PROJECT WHIRLWIND
(Device 24-x-3)

# SUMMARY REPORT NO. 9

JUNE 1948

Submitted to the
SPECIAL DEVICES CENTER, OFFICE OF NAVAL RESEARCH
under Contract N5ori60
Project NR-720-003

SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge 39, Massachusetts
Project DIC 6345

TABLE OF CONTENTS

## FOREWORD

### Project Whirlwind

Project Whirlwind at the Massachusetts Institute of Technology Servomechanisms Laboratory is sponsored by the Special Devices Center of the Office of Naval Research under contract N5ori60. The original objective of the Project was the development of a device that would simulate airplanes in flight. An integral part of such a simulator is a digital computer of large storage capacity and very high speed, to provide continuous solutions to the equations of motion of an airplane.

As Project Whirlwind has evolved, applications to other types of simulation and to control have become important. Because the digital computer is basic to all these as well as to important applications in mathematics, science, engineering, and military problems including logistics and guided missiles, nearly all project resources are at present devoted to design of a suitable computer.

### The Whirlwind Computers

The Whirlwind computers will be of the high-speed electronic digital type, in which quantities are represented as discrete numbers, and complex problems are solved by the repeated use of fundamental arithmetic and logical (i.e., control or selection) operations. Computations are executed by fractional-microsecond pulses in electronic circuits, of which the principal ones are (1) the flip-flop, a circuit containing two vacuum tubes so connected that one tube or the other is conducting, but not both; (2) the gate or coincidence circuit; (3) the electrostatic storage tube, which uses an electron beam for storing digits as positive or negative charges on a storage surface.

Whirlwind I (WWI), now being developed, may be regarded as a prototype from which other computers will be evolved. It will be useful both for a study of circuit techniques and for the study of digital computer applications and problems.

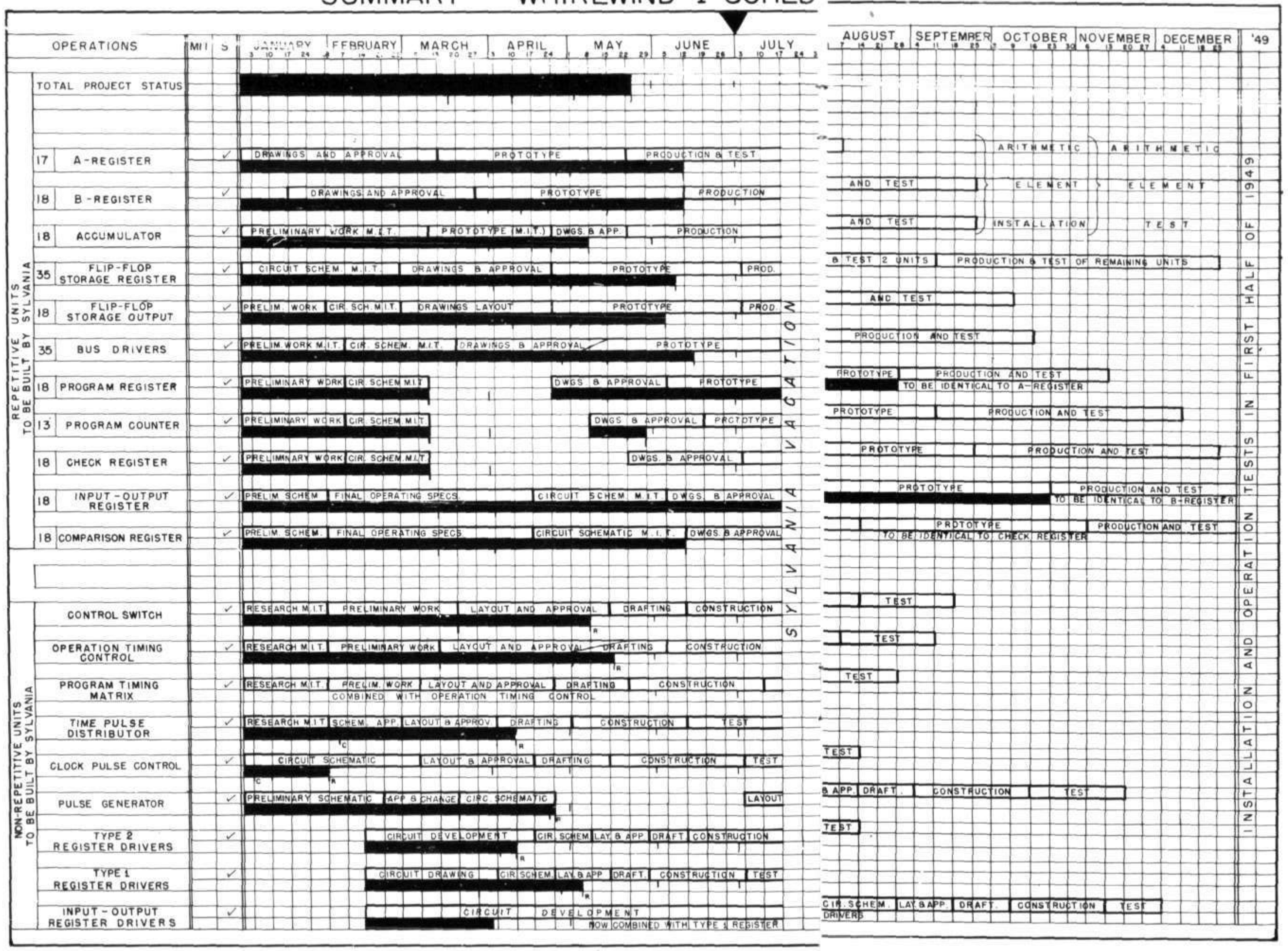
Whirlwind I will use numbers of 16 binary digits (equivalent to about 5 decimal digits). This length was selected to limit the machine to a practical size, but it will permit the computation of many simulation problems. Calculations requiring greater number length will be handled by the use of multiple-length numbers. Five special orders expedite the subprogramming of multiple-length operations, so that coding is no more complicated than for single-length numbers, but computing time is substantially increased. Rapid-access electrostatic storage will have a capacity of 32,000 binary digits, sufficient for large classes of actual problems and for preliminary investigations in most fields of interest. The goal of 20,000 multiplications per second is higher than general scientific computation demands at the present state of the art, but is needed for control and simulation studies.

