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Analysis of Digital Computer
Laboratory Proposed 1950-51
Budget

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ANALYSIS OF DIGITAL COMPUTER LABORATORY

PROPOSED 1950-51 BUDGET

by

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OBJECTIVES OF PROJECT WHIRLWIND

The primary objective of Project Whirlwind is research in applying digital computers to real-time problems. To work on such applications has first required the research, design, and development leading to the construction of a suitable machine. The machine, Whirlwind I, is not an end in itself; it is a tool to be used in the further work of the laboratory.

A digital computer for the significant real-time applications must be substantially faster than is perhaps justified for engineering and scientific work. The real-time research includes such studies as the presently contemplated air intercept control project. Similar applications exist in land and ship-board fire-control and probably in anti-submarine tactics. Real time computation shows great promise in the simulation of equipment, tactics, and team activity for systems study.

A digital computer for real-time applications must have a high degree of reliability because of the nature of the application and because the computer becomes but a part of a larger system. (See Appendix A)

Work on a digital computer to provide a real-time computing tool necessarily gives as a by-product a machine which can be useful for engineering and scientific computation. To use it for scientific and logistic research requires only the addition of suitable terminal equipment as suggested later.

The machine capacity is such that for a long time there is scant prospect of its becoming loaded beyond the point of handling both the available real-time and scientific work.

Proposed Tasks
Appendix A
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2. A statement of the proposed tasks

The work we propose doing on Project Whirlwind for the fiscal year 1950-51 falls logically into four areas:

2.1 Operate the Computer

Assembly of the basic computer will be complete at the beginning of the fiscal year. It will be necessary to:

a) Item A-1, keep the machine hot, maintain the computer in working condition, replace storage tubes, and other components as required.

b) Item A-2, complete the testing, reliability studies, and trouble-location method development needed to make WWI meet the reliability requirements needed for control and simulation work.

c) Item B-1, continue the present tube life investigation which has importance not only to computer reliability but throughout the electronics industry.

2.2 Extend the Terminal Equipment

Enough terminal equipment will be available at the beginning of the fiscal year to allow working introductory problems with WWI. Proposed further work is of two kinds:

a) Item A-3, extend the existing EK film units and their associated equipment to provide the flexible, convenient, and reliable terminal equipment necessary for efficient use of the computer. Included are: putting all EK units into operation, the development of auxiliary stepping registers, and improvement of display devices.

b) Item B-5, adds magnetic tape subsidiary memory to increase the usefulness of WWI in scientific and engineering calculation and in logistics work. The proposal is to procure 4 Raytheon tape drives already developed. A substantial amount of work is required to develop and construct the equipment needed to operate these units in combination with WWI.

2.3 <u>Improve the Storage Tubes</u>

The WWI maintenance, item 2.1a, includes the cost of supplying replacement tubes for WWI. In addition to this low level construction the following storage tube work is desirable.

a) Item B-3, Continue the present storage tube development in order to provide reliable 1024 digit storage tubes to replace the 256 digit tubes now available.

b) Item B-4, Construct enough 1024 digit storage tubes to provide 2 full banks in WWI. This will increase the storage in the computer to the design capacity of 2048 registers in place of the present 256.

c) Item C-1. Further develop the MIT storage tube with the aim of decreasing the access time, decreasing the cost, and increasing the storage density beyond 1024 points. Decreasing access time is important to increasing the speed for forthcoming real time application.

d) Item C-2. Investigation of promising new magnetic high-speed internal memory.

Appendix A Appendix B

2.4 Using the Computer for Mathematical and Application Studies

Item A-5. Set up a small group of mathematicians and engineers to study the uses of the computer, to carry out some research, to discuss computation with prospective users, and to put problems on the machine. This group would be an advisory body for the benefit of persons outside the laboratory who wish to use Whirlwind and initially is necessary if WW is to be put to effective use on scientific and engineering calculation.

Appendix A Appendix B

3. Summary of the Budget

Budget details will be found in Appendix D.

3.1 Operating the Computer

Item A-1	Maintain the computer	$94,000
Item A-2	Complete computer to meet reliability requirements	92,400
Item B-1	Continue vacuum tube life studies	17,100

3.2 Extend the Terminal Equipment

Item A-3	Complete film units and auxiliary equipment and displays	105,000
Item B-5	Add magnetic tape units	152,100

3.3 Improve Storage Tubes

Item B-3	Develop tubes for 1024 digits	59,700
Item B-4	Change to 2 banks of 1024 digit storage tubes in WWI	40,000
Item C-1	Advanced storage research	44,100
Item C-2	Investigation of new storage types	9,400

3.4 Using the Computer for Mathematical and Application Studies

Item A-5	Basic group for mathematics and applications	79,000

3.5 Project Supporting Organization	190,500
Details in Appendix B	
Total of all Budget Items	$883,000

SUMMARY:

Salaries and Wages	$509,300
Overhead	214,700
Materials and Services	159,300
Total	$883,300

