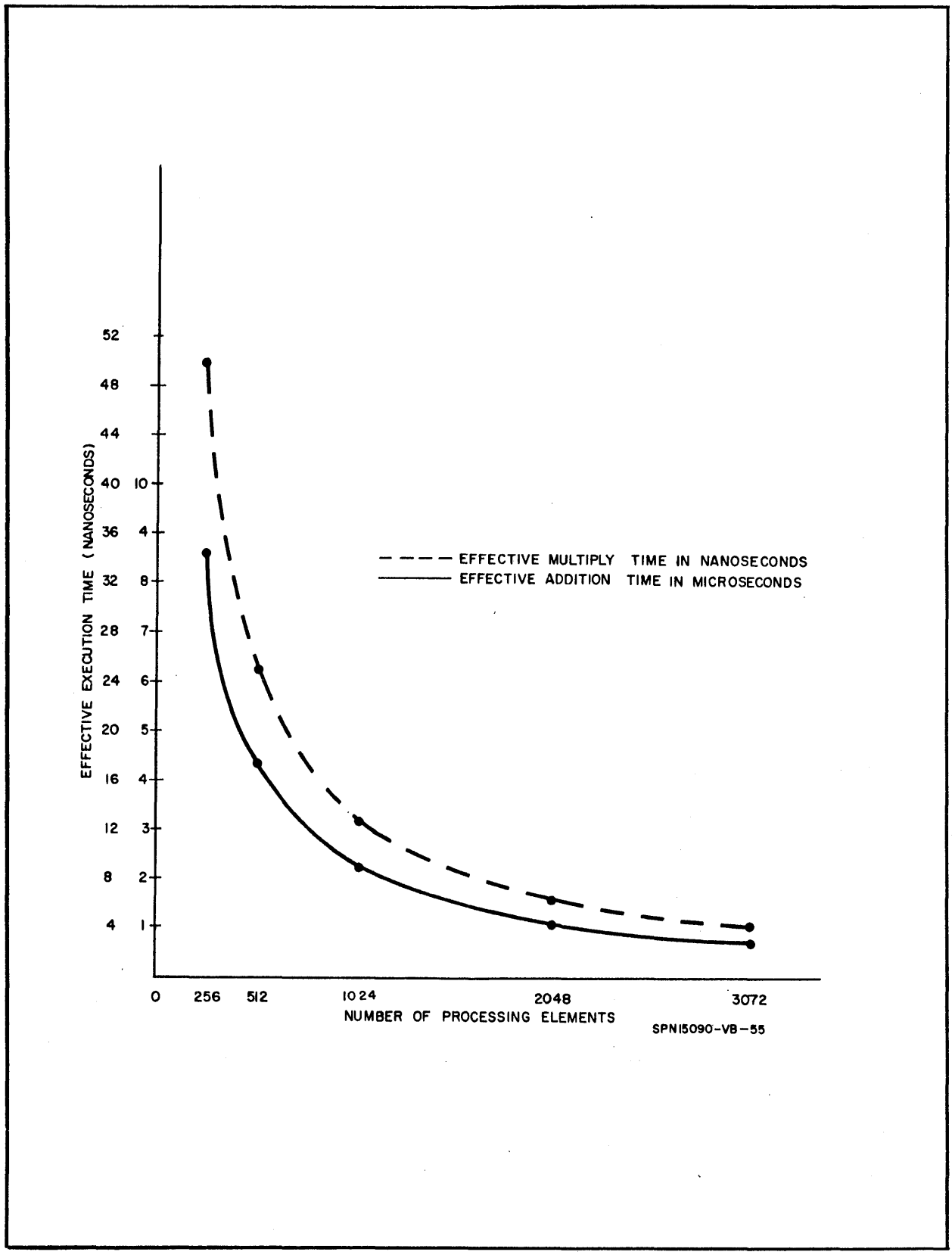

Figure 3-1. Execution Time Versus Number of Processing Elements

in providing a continuously problem - oriented computer in the face of changing problem requirements is an obvious advantage of SOLOMON over conventionally organized computer systems.

SOLOMON throughput capability also can be highly variable and problem oriented. The basic Network structure of n·8 by 32 PE modules provides 32 simultaneous input-output lines. To double the throughput rates, a simple change in the Network arrangement to n/2·8 by 64 plus an additional L-Buffer unit is required. Input-output on a "per PE" basis is an available option using a high speed parallel access disc unit.

It should be noted that the L-Buffer characteristics are such that a cathode-ray tube display can be used to directly output network status through a mode mapping operation. This optional capability can be used to display a dynamically changing status, such as baratropic contours directly from the mode registers of the entire PE Network.

3.4.2 Indirect Expandability

Another dimension of expansion and growth capability exists in SOLOMON beyond that which can be obtained by combining units directly and without factory reworking. This dimension represents the true growth potential that accrues from the basic SOLOMON premise of using state-of-the-art electronics and straightforward logic techniques. Follow-on SOLOMON systems can, and will, be developed to provide greater computing capability through faster circuits, faster memory units (thin films when commercially available economically), and more complex logical arrangements. It is important to note that SOLOMON does not require the latest, most exotic technological developments but can absorb them in its basic framework as they become accepted through use and become more attractive economically and with respect to reliability.

It is possible to increase the computer power of SOLOMON through a more complex PE structure at any time with existing electronic devices through alternate logical arrangements. For example, by doubling the adder stages in the basic SOLOMON PE, a multiply time of 7.5 microseconds

can be obtained without faster components. The PE structure can be modified through an alternate logical design to provide multi-bit parallel processing at the cost of additional components. A serial - by - character PE (rather than serial - by - bit) can be provided to speedup operations if required.

There are many possible variations on the SOLOMON theme to increase capability when cost and reliability of new devices offer an economical opportunity to factor them into the SOLOMON system. The fundamental point with respect to SOLOMON growth potential is that SOLOMON represents the first of a new generation of computers which will rely on parallel structures for increasing capability rather than on the development of ever faster devices for sequential systems.