### Reports

Summary Report No. 2, issued in November, 1947, was a collection of all information on the Whirlwind program up to that time. The present series of monthly reports is a continuation of the Summary Report series, designed to maintain a supply of up-to-date information on the status of the Project.

Detailed information on technical aspects of the Whirlwind program may be found in the R-, E-, and M-series reports and memorandums that are issued to cover the work as it progresses. Of these, the R-series are the most formal, the M-series the least. A list of publications issued during the period covered by this Summary appears at the end as an appendix. Authorized personnel may obtain copies of any of them by addressing a request to The Special Devices Center, Office of Naval Research, Port Washington, Long Island, New York; or where approval has previously been arranged, to Jay W. Forrester, Project Whirlwind, Servomechanisms Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

# SUMMARY - WHIRLWIND I SCHEDULES




LEGEND

JANUARY

Period of one month, comprising the total number of days in the month.

PROTOTYPE

Operation to be performed, and estimated time allotted for its completion. Estimates made in January 1948.

Work done. The ratio of the length of the solid bar to the length of the open bar above it shows percentage of completion at the end of the month.

Date of latest posting.

Summary line. Shows overall status of the project.

Diagonal line indicates overlapping of two operations.

| MIT | S |
|---|---|
| | ✓ |

Column showing whether M.I.T. or Sylvania will do major portion of the job.

NOTES

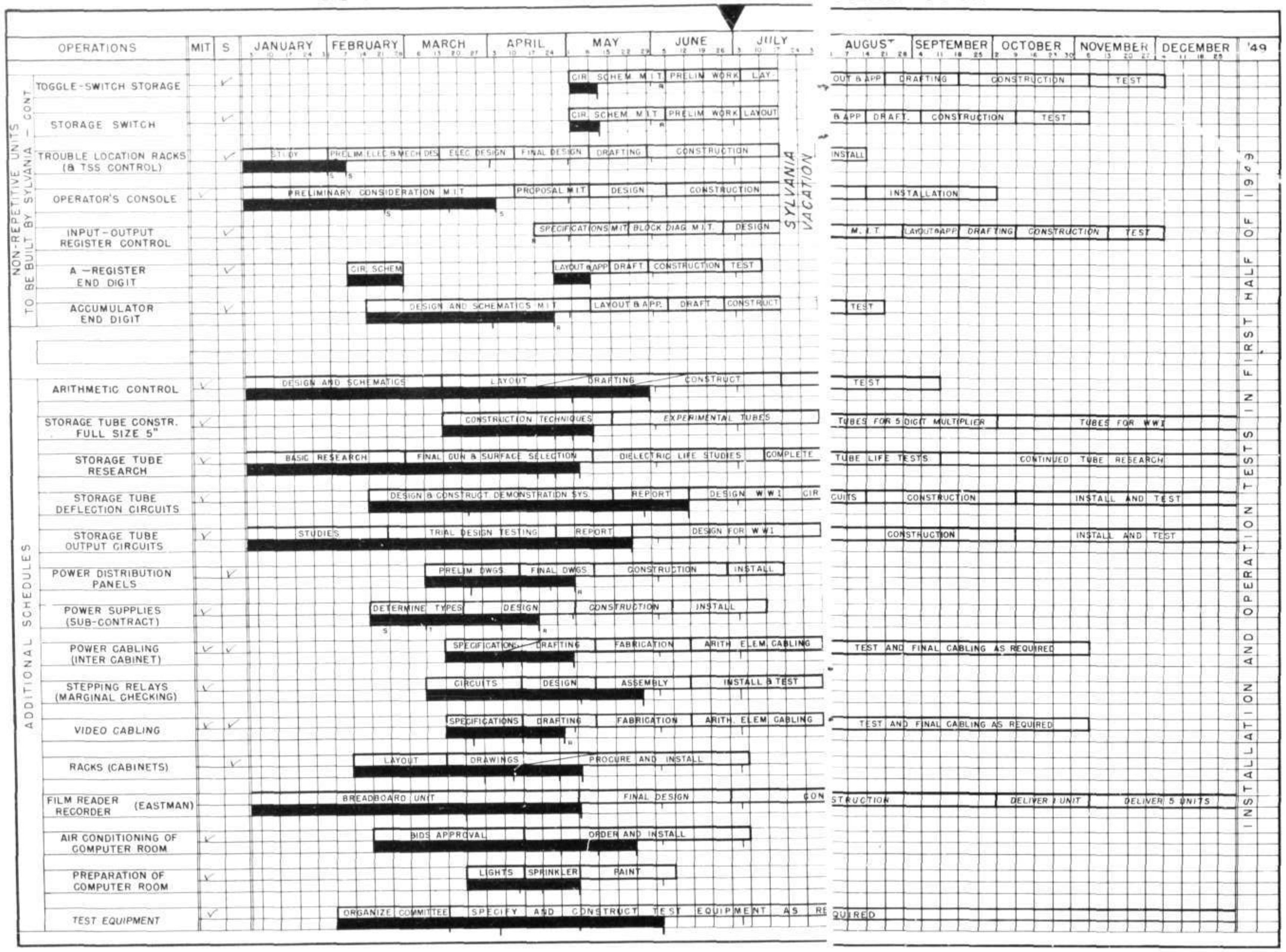
C Changes in specifications have delayed this item.

