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Memorandum L-10 (Draft)

Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: ANALYSIS OF WHIRLWIND PROGRAM

To: N. McL. Sage

From: Jay W. Forrester

Date: January 13, 1949

The Whirlwind I computer is now ~~in an advanced state of~~ approaching completion. Research ~~in the many new areas required in~~ underlying the development of the machine appears complete. Only a small amount of design, a fair amount of construction, and installation remain to be finished.

The plans for continuing at a budget rate of $1,200,000 per year would maintain a balanced organization which would bring Whirlwind I to an operating stage at the earliest possible time with the least total expenditure.

Reduction of this yearly expenditure rate is, of course, possible but ~~rapidly~~ leads to an unbalanced organization resulting in higher total costs and a delay in the effective use of the machine.

If funds to carry on a balanced program are not available, long-range research phases will be curtailed to give completion of the Whirlwind I computer top priority. Such a step is made necessary

by the present loss of confidence, by groups outside M.I.T., in digital computers and their engineering design. The research on Project Whirlwind has been considered a long-range effort to develop and use digital computers in Naval applications. It was assumed that this effort would require several years longer to materialize than other slower-speed, exploratory equipments under construction at the same time for demonstration and scientific laboratory use. Because a balanced organization has been maintained which was capable simultaneously of the required research and the engineering, there is now indication that first results from this long-range project may actually appear before the short-range ones of a few years ago.

Completion of Whirlwind I to an operable stage will generate the confidence and enthusiasm necessary to set up serious and effective work on digital computer applications to logistics, air traffic control, missile and fire control, anti-submarine defense, equipment and tactical simulation, engineering computation, and scientific studies.

The following tabulated information will help clarify the important considerations:

A. PRESENT STATUS

1. Research phases of the Whirlwind I computer are solved. complete.
   a. Storage tubes appear satisfactory for Whirlwind I. They are now being subjected to, and appear to be passing, final tests which will show them ready for computer use.
   b. A model arithmetic element has been in successful operation for over a year to prove video circuit techniques.

2. Design and Construction.

Final design and construction of Whirlwind I are well advanced as shown in the following estimates.

80% of the digital computer design is complete.

45% of machine construction is complete.

70% of machine construction will be complete when Sylvania has spent its present appropriation, and the government-furnished Eastman equipment is delivered.

3. The 30% of unfinished construction consists of the following:

a. About 10% (or $48,000 worth) of the Sylvania-subcontract work will remain unfinished, and unless additional funds are made available to them, this work will not be completed by them and must be finished by M.I.T.

b. In addition to the above unfinished Sylvania work, the remaining unfinished construction of machine elements consists of:

(1) A very small amount of construction work on input-output control.

(2) Construction of storage tube control, which is similar to parts of the machine already complete.

(3) Construction of storage tube coupling and output circuits, based on circuits now being developed.

(4) Storage tubes, which will be constructed by personnel and facilities diverted from tube research.

c. Design of several of the parts in a. and b. above must be completed. Present staff can finish this design sooner than it can be constructed by presently available technicians.

B. PRIORITY FOR FUTURE WORK.

Completion of the Whirlwind I computer to a working stage is assumed to be the top priority item. With Whirlwind I operating, plans for using computers in control, simulation, logistics, and engineering and scientific computation would go ahead with the certainty and confidence that is only possible when the required tools are available. The delay to long-range progress notwithstanding, it is therefore assumed that a reduction in total project level would be made by cancelling research in favor of Whirlwind I completion.