4. RELATED EXPERIENCE, FACILITIES, AND PERSONNEL

4.1 SOLOMON BREADBOARD

The breadboard system illustrated in figures 4-1 and 4-2 was designed and manufactured to test the major circuitry and the system operation of a portion of the full SOLOMON I system, specifically the PE Network and Sequencer. The breadboard system is controlled either by a program memory loaded from paper tape or from switches located on the instruction panel. The system may be operated in either single or continuous operation, depending upon the settings of control switches.

System operation is verified on the console by monitoring the mode states and the information entering the frame 2 memory, enabling the programmer to obtain the results of each instruction immediately upon completion of the instruction. The console panel figure 4-2, includes a flip-flop memory whose outputs are monitored by lights. Switches enable numbers to be set into the output registers, hence into the processing element matrix, through the input command. The top matrix of lights provides a dynamic display of the mode states of the 9 PE's $(00, 01, 10, 11)_2$.

The breadboard contains the essential processing element matrix, control circuits and drivers, a matrix of nine processing elements with two-core memories each. The two memories, each consisting of eight 8-bit words, supply data storage addresses for the routines. This permits the testing of the memory circuits. Additional loads on the drivers and sense lines were simulated through noninductive resistors to verify the operation of the full memory system. The commands selected are sufficient to carry out system tests on the machine hardware and to demonstrate SOLOMON capabilities. To achieve greatest efficiency in the use of hardware and program memory capacity, 16 commands (4-bit address decoding) were chosen for use in the breadboard.

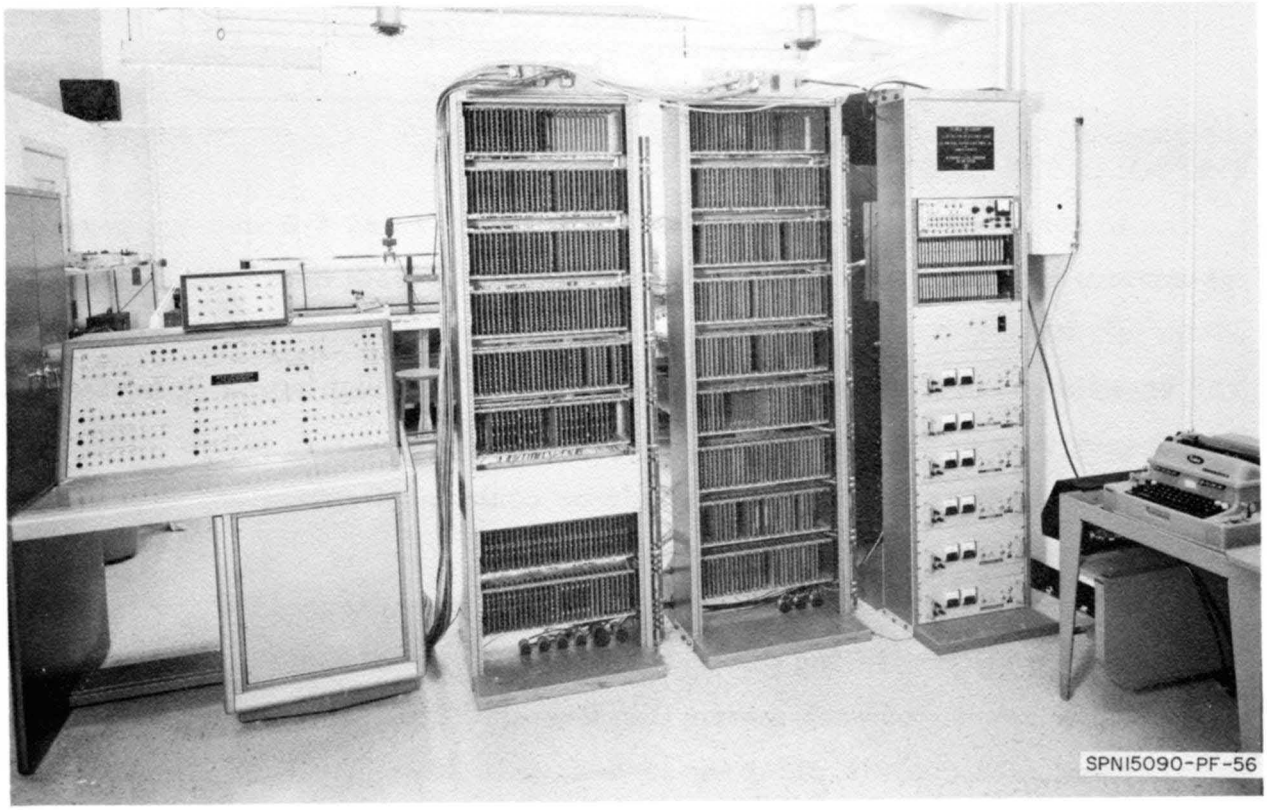

Figure 4-1. SOLOMON I Breadboard

To demonstrate the use of the SOLOMON Computer the following programs were written.

a. $$\Delta^2 U = 0 = \frac{\partial^2 U}{\partial X^2} + \frac{\partial^2 U}{\partial Y^2} = 0$$

Placed in finite difference form the equation is:

$$U^{n+1}_{(i,\ j)} = \frac{U^{n}_{(i+1,\ j)} + U^{n}_{(i-1,\ j)} + U^{n}_{(i,\ j+1)} + U^{n}_{(i,\ j-1)}}{4}$$

The convergence criterion is:

$$\left| U^{n+1}_{(i,j)} - U^{n}_{(i,\ j)} \right| < \epsilon$$

The mesh size is 11 by 11 providing a 9 by 9 mesh of interior points stored 9 to a processing element.