S Studies and specifications still incomplete, due principally to lack of staff time.

R Revised schedule does not call for same completion date as originally planned.

T Temporary arrangements can be made to meet required schedule.

# SUMMARY - WHIRLWIND I SCHEDULES CONT.




LEGEND

JANUARY

Period of one month, comprising the total number of days in the month.

PROTOTYPE

Operation to be performed, and estimated time allotted for its completion. Estimates made in January 1948.

Work done. The ratio of the length of the solid bar to the length of the open bar above it shows percentage of completion at the end of the month.

Date of latest posting.

Summary line. Shows overall status of the project.

Diagonal line indicates overlapping of two operations.

MIT | S

Column showing whether M.I.T. or Sylvania will do major portion of the job.

NOTES

C Changes in specifications have delayed this item.

S Studies and specifications still incomplete, due principally to lack of staff time.

R Revised schedule does not call for same completion date as originally planned.

T Temporary arrangements can be made to meet required schedule.

# SUMMARY — WHIRLWIND I SCHEDULES CONT.


LEGEND

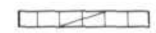

Period of one month, comprising the total number of days in the month.


Operation to be performed, and estimated time allotted for its completion. Estimates made in January 1948.

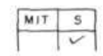
Work done. The ratio of the length of the solid bar to the length of the open bar above it shows percentage of comletion at the end of the month.

Date of latest posting.

Summary line. Shows overall status of the project.



Diagonal line indicates overlapping of two operations.




Column showing whether M.I.T. or Sylvania will do major portion of the job.

NOTES

C Changes in specifications have delayed this item.

S Studies and specifications still incomplete, due principally to lack of staff time.

R Revised schedule does not call for same completion date as originally planned.

T *Temporary arrangements can be made to meet required schedule.*

## GENERAL STATUS

As shown in the summary time schedule, work on Whirlwind I is now about five weeks behind the schedule set up at the beginning of the year. This lag, attributable to procurement delays, necessary design changes, and heavy demands upon personnel time, will be adjusted to a new plan next month when the regular semi-annual revision in time schedule is made. The schedules to appear in the next report will begin with the status of work actually existing in July.

One recent modification in the engineering design of Whirlwind I elements was the result of extensive Project research on little-known pulse phenomena within vacuum tubes. The reason for the substitution of type 7AD7 tubes in place of the type 6AG7 tubes, called for in the original design, is discussed below.

Continued progress on WWI has led to the clarification of a number of system requirements which until recently were not clearly defined. For instance, as described in one of the following sections, it is now apparent that the "delay counter" appearing in the block diagrams need not be an actual electronic counter. Electromagnetic delay lines in another unit will perform the required function, and a "delay counter" as such will not exist.

Whirlwind I power-supply requirements have been the subject of much study. The problem is difficult because many of the electronic circuits draw power in short-duration pulses, and because complex voltage-variation networks are needed for carrying out the trouble-location processes discussed in Summary Report No. 8 (May). A section below describes the present status of power-supply design.

The work on electrostatic storage tubes is undergoing the transition from basic research to engineering development. Recent work on Whirlwind memory tubes and auxiliary equipment is treated in this report.

As discussed below, work on aircraft simulation equipment has been postponed and the staff transferred to installation of WWI and storage tube work.

## SUBSTITUTE FOR DELAY COUNTER

When WWI was in the early design stages, the time required for the storage switch to set up was an unknown factor. For this reason, a so-called delay counter was proposed. (See report R-127.) When the switch was to be set up, the computer was to be stopped while the delay counter counted pulses. An end carry from this counter would then restart the computer.

Eventually it was found that the operation of the switch was fast enough to allow the delay counter to be discarded. Although the delay counter was still retained in WWI design to allow an interval during which the charge could be restored on the capacitors used for coupling flip-flop outputs, its only function then was to produce a "restart" pulse after the restorer pair. Since this required pulse can be obtained more easily by use of a delay line properly connected to the restorer-pulse generator, WWI is now being built without a delay counter.

## CHANGE IN TUBE TYPES FOR WWI

Experience with the five-digit multiplier has shown that the type 6AG7 vacuum tube does not have satisfactory life in Whirlwind computer circuits. This was explained in Summary Report No. 6. After 1500 hours of operation in the five-digit multiplier, the 6AG7's exhibited a large decrease in static plate current. This decrease was found to be caused by an effective internal resistance in series with the cathode.

