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PROJECT
WHIRLWIND

Contract N5ori60

NOTES FOR RDB COMMITTEE MEETING

L-14

Jay W. Forrester

August 29, 1949

SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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FIGURE

A. Review of Project History

Project Whirlwind was first started about December 1944 by the Special Devices Division which was then a part of the Navy Bureau of Aeronautics. The initial objective was development of an aircraft stability analyzer to be used as a simulator in design studies of large aircraft.

The original intention was to design the simulator as an analog type device. The first year from December 1944 to December 1945 was used to study analog computing methods and to determine that they were unsuited for the proposed simulator. The simulator was to accept many empirical functions determined from wind tunnel model testing. It was decided that only digital computing methods showed promise of meeting the requirements.

In late 1945, existing digital computer work was based on the serial type machine. About one year from October 1945 to the end of 1946 was used in studying serial type digital computers and in determining that they inherently lacked the required speed, and that to overcome the speed limitation led to an unjustified complication of the serial type digital computer.

A parallel type computer, if suitable parallel storage is available, has inherently a higher speed for the amount of equipment used than a serial computer. Before embarking on a full scale simulator using high speed digital computation, it was decided to build a prototype computer of the proposed type. This machine, known as Whirlwind I, was started about January 1947, which is a little over two and one-half years ago.

Block diagrams for most of Whirlwind I were complete by September 1947. A small 5-digit arithmetic element model was completed in October 1947. During the following year, it was used for studying circuit performance and vacuum tube life characteristics. In December 1948 the 5-digit arithmetic element was altered to include marginal checking trouble location circuits. It has since been on extended life and reliability tests to provide advance information on the operation of Whirlwind I.

During 1947 and 1948 the present Barta Building laboratory was established. Sylvania Electric Products became the principal subcontractor. Research, development, and establishment of standards were handled by M.I.T. Design and construction of repetitive elements of Whirlwind I were done by Sylvania; M.I.T. designed and constructed many of the non-repetitive units in central control. During this time the Servomechanisms Laboratory had a large group on research and development of the electrostatic storage tube.

When the nature of the project was changed from analog to digital computation, many other applications of the computer became apparent in addition to the original aircraft simulation. When the Special Devices group was transferred to the Office of Naval Research and became the Special Devices Center, the interest in digital computation shifted to the field of military control. Decreasing attention was given to the aircraft analyzer and increasing emphasis placed on possible fire control, anti-submarine and aircraft interception possibilities. In 1948 technical direction of the project was transferred from the Special Devices Center to the Mathematics Branch of the Office of Naval Research with continuing interest in control and simulation applications but with the introduction of an interest in digital computer applications to logistics and to scientific computing.

B. Whirlwind I Description

A complete summary of Whirlwind I details is given in the accompanying memorandum L-11 on Whirlwind I information.

Whirlwind I is a prototype ultra-high-speed parallel type digital computer. It has been designed for use in exploring digital computer applications and for demonstrating the performance of high speed computing circuits. No attempt has been made to conserve space and the design permits complete access to all parts during normal operation.

Speed: Whirlwind I is designed for a speed of about 16,000 airthmetic operations per second, including all transfers. To achieve such speed requires a storage access time of six micro-seconds, which has not yet been accomplished.

Storage: Switching capacity of the computer provides for 2048 words of 16 binary digits each, or a total of 32,768 binary digits. Storage is by means of deflection type electrostatic storage tubes which are being designed and constructed by the project.

Register Length: The Whirlwind I register length is 16 binary digits, chosen to keep the prototype model as small as possible. The type of single address instruction order used requires 16 binary digits and this was selected for the machine. Such a length is quite adequate for exploratory studies in control applications. In most mathematical work, this short register length would be a nuisance, but programmed double length and floating decimal point operations can be employed until such time as the register length is expanded. Experience indicates that the choice of a short register was wise. Much has been learned since the design was frozen and simplifications and improvements can be made before building more equipment.