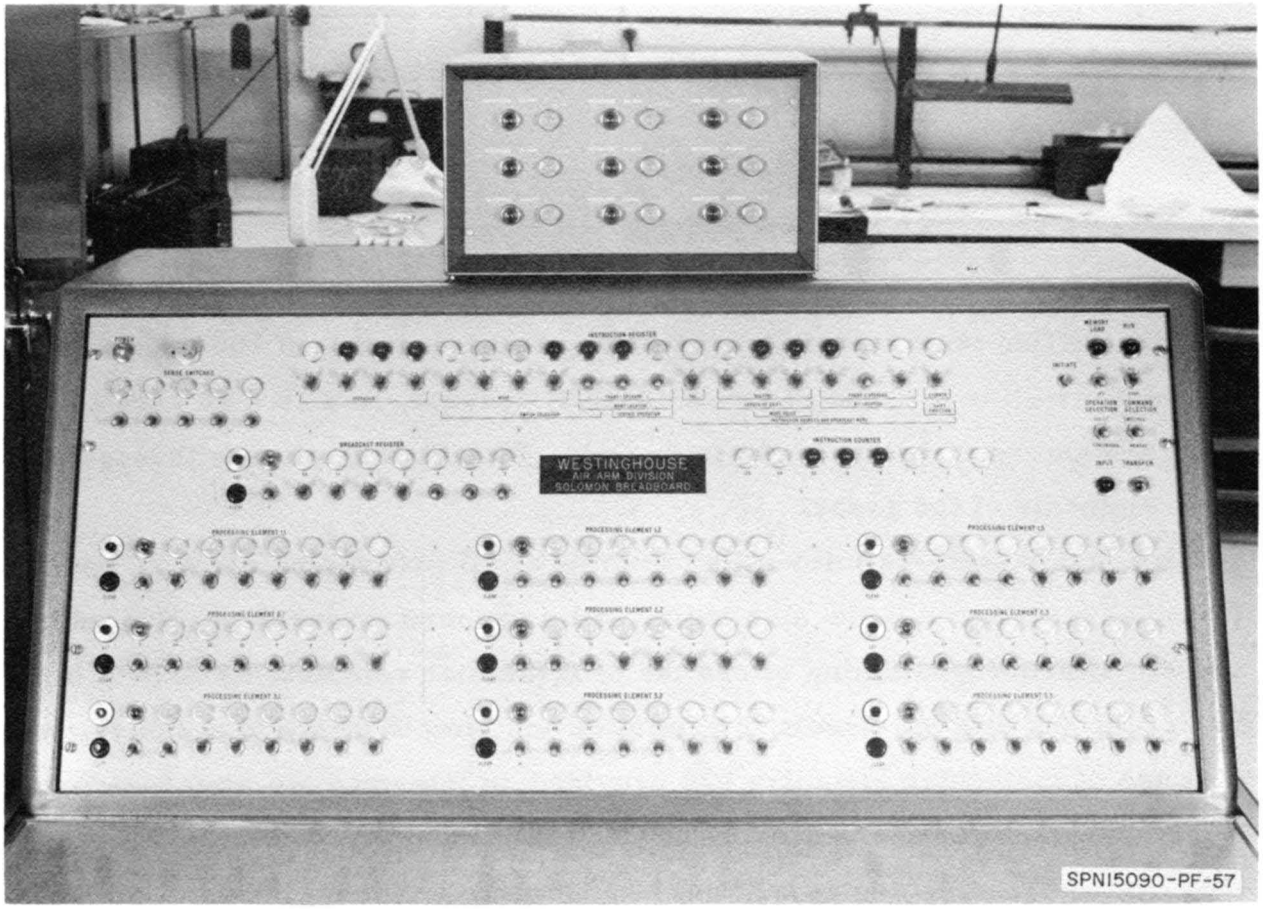

Figure 4-2. SOLOMON I Console Panel

b. An associative memory routine that allows the operator to load the PE memories with catalog information and then after loading the Broadcast Register with a bit pattern, perform, under command of the 5 sense switches, the following test between the Broadcast Register and 9 PE words simultaneously.

Sense Switch	Test	Mode Set To
1	EQUALITY (=)	3
2	GREATER THAN (>)	2
3	LESS THAN (<)	1
4	GREATEST NUMBER OF MATCHING BITS	3

When a PE responds to an inquire, it will set its mode according to the table above.

c. Sort Routine

The program will accept values and sort them in ascending or descending order by columns or rows.

d. Diagnostic Routine

4.2 ITERATIVE ARRAY COMPUTER

This AF Contract was awarded to Westinghouse for the design, fabrication, test, and installation of an iterative array computer consisting of 100 processing elements similar to those of the SOLOMON concept, in a 10 x 10 array. Data are entered into the array from Delay Line Shift Registers through the edge elements of the array.

The design features microprogramming of all processing element instructions, asynchronous molecular logic, and magnetostrictive delay line memories. Microprogramming offers the programmer complete flexibility in the use of the PE control signals for complex and simple instruction fabrication. The use of molecular circuitry has provided an intermediate step between the 3 x 3 array which first proved SOLOMON feasibility and the full scale iterative computer. The device will act as a practical demonstration of the advances in computer development and as a practical tool to test programming advantages in the parallel concept. The magnetostrictive delay lines produce a low cost bulk memory storage.

In the iterative array, each processing element contains a serial adder, a 24-bit delay line accumulator, and a delay line storage for 63 24-bit words.

The processing element consists of a single printed circuit card for all logic, and two cards for the delay line accumulator and memory. The circuitry consists of 6 of the basic molecular circuit types originally designed for SOLOMON and packaged in 10-pin TO-5 cans. This design is essentially a testbed to demonstrate reliability and performance of the molecular logic SOLOMON circuits.

4.3 THE 2402 COMPUTER

The Westinghouse 2402 Computer is a medium size, sequential, general purpose, stored program computer intended for rapid handling of large

quantities of complex data. The system offers a design which includes special features in molecular circuit design; high speed memory, high speed arithmetic unit and input-output data channels; and a unique logical organization resulting in a comprehensive instruction repertoire.

The computer is a single-address, 24-bit machine with both address modification and indirect address capability. It contains a flexible instruction repertoire with 53 basic instructions and add-on capabilities. Supplementing this repertoire are several variations of the basic instructions. The 2402 computer is a binary, fixed-point machine utilizing two's complement arithmetic. Data and program storage is accomplished through the use of a 16,384-word, random access, parity checked, ferrite core memory. With a full read-write cycle time of 2 microseconds, access to any memory location can be attained in 1 microsecond. The very high instruction execution rate permits the Westinghouse 2402 Computer to solve real-time problems.

Communication with the outside world is achieved through eight high-speed input-output channels, each capable of operating in either the buffer mode, the express mode, or the external function mode. An attractive interrupt philosophy is implemented to facilitate complete and rapid computer control over normal or abnormal situations.