The evidence indicates that this resistance may be due to an interface compound, possibly barium silicate, formed between the cathode nickel and the oxide coating. The silicon concentration in the 6AG7 cathode nickel has been found relatively high, approximately 0.2 percent as compared with 0.02 percent in "normal" cathode nickel. As determined by pulse measurements, the capacitance shunting the effective resistance is approximately the magnitude of capacitance that would be expected across such an interface. In addition, the resistance has been found to decrease at higher temperatures, as would be expected if an interface barrier were present.

Although the existence of an interface barrier has not been established beyond all doubt, a change to a tube type using normal cathode nickel was believed desirable. All 6AG7's in WWI have therefore been changed to the type 7AD7, which has a normal cathode nickel. The 6AG7 is known to be unsatisfactory. All evidence available at the present time indicates that the type 7AD7 is satisfactory. The only WWI design change necessary is a change in the sockets and possibly a change in screen



voltage. The video layout remains unmodified.

The 7AD7 is a Sylvania lock-in tube very similar to the 6AG7. Under the same operating conditions, the plate current of the 7AD7 is about twenty-five percent less than the 6AG7 plate current. However, the cutoff of the 7AD7 is sharper so that the plate current may be increased by increasing the screen voltage. When this is done, the difference between the 7AD7 and the 6AG7 is not significant. Life data are available from 900 hours of operation of the a-c flip-flop life test rack and from several 7AD7's which have been in operation approximately 500 hours in the five-digit multiplier. Results to date show no appreciable deterioration.

## WWI POWER SUPPLIES

Approximately 50 kilowatts of power will be required for the vacuum tubes in WWI. About a third of this power will be the d-c supplied to vacuum-tube plates, screens, and grids, while the remainder will be a-c for the tube filaments. The 550-volt power supplied by Cambridge Electric Co. is poorly regulated. For this reason, isolating motor-generator sets are being used for supplying both a-c and d-c power for the computer.

The filament power is 115-volt single-phase a-c supplied from a 50-kilowatt alternator which is driven by a 550-volt 3-phase synchronous motor. The alternator voltage is regulated to ± 1 volt and the alternator has a provision for raising the filament voltage slowly over a 10-minute period to reduce the effect of thermal shock on the tubes in the computer.

The d-c power requirements for the computer are greatly simplified by the use of the restorer-pulse technique. This permits capacitive coupling of d-c amplifier stages, which reduces the number and precision of power supplies required. However, one severe requirement remains. The supplies must have very fast responses to load changes. Although individual R-C decoupling circuits at each tube and L-C decoupling circuits at each rack minimize the effect of intermittent pulse currents, the supplies must be capable of withstanding a 10% instantaneous load change with less than a 1% voltage change. This requirement is met by the 6-phase thyratron supplies being built for the computer by the Power Equipment Company of Detroit. These supplies employ very fast control circuits, pulse triggering of the thyratrons, and two-stage L-C filters having very low inductance. The static ripple is less than 100 millivolts for all supplies. The supplies of this type include 50-ampere units for +250 and +150 volts, and 10-ampere units for +120, +90, and -150 volts. These units are all supplied with 208-volt 3-phase regulated power from a 30-KVA alternator which is driven by a synchronous motor fed from the primary power.

Two 2-ampere bias supplies for -15 and -30 volts are also under construction. The low current requirement permits the use of series regulator tubes which simplify the filtering and control problem. These supplies will have less than 50 millivolts ripple and 1% regulation.

The eighth supply is a 50-ampere 48-volt dry-disc rectifier unit which supplies power to the many telephone-type relays used in the control, marginal checking, and power distribution circuits.

All power is controlled by a single three-position switch at the console. The three switch positions are "off", "standby" (filaments on), and "on". Other switches located at a central point in the basement power supply room, where the supplies are located, permit operating the supplies singly or in combinations for test purposes. All power may be shut off instantly by pressing any one of several emergency switches located at strategic points in the computer and control rooms. Emergency connections permit operating the supplies without using the motor-generator set.

Monitoring of the supplies is accomplished by two methods. In the first method, individual voltmeters and ammeters are provided for each d-c supply and source of filament power both at the control room and on the supplies in the basement. The second method utilizes reference voltages produced by small independently operated supplies. These reference voltages will be continuously compared with the computer power supply voltages by means of high-speed relays. Excessive deviations in supply voltages will produce a trouble signal at the computer console.

## STORAGE

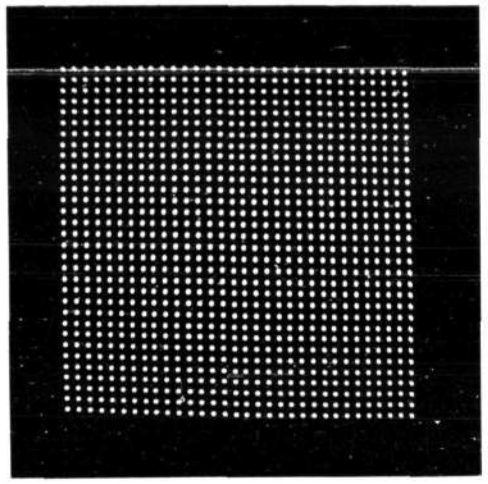
### Storage-Tube Research

During the last month, emphasis in storage-tube development has been placed on the study of storage surfaces consisting of mosaic of conducting beryllium squares evaporated onto an anodized aluminum signal plate. The surface of the beryllium squares is oxidized to produce a secondary-emitting surface with a high secondary-emission ratio and a low first-crossover point (i.e., a curve of secondary-emission ratio vs. voltage which crosses the unity-ratio line at low voltage). The conducting underlayer insures that the entire square is at the same potential. Growing or shrinking of stored spots must therefore occur by complete squares. All the holding-beam electrons which strike each individual charged area act to combat growing or shrinking of the charged region by preventing increase or decrease of the charge on each square. The squares are sufficiently small, from 40 to 100 per linear inch, so that the surface still appears continuous to the electron beam.