1. Order of Completion. Prior to actual completion of Whirlwind I, several intermediate stages will be reached which will demonstrate successful parts of the computer.

   a. Storage Tube Tests. Electrostatic storage tubes are undergoing tests which fully simulate computer operation. Results to date are favorable and the tubes can be fully evaluated for use in Whirlwind I in a few weeks.

   b. Arithmetic Element. The complete arithmetic element of Whirlwind I will soon be tested and in operation. The entire arithmetic element has now been delivered. Incomplete tests to date show excellent results and less than the normally experienced number of preliminary installation difficulties. Such success is directly attributable to the long and careful engineering tests which preceded final construction. The results of the operating tests on the arithmetic element will be available during February, March, and April.

c. Whirlwind I with Test Storage. The next important milestone will be operation of Whirlwind I complete with arithmetic element, central control and test storage. This stage will prove, by demonstration, the successful operation of all video circuitry and the entire machine except for electrostatic storage which can then be installed. This stage can be reached in October or November if sufficient funds are available immediately for the required electronic circuit construction rate.

d. Whirlwind I with Electrostatic Storage. The final step in the immediate program will be operation of Whirlwind I complete with electrostatic storage. Based on the present status of the arithmetic element, the storage tube tests, and the design and partial construction of central control, it appears technically possible to have the machine assembled with electrostatic storage ~~by the beginning of~~ early in 1950 if the project schedule and coordination are not upset by enforced omission or curtailment of essential phases of the work.

2. Curtailed Research. Giving the completion of Whirlwind I top priority over long-term research phases of the project would be the least undesirable way to meet budget pressures. It may, however, cost heavily in future preparation for effective use of computers. With any substantial budget reduction, it will be necessary to eliminate practically all work on mathematics, applications studies, data conversion, the interconnection of

computers and servomechanisms systems, the studies of terminal equipment which will eventually be required with Whirlwind I, research on storage tubes beyond the absolute minimum for preliminary operation of Whirlwind I, research on improved video circuits, magnetic recording studies, and some of the present complete reporting of work done. All of these research activities together total only about 12% of the optimum project budget but would have to be discontinued to give top priority to Whirlwind I completion. Nevertheless, this is probably the best long-range decision if a choice must be made, because completion of a computer of the high-speed modern type might provide an impetus sufficiently great to recover eventually the ground lost by suspending all auxiliary research.

C. COURSE OF ACTION

A budget of $100,000 per month or $1,200,000 per year appears sufficient to maintain the required staff and to provide materials and completed video circuits and storage tubes at the rate at which the staff can efficiently accomplish installation and tests. This would meet the schedule of Section B. 1. and carry through the preliminary operation period if the $100,000 per month rate through June 1950 could be authorized and assured by the end of January 1949. At the same time such minimum essential auxiliary research as listed in B. 2. above could be maintained in preparation for the period immediately following machine completion.

Prior to recent studies, the statement was made that a budget reduction would delay proportionately the time for machine completion. It now appears that completion time would be delayed disproportionately because of the serious upset which would occur in the timing of coordinated activities. Part of this inefficiency arises because in general there are not several staff members on a specific task. The budget and staff which have in the past been available have not permitted a desirable amount of overlapping. The undertaking is of such a magnitude that new staff have usually been assigned to their own new phases of the program. If the single staff member on a particular task leaves, the know-how, experience, and proper relationship of his work to other phases of the program may be lost. The particular task cannot then continue, even at a reduced rate, until another man has learned it. For a similar example in the non-staff and central service part of the project, closing photographic or sheetmetal shops as an economy measure would mean that this work must be learned on a part-time basis by others or placed outside with somewhat higher direct cost and, more important, substantial staff liaison time.

While no absolutely sharp dividing line can be drawn, the following approximate steps would be taken and results obtained if reductions in the optimum budget are made:

1. A reduction of $125,000, cutting the yearly budget to a rate of $1,075,000 would be made in all research activities directed at a period beyond the completion of Whirlwind I.

These activities are the ones listed in B. 2. and include all postponable storage tube research even though this leads to danger should unanticipated difficulties arise in tubes during the next year; nearly all mathematics and applications research; most of the study of computer terminal equipment; and all basic research on circuits, components, data conversion, and the communication between computers and servomechanisms.

The effect of this curtailment on Whirlwind I completion is hard to predict, but might be a delay of one to two months. The above research, while considered long-range, nevertheless makes a continuous contribution to work in progress. If things go well, Whirlwind I completion should not be affected by absence of the research. If unexpected trouble develops, the background information and an emergency source of staff for its solution would be unavailable. At the best, curtailment of this group represents a loss of some $77,000 in training and twelve months time to find personnel and restart the research in the future. Under unfavorable circumstances, it might delay completion of Whirlwind I several months with a corresponding accrual of total expenditure.