4.4 COMPUTER EXPERIENCE

Figure 4-3 depicts the various computer and related programs successfully completed by Westinghouse. Digital development programs are pursued by Computer and Data Systems Engineering which has extensive experience in both areas. The Company presently is engaged in performing computer developmental studies under military contracts and in the manufacture of computers and data processing equipments for both military and commercial applications.

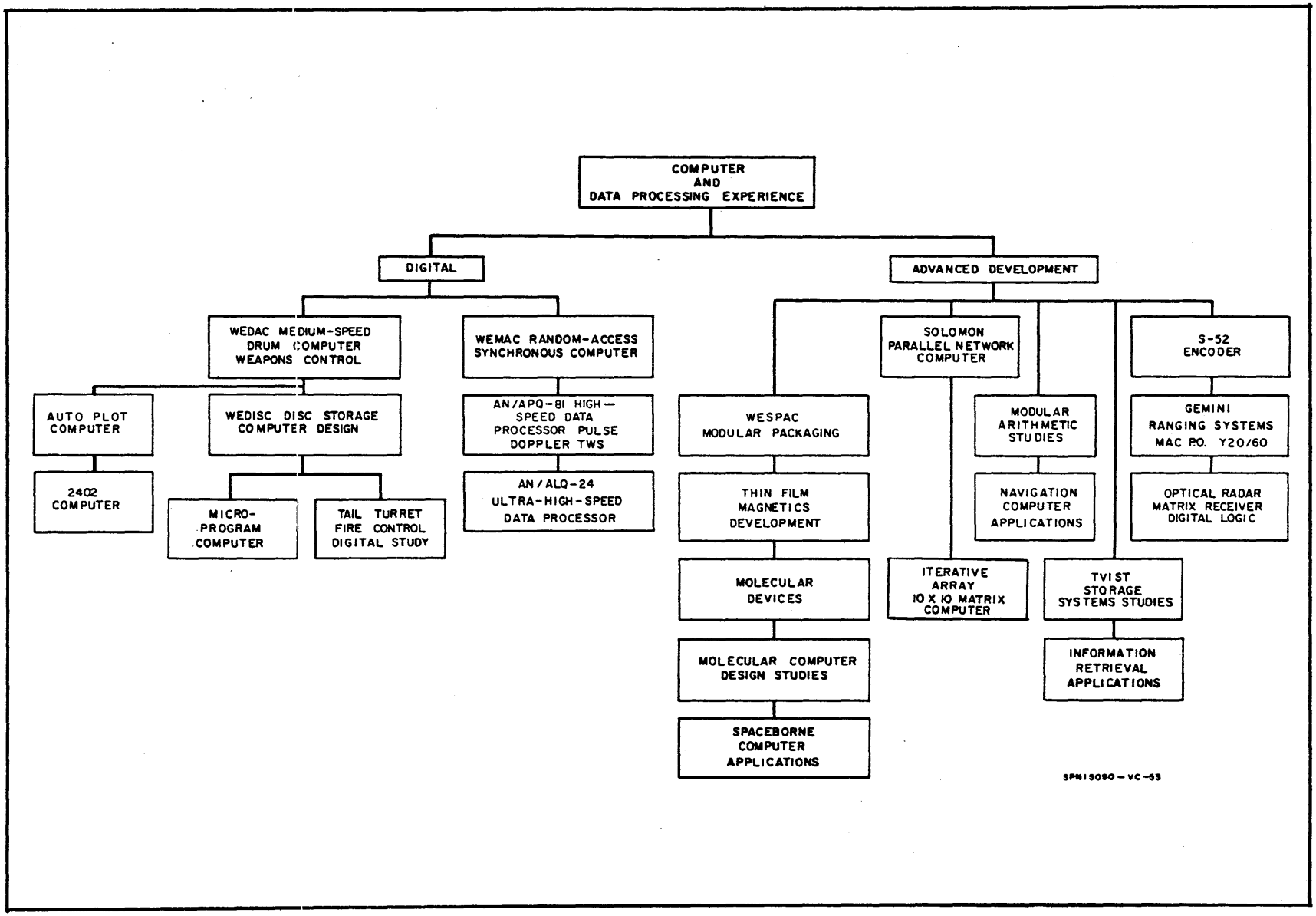

Figure 4-3. Westinghouse Computer Experience

4.5 ORGANIZATION AND KEY PERSONNEL

The SOLOMON II Program is being handled as a project task within the Computer and Data Systems organization.

The senior personnel shown on the Organization Chart (figure 4-4) are assigned to this task and resumes of key personnel are included on following pages.