Two presumably identical research tubes with 3/4"-diameter storage surfaces have been built and processed with great care. Although testing is not yet complete, preliminary results show that these tubes exhibit the best characteristics so far obtained. Results show that it may soon be possible to build 5" tubes of this type which will store arrays of 8 x 8 or possibly 16 x 16 spots. The goal of 32 x 32 spots will require further work. Construction is continuing on additional research tubes for investigation of special characteristics of the beryllium mosaics.

Construction of a 5" tube of the mosaic type is being delayed by difficulties in evaporating large mosaics. A detailed investigation is being made to discover and remedy the causes of the trouble. A preliminary model of a holding gun has demonstrated that a gun for covering a 5" surface can be built without great difficulty.

Plans for improving storage-tube test equipment include a proposal to build a television scanning device for studying charge patterns on storage surfaces. In addition, a high-speed read-write system for testing storage tubes under more nearly final operating conditions will be studied.



OSCILLOSCOPE DISPLAY OF DEFLECTION-CIRCUIT OUTPUT

For this oscillogram the flip-flops and read-out gate tubes of the decoding elements of both horizontal- and vertical-coordinate deflection generators were connected as scale-of-32 counters. One of these counters was driven by the pulse used to start the oscilloscope sweep, and its end carry applied to the second counter so that all 32 x 32 = 1024 different positions were scanned at a rate of about 20 frames per second. The oscilloscope, rather than the deflection circuits, was responsible for almost all of the distortion apparent in the pattern. In an actual storage tube, an electron beam like that which produced the fluorescent spots in the oscillogram will be used to store positive and negative charges (representing information in digital form) at positions on the storage surface, selected by control through the action of the deflection circuits.

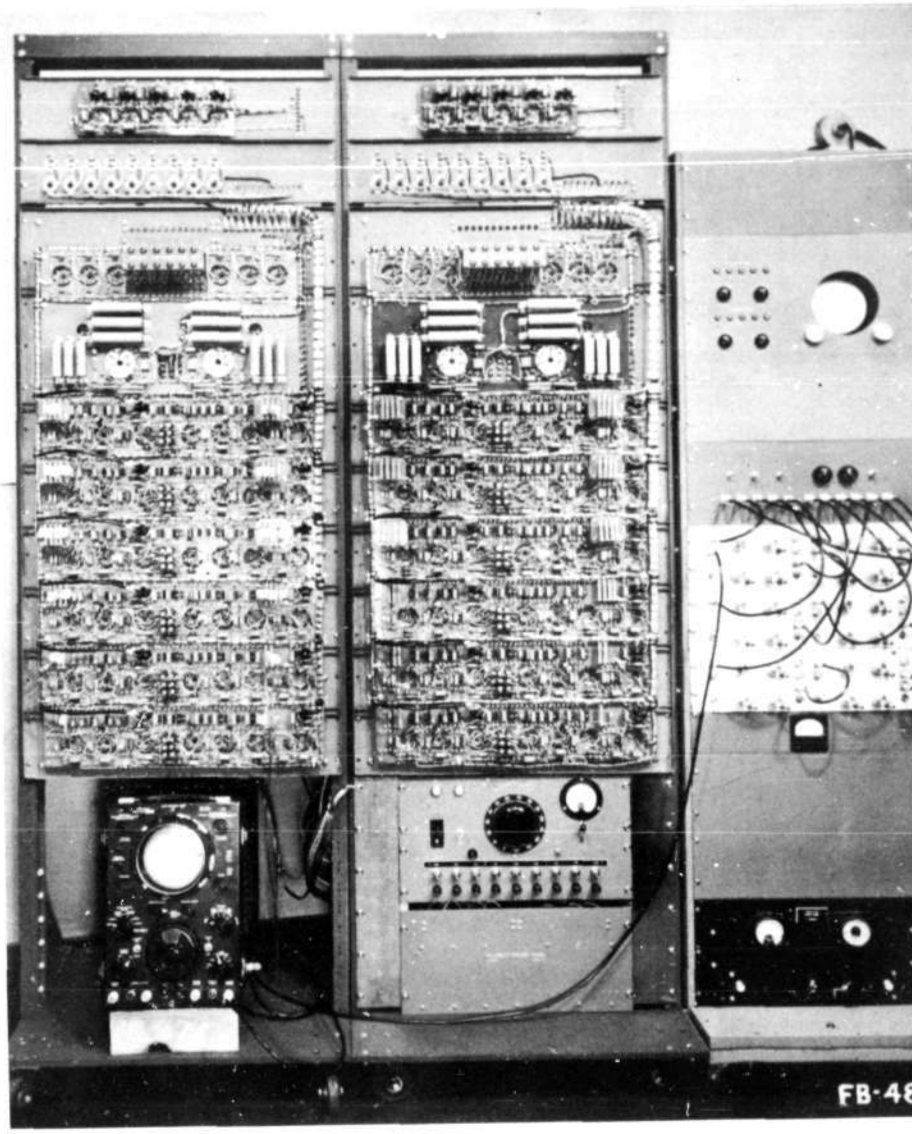
## Deflection Circuits

A second storage-tube deflection-voltage generator of the type discussed in Summary Report No. 7 (April) has been constructed, and the two are operating successfully in the demonstration unit shown in the accompanying photograph. One of the generators provides deflection voltage to the vertical plates of a cathode-ray tube used in place of an actual electrostatic storage tube, while the other provides deflection voltage to the horizontal plates.