APPENDIX A

Computer Reliability

RELIABILITY IN DIGITAL COMPUTERS

One of the controversial aspects of the M.I.T. digital computer work has been the high stress placed on reliability with the attendant increase in cost. Precautions to ensure successful operation have included development of the marginal checking procedure, research into improved vacuum tube life, careful testing of electronic subassemblies, complete checking of purchased components, and the development of test and trouble location problems. Doubts have been partially dissipated by the contrast between preliminary successful results of work at M.I.T. and the failures of some others to demonstrate satisfactory reliability in digital computers where similar precautions have not been taken. There is already a noticeable trend of digital computer groups to follow these practices. It may, however, be well at this time to set down some of the considerations which lead to the policies on which we have insisted.

Three principal reasons, singly and in combination, justify placing dependability of equipment above all other aspects of our work:

1. The basic nature of the modern digital computer is such that a fault is catastrophic in comparison to similar faults in other electronic equipment.

2. Electronic computers have received, from numerous machines, a reputation of reliability which has led to the discouragement of many potential users.

3. In spite of the first two points, we are proposing digital machines for the field of real-time problems where human life and large financial investments are dependent on completely error free operation of the information processing computer.

These three points will be discussed in the following paragraphs. At the beginning of Project Whirlwind, and until recently, there was no good reason to believe that the necessary reliability was achievable. The only procedure known then or now is to identify every source of error and take precautions to eliminate all. This has accounted for a sizable part of our time and cost. To one who really understands this field (and they are very few), principles are not so much at stake as their realization. The theory and potential usefulness of a digital computer can be established on the philosophical and paper-study level. Its ultimate utility depends on demonstrated successful operation. Now to return to the three points above.

First, we have the unique nature of the digital computer with which to contend. In most electronic equipment frequent noise and disturbances are tolerable. The radio can have static; television pictures flicker but sets still sell; an occasional mistaken character in teletype messages does not destroy message meaning.

This is perhaps merely a re-statement of the redundancy of information in the ordinary communications channel.

The digital computer is different. Each and every electrical pulse has a unique meaning. The signal codes in the computer are (except where intentionally duplicated) probably the most compact and the most random and free of redundancies of any present information handling equipment. A single isolated error can lead to chaos. The very feature of computable control orders that gives the great logical power to the modern computer and is its principal advantage is, at the same time, one of the biggest hazards. Whirlwind will probably be the first machine in active operation which can freely and flexibly do computing on its own control orders. The machine can (and usually will) alter its own control instructions by computing changes and indexes in them; this most powerful feature does, however, put the control instructions within reach of machine mistakes. An error may not only insert a mistake in a result but can completely devastate the instructions which the machine is following. Earlier computers were not subject to this hazard but, lacking the ability to compute program orders, are by comparison very difficult to program and inflexible and awkward to use. None of the following machines can compute control orders during a machine sequence: ENIAC, BTL Model V, IBM Selective Sequence Electronic Computer, Harvard Mark I and Harvard Mark II. So far as we know, the Harvard Mark III and BTL Model VI are equally limited. The Eckert-Mauchley BINAC and the University of Pennsylvania EDVAC were equipped to compute control orders but are not being operated due principally to failure to follow effective design procedures and lack of administrative policies which would provide proper transition from laboratory to end use.

A new class of computing machines is coming up. In the forthcoming machines the orders are stored in the internal memory where they can be altered by the computing processes. Whirlwind should be the first of these to operate successfully. All of them (Whirlwind, Raytheon, UNIVAC, Institute for Advanced Study, Bureau of Standards, University of California at Berkeley, University of California at Los Angeles, etc.) will be vulnerable to electronic disturbances like nothing else before them. Our opinion is that the best one can do at the present state of the art is no more than sufficient to provide satisfactory equipment. Anything less than the best will lead to almost certain failure.

The second point is the bad reputation for reliability which electronic computers have acquired. Many people have come to presume that only by repetition of the work or by simultaneous operation of more than one machine can dependable results be obtained. Even the twin BINAC machines, doing simultaneous computation, have not solved the reliability problem. Based on latest information, the ENIAC, which has been operated for some six years, is still making random errors at average intervals of 30 minutes; most of these are found by mathematical and duplication checks which must be programmed. Various reports come from the IBM SSEC machine in New York; the only first hand information is from Dr. von Neumann and the Carter Oil Company.

These people are completely discouraged with the SSEC after being able to get only 11 hours of successful performance out of a three-week period. There is no information available on the Harvard Mark III and probably none will be available until after the move to Dahlgren. If Whirlwind does not break the progression of unreliable, temperamental machines in its earliest periods of operation, there will be no confidence to support its application to the more important types of problems for which it was designed.