2. A further reduction of $100,000 per year to a yearly rate of $975,000 would be accomplished by a reduced rate of materials, purchased services, and video construction both

inside the laboratory and on subcontract. The delayed receipt of these machine components would result in lowered staff efficiency and greater total staff time because of the necessity for temporary testing, substitution of makeshift equipment, and improvisation in the installation and testing of those machine parts which do become available. The delay, corresponding to this $100,000 saving in yearly expenditure, is estimated at an additional three to four months. Total expenditure to the assembly of Whirlwind I would be increased some $140,000 over that if a rate adequate to carry on the work already underway were followed.

3. Additional reduction in Whirlwind I Activity. Reducing the yearly budget below $975,000 per year would have to be done by further reduction in staff and construction on the Whirlwind I computer with resulting delays in the completion date beyond June 1950. No careful analysis of this situation has been made, but the extension of time would be more than proportional to the saving in cost because of the loss of trained staff, the necessity for relearning techniques and experience which this staff had acquired, and because there are substantial fixed charges which tend to be independent of group size. These fixed charges are considered under the following section. As a rough estimate, for an additional reduction of to $875,000 $100,000 per year in total budget, the time extension might be another four months to October 30, 1950 and the total overall costs to the completion of Whirlwind I might be increased by another $140,000.

D. DISCUSSION.

At the present time the Project is operating with sharply curtailed expenditures for subcontracting and construction. This curtailment has been made to conserve funds until a decision has been made on Whirlwind I financing. This reduction in construction is delaying Whirlwind I components which are already designed and is most detrimental to an efficient program. For an optimum program the restoration to a rate of $100,000 per month should be made as soon as possible, but in any case a decision is important to permit exercising the priorities of Sections B. and C. if a permanent long-range reduction must be made in the next 18 months.

Under any of the curtailed expenditure rates, operation would be planned to use the maximum available budget, and no funds would be available to meet contingencies; therefore, any unforeseen circumstance would have to be met by an extension in the time factor.

The $125,000 reduction in Section C. 2. would necessitate reducing research at a time when this is most important to future programs and when the applications and mathematics work should actually be expanding in anticipation of operating digital computers.

Direct charges to the contract, which tend to be independent of total project activity level, lower the efficiency as the total budget is reduced. These direct fixed charges amount to about $140,000 per year. Large items in this total are $27,000 for military security, $24,000 for report editing and reproducing, and about $36,000 indirectly

chargeable to the training period of new staff members. Most of this revolving staff is in the research assistant group working for advanced degrees and who must be replaced as they graduate. The remainder of the $140,000 includes personnel management, a small amount of laboratory equipment and facilities, maintenance of present Navy and laboratory equipment, and the staff time devoted to discussions with visitors and other items chargeable to education and training. The above figure represents direct charges and does not include other indirect fixed charges such as light, heat and building maintenance which are also paid by the Goverment via overhead on salaries.

Progressive curtailing of the present organization would affect the computer program in the following sequence:

Reduction from Optimum	Yearly Budget	Assembly of WWI	Cost from 1/31/49 to Whirlwind I Assembly Date	Comments
none	$1,200,000	Jan. 1950	$1,200,000	In addition to completion and assembly of WWI, present research could be continued.
$125,000	$1,075,000	Feb. 1950	$1,160,000	All postponable research cancelled.
$225,000	$ 975,000	May 1950	$1,300,000	Reorganization of WWI personnel necessary at peak of job.
$325,000	$ 875,000	Sept.1950	$1,460,000	Additional serious personnel loss and reorganization.

Elimination of research aspects of the work is unsafe in any program as new and unknown as digital computers. There is, however,

enough confidence in present research results to justify the priority judgments in Section B. as the course of action with minimum risk if a reduction is made.