The oscillogram shows that these two deflection-voltage generators could be used to position the beam from an electron gun so as to permit storage of binary digits in any of 1024 spots on the storage surface of an electrostatic storage tube. The selected position is determined by the binary-number content of the register of five flip-flops associated with the deflection circuits for each coordinate. Here all possible positions are pictured simultaneously; both flip-flop registers are connected to operate as scale-of-32 counters, causing all positions to be scanned at a frequency which is high with respect to the exposure time of the photograph.

The demonstration unit is at present undergoing a life test to determine if its operation is adversely affected by the ageing of its components. After 500 hours on one and 133 hours on the other generator, no appreciable changes in performance were noted. It is hoped that much-needed infor-






DEFLECTION - CIRCUIT DEMONSTRATOR

The two large equipment racks in the photograph contain circuits for producing vertical and horizontal deflection voltages capable of selective positioning of the high-velocity electron beam in an electrostatic storage tube. The auxiliary rack at the right contains standard Project test equipment for operating the circuits, and the cathode-ray tube used for demonstrating performance (see oscillogram). The oscilloscope beneath the vertical-deflection generator is used for observing waveforms in individual circuits.

mation on vacuum-tube deterioration will be obtained through continuation of this life test.

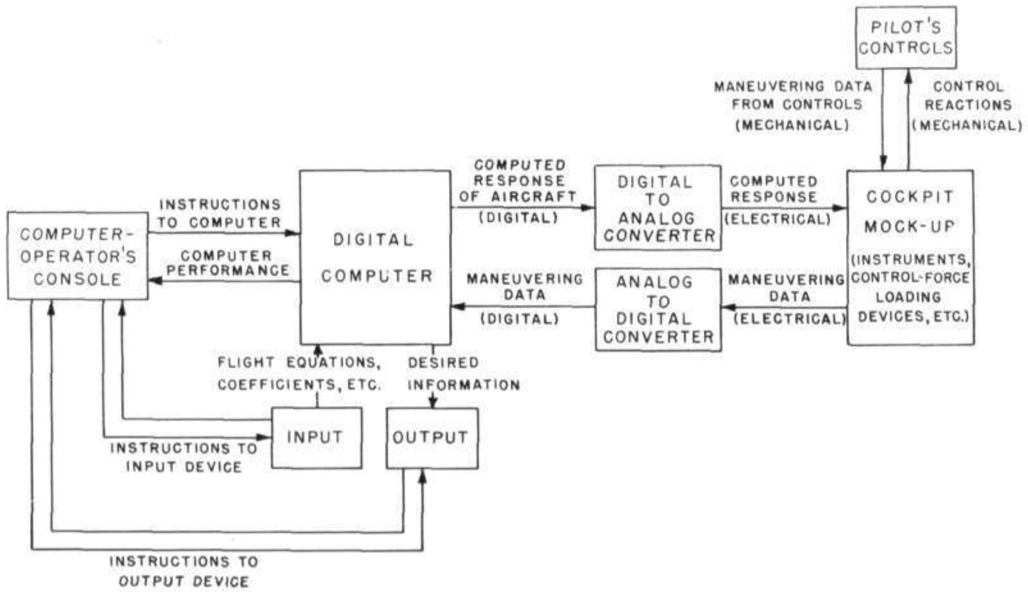
When satisfactory 5-inch electrostatic storage tubes are available, these deflection circuits will be employed in storage-reliability tests.

## SIMULATION

### Postponement of Cockpit Design

The design work on aircraft cockpit simulation equipment has been indefinitely postponed for two reasons. The design for experimental equipment has gone as far as possible until additional information becomes available on data conversion methods. This in itself is not at present being pursued actively because of the pressure for staff time on other phases of the research program. Furthermore, the pace which had been set for the design and construction of simulation equipment would have made it available substantially ahead of the computer with which it would be used, and work on the equipment is therefore unnecessary at the present time. The staff members who were working on simulation equipment have been transferred to the design of power supplies for Whirlwind I and to the development of facilities and instrumentation for the storage tube laboratory. The work to date is being consolidated into a report on the present status and the plans as now formulated.

The accompanying block diagram illustrates the relationships among the various elements of an aircraft analyzer, which is but one of many possible simulation applications foreseen for digital computers like WWI. The role of the computer here is to calculate the response of functioning components of an aircraft under simulated flight conditions. The pilot in the mock-up cockpit can then study the behavior of his instruments and controls as the computer supplies an apparently continuous flow of calculated data. In this manner much can be learned about a new aircraft design without the necessity of actually building an airplane, since wind-tunnel tests on models can provide the constants and coefficients necessary for solution of the equations of flight for a particular aircraft design.