Terminal Equipment: The input-output register and input-output control of Whirlwind I will permit its connection to any foreseeable type of terminal equipment. The design specifically provides control facilities for Eastman Kodak 35 mm digital reader-recorder units. Present plans provide for using the high-speed, high-density photographic film units which are being supplied as government furnished equipment. In addition some teletype facilities will be provided. Most terminal equipment has been left as part of the planning of specific applications of Whirlwind I.

C. Whirlwind I Status

A basic computer like Whirlwind I, not including terminal equipment unique to particular applications, consists of three major parts, the arithmetic element, the central control and the storage.

The arithmetic element of Whirlwind I was installed during January 1949. It has been in successful operation since and is now being used as a tool for the testing of other parts of the machine.

The central control was installed during June and July and is now being placed in operation. Whirlwind I includes a system of "test storage" to permit preliminary operation of central control and the arithmetic element before electrostatic storage is installed. Test storage has 27 registers of toggle-switches and 5 registers of flip-flops. This amount of storage permits complete testing of the combined central control and the arithmetic element operating as they will in the final machine. Prior to installation of electrostatic storage, test storage can be used for a number of interesting demonstration computing sequences and for reliability tests on the computer.

Storage: Storage control which is a part of the storage system has been installed. Circuits associated with the storage tubes have been designed and one prototype setup is being installed. A storage tube design having a 16 x 16 array or a total of 256 binary digits appears ready for preliminary use in Whirlwind I. Thirteen tubes have been made since the latter part of June, of which 8 are free of defects and appear suitable for use. Initially, the computer will be installed with one bank of 16 of these tubes. Access time of the present tubes is 30 micro-seconds. Additional development will be required to double the linear density of storage to a 32 x 32 array, and to decrease the access time from 30 toward 6 micro-seconds. Present tubes should be entirely suitable for the first several months of Whirlwind I operation.

It is expected that Whirlwind I will be assembled with one bank of storage tubes by January or February, 1950.

D. Future Plans

No specific contracts and long range plans for the use of Whirlwind I have yet been worked out. It is intended that Whirlwind I will be used for exploring many of the large number of uses of high-speed computers.

Many potential uses of the machine in simulation exist in addition to the original aircraft analyzer. War college trainers and combat simulators fall naturally to the high-speed digital computer.

To make effective use of the equipment now being assembled, project plans should include design of suitable terminal equipment for those applications which are undertaken first. For some types of scientific work, page printing of results is sufficient. For many engineering jobs the easy automatic plotting of curves will be necessary. In control applications, the computer needs direct access to devices for converting to the analog quantities of associated control and simulation equipment. In many applications an erasable external medium such as magnetic tape will be required and plans, funds and contract for this work should be arranged.

As Whirlwind I has been designed and built, many possible simplifications and improvements have become apparent. To save and consolidate this information, a research program should continue with the simplifying, improvement and condensing of the present equipment.

E. Administration

Budget and Contract:

Enclosed curve sheet B-34700 shows the actual and estimated monthly expenditures of Project Whirlwind with a separate indication of the principal subcontract to Sylvania Electric Products.

The ONR contract for Project Whirlwind expired June 30, 1949 and extension is awaiting Congressional action on Navy appropriations. Informal advice to the project indicated that the expenditure rate for the present fiscal year should be reduced to $750,000. It was agreed that this should be done by eliminating all long range activity not directly contributing to completion of Whirlwind I. Consequently it has been necessary to eliminate work on terminal equipment, magnetic recording, mathematical research, computer applications studies, data conversion, interconnection of digital computers and servomechanisms systems, research on storage tubes beyond the absolute minimum for preliminary operation of Whirlwind I, and work on miniaturization for mobile and semi-mobile applications.