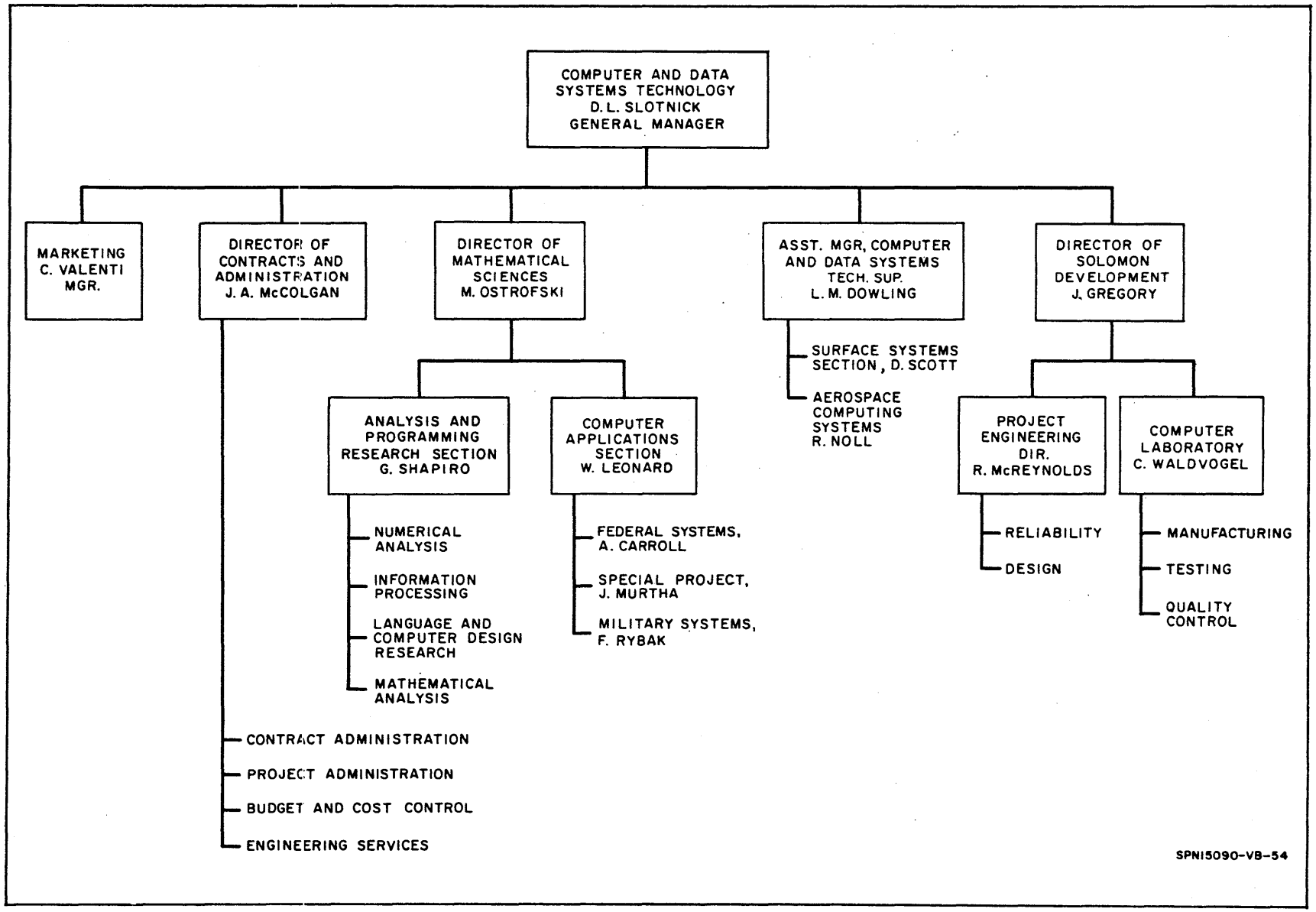

Figure 4-4. Organizational Chart

NAME: Daniel L. Slotnick, General Manager, Computer and Data System Technology Group

EDUCATION: B. A., Columbia College, 1951
M. A., Columbia University, 1952
Ph. D., Applied Mathematics
New York University Institute of Mathematical Sciences, 1956

EXPERIENCE:

1951 - 1952	Columbia University, Department of Mathematics. Research Fellow. Research in the theory of games.
1952 - 1954	Institute for Advanced Study, Electronic Computer Project. Analyst. Analysis, programing, and logic design.
1954 - 1956	New York University Institute of Mathematical Sciences. Research Assistant. Research in celestial mechanics.
1956 - 1957	Princeton University, Nonlinear Mechanics Group. Research Assistant. Consultant in operations research. Research in nonlinear mechanics.
1957 - 1960	International Business Machines Corporation, Research and Advanced Systems Divisions. Advisory Engineer. Chief Engineer on communication-based data processing system for stock brokerage business. Design of scientific computer. Organization and operation of Analysis and Programing Department, Research Division, Scientific Computing Center.
1960 - 1963	Westinghouse Electric Corporation, Aerospace Division, Baltimore, Maryland. Manager, control and computing systems, and advanced computing systems and digital techniques. Responsibilities included direction of research on Residue Class Computers as well as design and applications of the SOLOMON Computer.
1963 - Present	Defense and Space Systems Operations, Baltimore, Maryland.Responsible for all Computer and data processing work in the Westinghouse Defense and Space Center.

NAME: Daniel L. Slotnick, Continued

PATENTS: 39 disclosures and patents pending in field of digital computers.

PUBLICATIONS: "Numerical Integration in the Complex Domain," Institute for Advanced Study Electronic Computer Project Report, 1953.

"The Asymptotic Convergence of the Method of Krylov and Bogoliubov," Institute of Mathematical Sciences, New York University Memorandum, 1965.

"Asymptotic Behavior of Solutions of Canonical Systems Near a Closed, Unstable Orbit," Contributions to the Theory of Nonlinear Oscillations, Volumne IV, Princeton University Press, 1958.

"The Computation of Characteristic Exponents of Linear Systems with Periodic Coefficients, "IBM Research Computing Center Report, February, 1957.

"The Numerical Integration of Hill's Equation," IBM Research Computing Center Report, February, 1957.

Coauthor with J.C. Cocke. "The Use of Parallelism in Numerical Calculations," IBM Research Memorandum, July, 1958.

Coauthor with R. Rice, "A Pattern Logic Digital Processor," IBM Research Report.

Coauthor with H.S. Shapiro, "On the Mathematical Theory of Error Correcting Codes," IBM Journal of Research, Vol. 3, (1959), pp. 25-34.

Coauthor with W.C. Borck, and R.C. McReynolds, "The SOLOMON Computer" Proceedings - Fall Joint Computer Conference, 1962, Vol. 22.

Coauthor with W.C. Borck, and R.C. McReynolds, "Numerical Analysis Considerations for the SOLOMON Computer," to be published in the Proccedings of the AFRADC-Westinghouse Workshop in Computer Organization.

"Parallelism" Proceedings of the 1963 National Aerospace Electronics Conference. To appear.

SOCIETIES: American Mathematical Society.
Society for Industrial and Applied Mathematics Secretary, Baltimore Chapter
Association for Computing Machinery.
IEEE, Senior Member.

NAME: Arthur B. Carroll, Acting Supervisor, Computer and Data Systems Technology Group

EDUCATION: B.S.E.E., Pennsylvania State University, 1958
M.S.E.E., University of Michigan, 1962

EXPERIENCE:

1951 - 1953	USAF. Military duties as radar operator and identification clerk.
1958 - 1961	International Business Machines Corporation, Federal Systems Division, Owego, New York. Participated in development and flight testing of experimental and engineering models of the B-70 computing system. Assisted in assembling and checking the first prototype digital computer for the Titan Ballistic Missile Guidance System. Responsible for providing diagnostic programs for the B-70 Logic Simulation Program.
1961 - 1962	University of Michigan, Graduate Student. Primary responsibility for maintaining the Michigan Instructional Computer and improving a digital (MIC) computer for laboratory use. Designed a core memory system for the MIC breadboard.
1962 - Present	Westinghouse Defense and Space Center, Defense and Space Systems Operations, Baltimore, Maryland. Acting supervisor Computing Systems. Responsible for development of parallel organized computers for the SOLOMON concept and for application studies associated with this program.