FUNCTIONAL SCHEMATIC OF AIRCRAFT ANALYZER



Before the decision to postpone work on all other phases of the aircraft analyzer and concentrate on the computer, an overall design for a simple mock-up cockpit to operate with WWI had evolved after an extended study of requirements. Unlike a previously proposed version, which called for accurate reproduction of all the psychological impressions and physiological sensations experienced by a pilot during flight, this design sought only to duplicate the most fundamental quantities. Only forces on the controls and readings for the basic flight instruments were to be provided, and computing requirements were made consistent with the capabilities of WWI.

When WWI is completed, a study of the simulation problem will be undertaken with such relatively simple apparatus. For the future, however, when computers of greater register length and internal storage capacity are available, more elaborate and refined simulation equipment is envisioned, and simulation techniques are expected to effect great savings in time and money in many military and industrial applications.

### Digital-to-Analog Conversion

The use of a computer in simulation applications requires that correct information be provided to a number of analog devices in an apparently continuous manner. In many applications large numbers of quantities must be converted from digital form, as represented in the computer, to voltage or current magnitudes, mechanical shaft positions, etc. The equipment associated with each separate input or output should be as simple and as accurate as possible. Unfortunately, no equipment now exists that is truly suitable for this application.

The preliminary study of one digital-to-analog conversion method was discussed in Summary Report No. 7 (April). During the past few months additional work was done on the "decoder" of the block diagram appearing there, and results were reported in a graduate thesis by a member of the Project staff. This investigation has now been discontinued along with other activities pertinent to simulator applications (see Cockpit above).

The work on the decoder for the conversion servomechanism was based on the assumption that it will be sufficient to convert to analog form (specifically, to a voltage magnitude) only the right-most 7 digits of the digital error signal. If the computer output were to be converted directly, without the servomechanism, for WWI a 15-digit binary number would have to be decoded. This would require a decoding accuracy of one part in $2^{15}$, which is difficult to achieve, whereas with the servomechanism error signal the decoder need only be accurate to one part in $2^7$ (=128). In this system, errors of magnitude greater than $2^7$ would merely be used to actuate an on-off device which would tend to reduce the error at maximum possible rate until it could be completely described by 7 digits, at which point the decoder would operate normally.

Although in an actual simulator the number to be decoded will change many times per second as the computer solves for the various required quantities, for simplicity the repeated conversion of a given 7-digit pulse-coded number was investigated. The following step-by-step method was adopted:

1. Conversion of the pulse-coded digital error signal to a pulse-time signal by a counting device.
2. Generation of a pulse-width signal, or gate, from the pulse-time signal.
3. Integration of the gate in a simple R-C circuit to obtain a pulse-amplitude signal.
4. Amplification of the low-level pulse-amplitude output from the integrator.
5. Detection of the amplified pulse-amplitude signal by a peak-reading vacuum-tube voltmeter, which then made available a voltage whose amplitude corresponded to that of the original digital error signal, and whose duration after each conversion was sufficient to permit control of a servomotor having a response time constant of the order of milliseconds.

Corresponding to the 128 possible numbers represented by the 7-digit pulse code, 128 output voltage levels were successfully produced by this decoding method. The maximum time required to perform a conversion was about 1270 microseconds, and output was a linear function of input within about 2%.

## VISITORS

Dr. Douglas R. Hartree of the University of Cambridge, who is at present acting head of the Institute of Numerical Analysis at the University of Southern California at Los Angeles, visited the Laboratory to exchange information on the progress of computer development in England and America.

Dr. A. V. Haeff of the Naval Research Laboratories, with Dr. S. N. Alexander and Mr. G. F. Rouse of the National Bureau of Standards and Mrs. F. R. Darn of BuShips, came to discuss storage-tube progress, particularly stability under the holding beam. They inspected tube construction facilities and deflection-setup equipment.

Mr. I. J. Gabelman of Watson Laboratories and Dr. R. F. Nicholson of the Electronics Research Laboratories, U.S.A.F., discussed the use of computers in air traffic control and the need for investigation in this field.

The use of computers for research, simulation, and control of missiles was discussed with G. H. Stoner of Boeing Airplane Co.

The Project Standards Group exchanged information on materiel standards with H. C. McDonald, C. P. Sawyer, and J. G. Powell of the Naval Underwater Sound Laboratory.

Commander Leslie M. Slack, Armament Branch of ONR, inspected the laboratory with Mr. Perry Crawford of Special Devices Center, ONR, and discussed Project status and organization.



# APPENDIX

## REPORTS AND PUBLICATIONS

The following reports and memorandums on Project Whirlwind work were issued during June.