Staff:

Project Whirlwind personnel at present include 51 staff and 100 non-staff members. In addition 10 staff and 16 non-staff are working on air traffic control. The maximum personnel was during the month of July 1948 with 69 staff and 130 non-staff.

Of the staff members, about 30% are academic appointees who are nominally on full-time appointment while taking two academic courses toward a master's degree. These men as they graduate leave with a good background in digital computers and are finding their way into government and commercial groups working in this field.

F. Related M.I.T. Work

The Servomechanisms Laboratory is beginning a project associated with Project Whirlwind in studying the application of high-speed digital computers to air traffic control. This project is just starting and the First Summary Report is included. Such study is a part of a very long-range program.

The education program in digital computers at M.I.T. is centered in four laboratories of the electrical engineering department. The differential analyzer is in the Center of Analysis directed by Professor S. H. Caldwell who teaches a course on machine aids to computation. Professor Z. Kopal is in charge of the computation laboratory for the study of numerical processes and the operation of a hand computing center. A punched-card installation is operated by the Division of Industrial Cooperation under Mr. Frank Verzuh. The Whirlwind I digital computer is being constructed in the Servomechanisms Laboratory.

M.I.T. does not yet offer a packaged advanced study program in digital computation as does Harvard. However, available from the courses in the graduate school, is a fairly complete master's degree level study selection. It is perhaps best to study numerical analysis and digital computation with some preferred field of application in mind. The servomechanisms student can add to his work in automatic control the necessary mathematical analysis and machine computation courses to allow the use of these tools in his special field. Likewise the student of mathematics, physics, fluid flow, or statistics and operations analysis can add a study of digital computation techniques to his curriculum.

During part of the spring term, Mr. W. Gordon Welchman taught logic and coding for a digital computer and how to set up problems for automatic solution. This work will be expanded when Whirlwind I is operating and when arrangements are made to use it for student laboratory work.

A major part of the M.I.T. training in digital computer electronic techniques is made through the academic staff program. About a third of the project Whirlwind staff are working toward advanced degrees. The men are on nominal full-time appointment which permits taking two graduate courses. Fifteen to twenty research theses per year are related to the digital computer program. Last year these included electronic circuitry such as studies of flip-flop circuits, and secondary emission in vacuum; several were on trouble location methods in digital computers; and others in problem coding. One of the latter on the naval architecture procedure of <u>Intact Stability Study</u> of surface ships developed the digital computer coding to go automatically from hull cross-sections to righting-moments at various water lines and ship displacements. Another thesis student studied the use of an automatic digital computer in solving the alternating current power system problem for which the a-c network analyzer is commonly used. Now that machine construction is nearing completion and computer applications begin to occupy more of the staff time, thesis studies are less often on circuits and more often on computer coding and mathematics. Last year a doctorate thesis dealt with the theory of sampling servomechanisms where data from a digital computer is transmitted intermittently to control an external physical system.

Another indirectly related project is being sponsored by the Carnegie Foundation on the logic and coding of bibliographical information. Here methods of doing indexing by the association of ideas rather than in the elementary manner of card catalogues will at least require flexible computing facilities for the research if not for the ultimate location of information.