PATENTS: Three patent disclosures

PUBLICATIONS: A.B. Carroll and W.T. Comfort, "The Logical Design of a Holland Machine," University of Michigan, Electrical Engineering Department Internal Report, Ann Arbor, Michigan.

SOCIETIES: Institute of Electrical and Electronics Engineers, Association for Computing Machinery
Eta Kappa Nu

NAME: G. Shapiro, Manager, Analysis and Programming Research

EDUCATION: B.A., Brooklyn College, 1947
M.A., The Johns Hopkins University, 1948
Additional Graduate Work and Teaching, The Johns Hopkins University, 1948-1951

EXPERIENCE:

1951 - 1955	Aircraft Armaments, Inc., Senior research mathematician. Systems analysis of fire control systems, and preliminary design, radar, missiles, simulators, computers.
1955 - Present	Westinghouse Defense and Space Center, Baltimore, Maryland
1955 - 1962	Missile Seeker Systems Analysis. Statistical detection theory and antijamming problems. Trajectory analysis and space guidance problems for satellite, lunar, and interplanetary flight. Study of modular arithmetic computations.
1962 - Present	Manager of Analysis and Programming Research in the Computer and Data Systems Technology Department. Responsibilities include direction of research and development in numerical analysis, programming languages, software, and computer organization and design techniques.

PUBLICATIONS: "Non-Vanishing at S = 1 of Certain Dirichlet Series," Amer. Journ. Math, Vol. 71 (1949) No. 3.

"The Dirichlet Series Associated with Ramanujan's - τ Function," Amer. Journ. Math., Vol. 74(1952) No. 2.

"A Convergence Problem," Proc. Amer. Math. Soc., Vol. 6(1955) No. 6.

"A Pattern Bombing Problem," Eighth National Meeting of ORSA, Ottawa, 1956.

"Performance of Closed Loop Flip Flop Control Systems in Missiles and Rockets," Second International Rocket and Satellite Congress, Paris, 1959 (Coauthor).

"Trajectory Problems in Cislunar Space," Proc. National Specialists Meeting on Guidance of Aerospace Vehicles, Boston, May 1960.

"Closed-Loop Flip-Flop Control System," Journ. of Aerospace Sciences, Vol. 27(1960) No. 11 (Coauthor).

NAME: G. Shapiro, Continued

PUBLICATIONS: "Analytic Solution of a Microthrust Problem," 17th Annual Meeting, American Rocket Society, Nov. 1962, (Coauthor).

"Magnitude Comparison and Overflow Detection in Modular Arithmetic Computers," SIAM Review, Vol. 5 (1963) No. 4 (Coauthor).

"Gauss Elimination for Singular Matrices," Mathematics of Computation, Vol. 17 (1963) No. 84.

SOCIETIES: Institute of Electrical and Electronic Engineers
American Mathematical Society

NAME: Chester W. Waldvogel, Fellow Engineer, Computer and Data Systems

EDUCATION: Polytechnic Institute, Baltimore, Maryland, 1936

EXPERIENCE:

1938 - 1942	The Glen L. Martin Company, Tool designing.
1942 - 1944	Westinghouse Electric Corporation. Die and and electronic package design.
1945 - 1946	Chase Engineering Company, Engaged in the design of various tools and plant layouts.
1946 - 1948	Conlan Design and Engineering, Designed tools, fixtures, machines. Assisted in building designs.
1950 - 1951	Alexandria Iron Works, Structural steel design for buildings and bridges.
1951 - 1953	Machine and Tool Design, Worked on design of tools and dies, wire drawing machinery and the first coaxial cable machine.
1953 - 1954	Mathieson Chemical Corporation. Design Engineer. Duties consisted of the design of a hydrazine plant, including its special handling equipment.
1954 - 1955	Aircraft Armaments, Design Engineer. Design and packaging for a receiver which could be air dropped on either land or water and was triggered from a distance. Design for a training device, housed in a trailer, to simulate radar gun control.
1955 - 1960	The Martin Company, Chief Engineer. Responsible for the Ground Support Equipment on the Titan Program at Cape Canaveral. Conducted R and D contract on ultrasonics for the P6-M aircraft. Participated in the design and manufacture of a simulator for the Pershing missile and the test and checkout equipment for the Titan Program. Group Engineer on P6-M navigation and mine laying system which included the test and checkout of the astrocompass manufactured by General Precision Labs.
1960 - 1962	Electronic Products Corporation, President. Formed and developed corporation which ultimately employed 100 people in

NAME: Chester Waldvogel, Continued

EXPERIENCE: (Continued)

the design and manufacture of timing devices. In addition to managing the company, duties included monitoring and assisting in the package configuration of all products.

1963 - Present Westinghouse Defense and Space Center, Defense and Space Systems Operations, Computer and Data Systems Technology Group. Responsible for the computer development laboratory including technicians, draftsmen, all necessary electronic equipment, calibration, components, and storage.

NAME: John G. Gregory, Supervisory Engineer, SOLOMON Section, Advanced Development

EDUCATION: B.E.E.E., The Johns Hopkins University, 1948

EXPERIENCE:

1948 - 1950	General Electric Company. Test Engineer. Field applications engineer.
1950 - 1952	U.S. Army
1952 - 1962	U.S. Army, Ballistics Research Laboratory. Chief of the Research and Development Section, Computer Research Branch, Aberdeen Proving Grounds, Maryland. Responsible for the design of EDVAC Floating Point Arithmetic Unit, EDVAC Magnetic Tape System. Responsible for the design and development of BRLESC and BRLESC Off Line Converter, believed to be "the world's fastest operating computer, 1962."
1962 - Present	Westinghouse Defense and Space Center, Aerospace Division, Baltimore, Maryland.