| No. | Title | No. of Pages | No. of Drwgs. | Date | Author |
|---|---|---|---|---|---|
| SR-6 | Summary Report No. 6 | 21 | | 3-48 | |
| E-122 | Variable Frequency Clock Pulse Generator, Model 2 | 1 | 1 | 5-19-48 | H. Kenosian |
| E-124 | Variable Frequency Clock-Restorer Pulse Source | 2 | 2 | 5-21-48 | H. Kenosian |
| E-125 | Clock Pulse Control | 6 | 1 | 5-27-48 | J. A. O'Brien |
| E-127 | Comparison of 7AD7 and 6AG7 | 1 | 1 | 6-15-48 | H. Kenosian |
| E-128 | Crystal Rectifiers for WWI | 2 | - | 6-21-48 | D. R. Brown |
| M-407 | Power Supplies for Sylvania Testing | 3 | 6 | 5-11-48 | R. L. Massard |
| M-422 | Power Supply Proposal No. 3 | 6 | - | 6- 1-48 | H. R. Boyd |
| M-435 | Temperature Effects on Cathode Resistance of Aged 6AG7 Tubes | 3 | 2 | 5-24-48 | J. J. O'Brien |
| M-445 | Electrolytic Tank | 3 | - | 5-27-48 | A. R. Curtiss |
| M-446 | Progress Report: An Investigation into the Reliability of the Capacitively-Coupled Flip-Flop | 3 | 3 | 4-10-48 | W. P. Horton |
| M-447 | Bi-Weekly Report, Part I, May 28, 1948 | 14 | - | 5-28-48 | |
| M-448 | Bi-Weekly Report, Part II, May 28, 1948 | 19 | - | 5-28-48 | |
| M-449 | Progress Report: An Investigation into the Reliability of the Capacitively-Coupled Flip-Flop | 1 | - | 4-22-48 | W. P. Horton |
| M-450 | Power and Indicator Connections to Panels | 2 | - | 5-28-48 | C. W. Watt |
| M-451 | Evaporation Tubes ET36 and ET39 | 1 | - | 5-28-48 | R. Shaw |
| M-453 | Selection of a Test Equipment Truck for WWI | 2 | - | 6- 3-48 | R. E. Hunt |
| M-454 | 7AD7 Substitution for 6AG7 in WWI | 2 | 1 | 6- 3-48 | H. Fahnestock |
| M-457 | Addition to Check Register | 1 | - | 6- 4-48 | R. P. Mayer |
| M-458 | Pulse Mixer | 1 | - | 6- 8-48 | C. A. Rowland |
| M-459 | Indicator & Voltage Variation Panel Details | 2 | - | 6- 8-48 | C. W. Watt |
| M-460 | Time Schedules | 1 | - | 6- 8-48 | H. Fahnestock |
| M-469 | Evaporation Tube ET45 | 1 | - | 6-11-48 | R. Shaw |
| M-470 | Bi-Weekly Report, Part I, June 11, 1948 | 16 | - | 6-11-48 | |
| M-471 | Bi-Weekly Report, Part II, June 11, 1948 | 18 | - | 6-11-48 | |
| M-472 | Filament Transformer, WWI | 1 | 1 | 6-11-48 | H. S. Lee |
| M-473 | Proposal for Monitoring System of WWI Power Supplies | 1 | - | 6-11-48 | N. H. Taylor |

| No. | Title | No. of Pages | No. of Drwgs. | Date | Author |
|---|---|---|---|---|---|
| M-477 | Proposed Register Panel | 1 | 2 | 6-11-48 | H. Kenosian |
| M-481 | Storage Tube 32A | 1 | - | 6-16-48 | P. Youtz |
| M-482 | Thermal Expansion of Al and $Al_2O_3$ Layer | 2 | - | 6-16-48 | H. Klemperer |
| M-484 | Voltage Variation Panels | 2 | - | 6-16-48 | C. W. Watt |
| M-485 | Input-Output and Comparison Registers | 3 | 2 | 6-16-48 | E. S. Rich |
| M-486 | Program Register and A-Register Similarity | 1 | - | 6-16-48 | E. S. Rich |
| M-487 | Toggle-Switch Storage; Switch Location | 1 | - | 6-16-48 | E. S. Rich |
| M-490 | In-Out Register, Omission of Manual Resets | 1 | - | 6-17-48 | R. R. Everett |
| M-492 | Substitute for Delay Counter | 2 | - | 6-17-48 | R. P. Mayer |
| M-493 | Warpage of Signal Plates | 3 | - | 6-17-48 | R. Shaw |
| M-494 | 7AK7 Tubes, Conference with E. W. Butler | 1 | - | 6-18-48 | H. Fahnestock |
| M-497 | Prototypes of WWI Panels | 1 | - | 6-18-48 | H. Fahnestock |
| M-499 | Discussion of 7AK7 Production, Emporium, Pa., June 15 | 2 | - | 6-18-48 | D. R. Brown |
| M-500 | Fabrication of Power Cables | 1 | - | 6-21-48 | H. S. Lee |
| M-502 | Meetings of Electronics Group, June 4, 11, & 18, 1948 | 2 | - | 6-21-48 | J. J. O'Brien |
| M-507 | WWI Time Schedule Conference | 2 | - | 6-24-48 | H. Fahnestock |
| C-52 | Project Whirlwind Seminar No. 26: Runge-Kutta Method of Numerical Integration | 5 | - | 5-10-48 | P. Franklin |
| C-53 | Project Whirlwind Seminar No. 27: Runge-Kutta Method of Numerical Integration | 7 | - | 5-12-48 | P. Franklin |
| C-54 | Project Whirlwind Seminar No. 28: Runge-Kutta, etc. | 4 | - | 5-17-48 | P. Franklin |
| C-55 | Project Whirlwind Seminar No. 29: Runge-Kutta, etc. | 3 | 1 | 5-19-48 | P. Franklin |
| C-56 | Project Whirlwind Seminar No. 30: Runge-Kutta, etc. | 5 | - | 5-24-48 | P. Franklin |