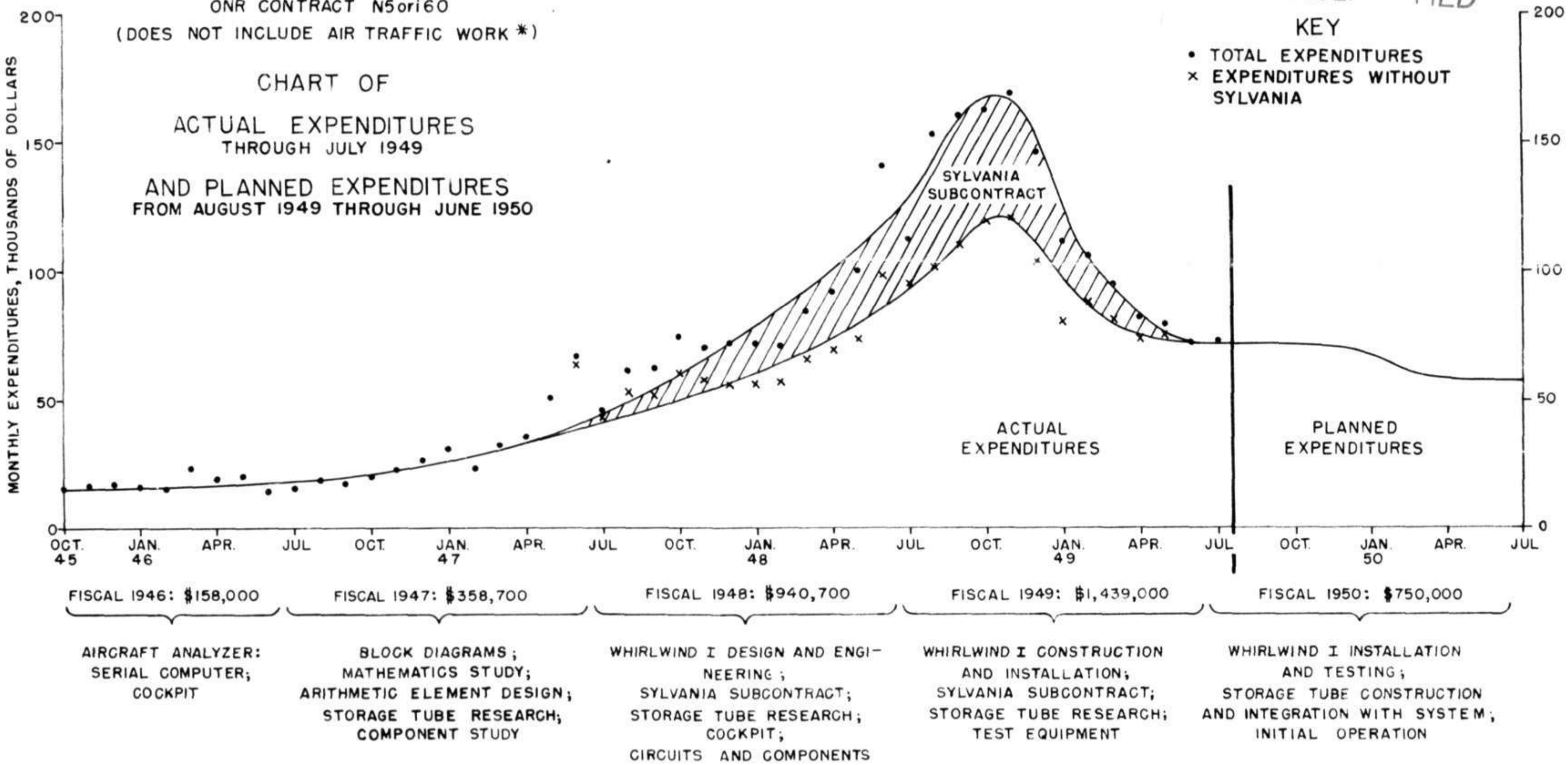
Attachments:
L-11
L-3
L-12
Air Traffic Summary Report No. 1

B-34700

PROJECT WHIRLWIND

ONR CONTRACT N5ori60
(DOES NOT INCLUDE AIR TRAFFIC WORK*)

CHART OF ACTUAL EXPENDITURES THROUGH JULY 1949 AND PLANNED EXPENDITURES FROM AUGUST 1949 THROUGH JUNE 1950



*AN AIR FORCE PROJECT AT A LEVEL OF ABOUT $10,000 PER MONTH, STUDY DIRECTED TOWARD THE APPLICATION OF DIGITAL COMPUTERS TO THE AIR TRAFFIC CONTROL PROBLEM, STARTED MARCH 1, 1949.