HONORS: Member BRL Scientific Staff
U.S. Army - Sustained Superior Performance Award, 1960
U.S. Army - Special Act Commendation, 1962
Honorary Journalistic Fraternity

NAME: Joseph David McGonagle, Engineer, Computer and Data Systems Technology Group.

EDUCATION: Belmont Abbey Junior College, 1949
University of Pennsylvania, 1951
University of Dayton, Mathematics courses, 1951 - 1955
University of Pennsylvania, graduate studies in econometrics and statistics

EXPERIENCE:

1951 - 1955 Wright Air Development Center, Wright Patterson Air Force Base, Ohio. Designer and tester, Computation Laboratory, Aeronautics Research Laboratory. Designed, wired, and tested control panels for IBM CPC's Mod. I and Mod. II. Acted as consultant to research groups on data collection and processing techniques. Tested and developed algorithms for problem solving on CPC's, ORAC, and 1103A.

1955 - 1956 Consultant in data processing. Designed and installed data conversion system for AF theodolite data at University of Dayton. Designed the experiment, collection and reduction of data in psychometric research at Fels Institute, Yellow Springs, Ohio.

1956 - 1959 Self-employed. Bookstore on University of Pennsylvania's campus. Supervisory experience.

1959 - 1963 University of Pennsylvania. Lecturing on data processing techniques to faculty and student seminars. Statistical and data processing consultant for University research projects. Development, programming, and testing of mathematical algorithms. Development, programming and testing of utility and service routines for all types of computers, both as a designer and as a lead programmer. Consultant to and supervisor for open-shop users. Field testing manufacturers software and systems. Systems design and programming for university administration. Used the Univac SS-80 Tape, Univac I, IBM 7070, IBM 1401, and IBM 1620. Language used was Univac I (Machine language, G. P. and Unisap Assemblers, Mathematic and Matrix Math

NAME: Joseph David McGonagle, Continued

EXPERIENCE:

Compilers); Univac SS-80 (Machine language, X-6 and S-4 assemblers, Fortran and Unitran Compilers); IBM 7070 and 1401 (Auto Coder Assembly System and Fortran Compiler); IBM 1620 (Machine language).

1963 - Present Westinghouse Defense and Space Center, Defense and Space Systems Operations, Computer and Data Systems Technology Group. Conducting research on language structure (semantic, syntactic, and grammatic) as a function in the design and implementation of assembly and compiling systems for large scale digital computers (both parallel and serial processing machines).

SOCIETIES: ACM
SIAM

NAME: Peter Zilahy Ingerman, Senior Engineer, Computer and Data Systems Technology Group

EDUCATION: B.A., Physics, University of Pennsylvania, 1958
M.S., Electrical Engineering, University of Pennsylvania, 1963

EXPERIENCE:

1958 - 1963 University of Pennsylvania. Research Instructor. Responsible for research into and development of techniques for the machine translation of mechanical languages. Earlier work included assisting in the design of a construction technique for microflow charts for the U.S. Army's MOBIDIC (coupled with an analysis of the compatibility of two versions of this computer) and the production of a version of the Flexi-Matic Compiler (orginally written by Remington Rand) for use at the University. Most of the earlier work, however, was involved with assisting various departments at the University in using a computer for their specific problems. Consultant to area industry. This work included the programming of a simulation of a submarine target tracking method, the analysis of a technique to simulate a simulator for training purposes, and the design of a language for piece-part fault testing on the FADAC computer. Other consulting included a series of lectures on compiler construction, the application of digital techniques to real-time simulation of radar displays, and the evaluation of a digital computer for use on a submarine trainer.

1963 - Present Westinghouse Defense and Space Center, Defense and Space Systems Operations, Baltimore, Maryland, Computer and Data Systems Technology Group. Responsible for R and D Contract on languages, compilers, etc, for parallel processing machines.

PUBLICATIONS: "A New Algorithm for Algebraic Translation," 14th National Meeting of the Association for Computing Machinery.

NAME: Peter Zilahy Ingerman, Continued

PUBLICATIONS: (Continued)

"Towards a Theory of Recursive Processors," 16th National Meeting of the Association of Computing Machinery.

Gorn, Ingerman,and Crozier, "On the Construction of Micro-Flowcharts," Communications of the ACM,Vol. 2, No. 10.

"Thunks," Communications of the ACM, Vol. 4, No. 1.

"Dynamic Declarations," Communications of the ACM, Vol. 4, No. 1.

"A Translation Technique, "Symposium on Symbolic Languages in Data Processing, Rome, Italy, March, 1962.

SOCIETIES:

Institute of Electrical and Electronic Engineers
ACM
SIAM
AAAS
IEEE-PTGIT, IEEE-PTGCT, IEEE-PTGEC
Franklin Institute
ASA Committees X3.4, X3.4.2 (Chairman), X3.4.5, and X3.4.6
IFIP WG2.1 (ALGOL)

NAME: Jon Stuart Squire, Senior Engineer, Computer and Data Systems Technology Group

EDUCATION: B.S., Electrical Engineering, University of Michigan, 1960
M.S., Electrical Engineering, University of Michigan, 1962
M.S., Mathematics, University of Michigan, 1963

EXPERIENCE:

1960 - 1962 University of Michigan Research Institute, Programmer-Analyst. Development of a Powerful Problem Oriented Language and Translator. The translator produced programs in several compiler languages from a description of an electro-mechanical system.

1961 - 1963 University of Michigan, Instructor, Department of Mathematics.

1961 - 1963 University of Michigan Research Institute, Assistant Research Engineer. Developed machine organization of a Multiple Processor Computer. Developed a translation algorithm for use in producing code for the Multiple Processor Computer. Determined statistics for concurrent addessibility of information in lattice connected memories by the Multiple Processor Computer.

1963 - Present Westinghouse Defense and Space Center, Defense and Space Systems Operations, Baltimore, Maryland, Computer and Data Systems Technology Group.

PUBLICATIONS: "Iterative Circuit Computers," Coauthor, Computer Organization, Spartan Books, Inc., 1963

"Programming and Design Considerations of a Highly Parallel Computer," Coauthor, Proceedings, SJCC, 1963.

"A Translation Algorithm for a Multiple Processor Computer," ACM National Conference, Denver, Colorado, 1963.