The work of several years under enthusiastic ONR sponsorship with constant pressure for accelerated activity is so near to the completion of a high-speed computer to be used in further research toward applications of importance to the Navy, that continuation of an optimum well-balanced program until June 1950 seems to us to be in the best interests of the Navy.

Some comments which are significant in this discussion are well summarized by Professor F. J. Murray of the Columbia University Mathematics Department, who was requested by Dr. Mina Rees of ONR in November 1947 to examine and evaluate Project Whirlwind and compare its objectives with those of other computer projects, particularly that at the Institute for Advanced Study at Princeton. His report submitted to the Special Devices Center is dated 21 November 1947. Relative to Items 1 and 3 in the preceding paragraph on delaying Whirlwind I, we might quote Section 4 of Professor Murray's report:

> "4. It should be clear from the above, that engineering development is not the real concern of the Electronic Computer at IAS and this is quite proper. However, it is also true that engineering development is absolutely necessary for the development of electronic computers and delaying engineering development, say by postponing Whirlwind, will delay the use of digital computers in the type of problem with which we are concerned.

Relative to Item 2 of the paragraph above, Professor Murray's comments on the mathematics and applications studies in his Conclusion 9 also apply to the several other forms of research which would need to be curtailed:

"9. The following essentially negative statements can be made:

A. The present engineering program should not be delayed for a mathematical analysis.

B. The mathematical analysis of these problems should not be assigned to any separate organization but should be part of Whirlwind.

C. The mathematical analysis should not be delayed until the computer is available."

Jay W. Forrester

JWF:bc

cc: Dean Edward L. Moreland
Dean Thomas K. Sherwood
Mr. N. McL. Sage
Professor Gordon S. Brown
Professor Harold L. Hazen
Mr. Henry Loomis
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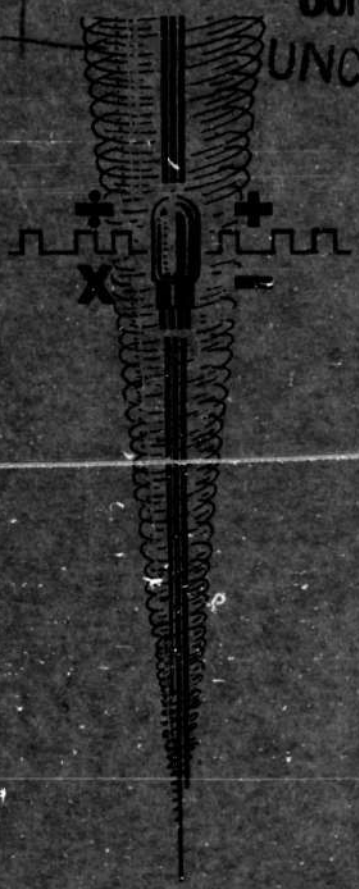
Rec'd 2-21-49 (from DRC)

PROJECT
WHIRLWIND

Contract N5ori60
Project NR-720-003



L-11

INFORMATION ON WHIRLWIND I AS REQUESTED BY LT. CMDR. RUBEL, RESEARCH AND DEVELOPMENT BOARD IN LETTER DATED 7 FEBRUARY

BY

JAY W. FORRESTER

FEBRUARY 15, 1949

SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Copy 16

SUBJECT: RECEIPT OF CLASSIFIED MATERIAL

FROM: MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY, PROJECT WHIRLWIND DIVISION
211 MASSACHUSETTS AVENUE
CAMBRIDGE 39, MASSACHUSETTS

TO: Mr. N. McL. Sage
Room 5-105
MIT

TRANSMITTED: ☒A. HEREWITH
☐B. UNDER SEPARATE COVER IS THE FOLLOWING MATERIAL:

DESCRIPTION:

Copy 16 - L-11 Information on Whirlwind I as Requested by Lt. Cmdr. Rubel, Research and Development Board, in Letter dated 7 February.

Please sign and return this receipt immediately. One copy may be retained by you.

I have personally received the material described above and accept full responsibility for its safe-handling, storage, and transmittal elsewhere in accordance with existing regulations of the Navy Department.

Signed: ..... Title: ..... Date: .....