"An 11 Cryotron Full Adder," IEEE-Transactions, Electronic Computers Correspondence, 1962.

SOCIETIES: Institute of Electrical and Electronic Engineers
IEEE Professional Technical Group on Electronic Computers
Association for Computing Machinery

This page intentionally left blank

4.6 DESIGNING FOR RELIABILITY ASSURANCE

The SOLOMON II Computer contains a total of approximately one million components excluding memory cores. To assure that the computer is adequately reliable, a reliability assurance program is an integral part of the computer development program. This program is designed to ensure that strict adherence to the philosophy of designing for reliability is obtained. The program is briefly described below:

a. Components

All transistors, diodes, resistors, and capacitors are of the same reliability level as corresponding Minuteman components. All transistors and diodes are silicon. The molecular electronic devices which are used for the majority of the logic of the system are silicon devices. Present industrial evidence indicates that the reliability of such a device is, due in part to the closely controlled environment in which it is produced, essentially independent of the number of discrete component equivalents it contains. Thus the molecular electronic devices used in SOLOMON II can be expected to have failure rates no greater than the failure rate of a quality silicon transistor.

b. Circuit Design

The standard practices of conservative circuit design to ensure extreme reliability of circuit operation and of components in the circuit are followed for all circuits. An extra measure of design effort is spent in reducing circuit power dissipation to a minimum consistent with proper circuit operation at the required speed. This minimization is primarily for the purpose of lowering semiconductor junction temperatures and consequently maximizing the life of the semiconductors. (Semiconductor failure rates are exponential functions of absolute temperature of semiconductor junctions.) In addition to the above, load sharing matrices with their inherent redundancy features are used in all memories.

c. Manufacture and Assembly

The methods used in the manufacture and assembly of SOLOMON II add an additional measure of reliability. For example, all printed circuit cards

have plated-through holes and components are wave soldered to the cards. An improved wire-wrap technique is used for back panel connections.

4.7 FACILITIES AND EQUIPMENT

4.7.1 General

Computer and Data Systems Engineering comprises a concentration of Westinghouse talent and facilities directed toward the development and manufacture of advanced computer and data processing equipments for military and commercial needs.

The scope of this activity includes basic research study programs, design, development,and volume production of computers and data processing systems.

The Computer and Data Systems Engineering activity utilizes a newly completed 33,000-square foot, 2-story building devoted exclusively to computer technology. Approximately 100 engineers of this group are directly assigned to SOLOMON II Computer applications and 13,000 square feet of computer manufacturing space has been allotted solely for this program.

Advanced manufacturing techniques such as automated printed circuit fabrication which includes plated-through-hole capability are employed. Manufacturing is further equipped to perform etching, silk screening, and printed circuit card assembly. Wave soldering facilities, dark room, and complete Quality Control function are also included in the computer manufacturing area. This facility is especially adapted for manufacturing techniques using integrated circuit components.

In addition to the design and development of computer systems this activity is responsible for Field Service Engineering.

4.7.2 Available Equipment and Services

In addition to the facility described above, the following Westinghouse activities will be utilized in the performance of this program.

a. Digital Computer Facility

This extensive facility has had experience in the development of a number of computer simulation programs. Several simulations of digital computers have been programmed and used to enable check out of computers prior to manufacturing. Further experience has been obtained in the creation of the Sparrow and Eagle missile system simulation programs, as well as programs for the Typhon System.

b. Molecular Circuit Development Laboratory

With the increasing demand for smaller, lighter, and more reliable electronic systems, the importance of molecular circuit development has become a major factor in the development of advanced computer systems. The Molecular Circuit Development Laboratory conducts special research and development programs in the areas of molecular circuitry, including thin-film techniques, for application to advanced circuit designs.

c. Westinghouse Aerospace Division

This $40,000,000 investment in modern engineering and manufacturing facilities and equipment has 355,313 square feet of floor space occupied by the Manufacturing Department and a maximum capacity of 6000 people on a 3-shift basis.

In addition to the manufacturing capabilities, the following specialized Engineering sections with an overall allocation of 273,000 square feet will be utilized as applicable through the life of this program.

d. Solid State Advanced Development Laboratory

Established to support the Westinghouse Defense and Space Center in the design and development of advanced military electronic systems, this laboratory has as a prime mission the design and fabrication of advanced solid-state electronic devices and components. By direct contact between systems design and device design engineers, the most recent concepts in solid-state technology are applied to the design of advanced computation, communication, guidance, and detection systems.

Complete facilities for carrying out the exacting processes of solid-state device design and fabrication are provided within the solid-state laboratory, and products of the laboratory are utilized in advanced digital circuits.

e. Engineering Services

The design and development groups in the Engineering Department are assisted by several important service units of the engineering organization. Components and Materials Engineering personnel work with computer design engineers and manufacturing personnel to ensure that selected materials, components, and manufacturing processes meet or exceed contract requirements. The Reliability Organization comprises a policy-making Reliability Panel which represents the managers of Engineering, Manufacturing, Marketing, Purchasing, and Field Engineering; a full-time Reliability Engineering Section which develops, coordinates, and evaluates reliability procedures; and a Reliability Committee of representatives from the various projects, sections, and groups, which implements the policies established by the Reliability Panel and transmits information to the design and operating groups. A large Drafting Section is included within the Engineering Department.

f. The Engineering Laboratory

The Engineering Laboratory provides facilities for complex developmental experimentation and design testing of systems. It is responsible for the arrangement, utilization, and maintenance of all engineering laboratory space and equipment, as well as for assignment of non-professional technical support personnel, and maintains an inventory of electronic components valued at $140,000 and over 6200 items of test equipment and instrumentation valued at approximately $3,000,000.

g. Engineering Qualification Laboratory

The Engineering Qualification Laboratory is fully equipped to simulate the natural and induced environments encountered in equipment use-life. Developmental, qualification, and reliability testing of electronic and mechanical equipment is accomplished under actual environmental stresses known to be encountered from initial transportation, handling, and storage conditions

through mission completion.

Technical direction of this laboratory is provided by a specialized group of systems and environmental engineers who plan and direct the execution of all electrical, structural, thermal, climatic, and related tests.