Point three, on the need for reliability in real-time control problems, is quite apparent. Any contemplation of digital computers for air traffic control, fire control, or aircraft interception must be supported by a plan for getting a machine of the dependability required. Reliability is by far the most important unknown quantity. A system need not be set up to prove the basic theoretical possibilities, but it is necessary to demonstrate successfully operating equipment. An experiment in air intercept control, plagued by digital computer failures, could easily do much more harm than good. In ultimate real-time applications one has not the opportunity to start over and repeat a run as in scientific computation.

Perhaps now some brief comments are necessary on what we are doing to protect ourselves against the obvious pitfalls.

A first useful principle is to place no confidence in the benevolence of Nature and the hope that freedom from trouble can be expected in a computer circuit when its operation is not fully known and understood. There is an amazingly prevalent and unfortunate tendency to believe that an untested and unverified component or circuit will operate satisfactorily.

We have made a 100 percent inspection of purchased components; often with equipment superior to that possessed by the manufacturer and sometimes to standards stricter than those established for military equipment. For instance, vacuum tubes are tested for intermittent vibration shorts or opens with a wide band video amplifier to guard against failures too short in duration to operate ordinary tube testers but long enough to cause a circuit to miss a 0.1 microsecond pulse. As one minor example of the result of component testing, we have had almost no difficulty with coaxial plugs and connectors (of which several thousand are used) much to the surprise of those with extensive experience in electronic equipment.

At the start of our work, we began a study and life test program on vacuum tubes in pulse circuits surpassing any that has been made by vacuum tube manufacturers or users (a statement more derogatory to the extent of other tube studies than indicative of our own comprehensiveness). As a result, we anticipated by many months a wave of vacuum tube failures which has struck pulse communication systems, nickelodeons, other computers, and the multitude of post-war equipments using pulsed circuits. The cathode interface deterioration which we first spotlighted and explained clearly enough that it was recognized by industry has brought to us nearly every large American vacuum tube manufacturer for advice and consultation. The trouble has long existed unrecognized and has been erroneously diagnosed as cathode poisoning, loss of emission, presence of contact potentials, etc. The effect had been known earlier in magnetron work, and physics laboratories, but its relation to pulse communication was not recognized, its appearance as a result of low duty factor operation not identified, and adequate steps in industry were not being taken to prevent it. Tubes can now be obtained which are relatively free from cathode interface deterioration. In a recent discussion with Dr. Nergaard of RCA, neither of us can see why a continuation of the present work should not lead to receiver-type vacuum tubes with tens of thousands of hours life. Many others are now studying this difficulty in vacuum tubes.

Every chassis and electronic subassembly which has gone into the Whirlwind computer has been thoroughly and completely tested for its various modes of operation and repetition rates. It should be remembered that the circuits work on pulses 0.1 microsecond wide at the base line (an almost completely unknown situation when the computer was started) and most must be completely free of sensitivity to repetition rates from manual push-button to two megacycles.

By far our most important principal and basic contribution to computer reliability is marginal checking. The system of marginal checking finds deteriorating components and permits their replacement before they reach the threshold where they can cause random errors. Experimental results show that marginal checking can easily decrease the random error rate by a factor of 40 to 1. Marginal checking, along with properly designed check problems (which have taken several

Appendix B

staff-years to develop) can cross-section the machine so that defective parts can be readily isolated. Work is not yet sufficiently complete but results to date prove, to our own satisfaction, the necessity of these methods.

Other groups have become interested in and some converted to the necessity of marginal checking. Recent advances in understanding the method show that marginal checking can be done quite simply.

Our program of improving reliability is much more than mere development and design work. It is basic engineering research in a field where many current beliefs are inaccurate and founded only on prejudice, rumor, trial and error, and preconceived opinion having no foundation in fact.

APPENDIX B

Whirlwind Supporting Organization

Project Whirlwind is a large engineering organization engaged in the development of a large and complicated piece of electronic equipment. The Project consists of about 50 staff and 91 non-staff personnel and has an annual expenditure rate of over $800,000. The effective operation and efficient direction of such a group demands the existence of well-organized supporting services. These services include project direction on a high level, non-staff administration, the establishment and competent direction of centralized drafting and shop facilities, procurement, purchasing, and material control services, building maintenance, guards, receptionists, etc. Such services must be provided for any group, large or small. In small groups the engineers themselves perform much of the supporting work with reasonable success. In larger groups, it is more efficient to assign particular people to do specific jobs for all, in fact if all the engineers are allowed to do their own purchasing etc., plain chaos will result.

In making this budget we have attempted to describe separately those project people, both staff and non-staff, who perform services for all. The directly allocated people working on specific technical tasks can then be examined, unaffected by the existence of guards, etc. This total supporting organization is about 25% of the entire group; it is our firm belief that this is a reasonable situation.

The distinction between supporting and direct personnel is arbitrary since any of the supporting people can be directly allocated on some basis or other. We have made the distinction on the basis of whether the person was performing a genuine central service difficult to directly allocate. Other groups make the distinction in other ways. However, if the same basis of evaluation is used on other groups, both at MIT and in industry, then the comparison becomes valid and favorable to Whirlwind. This comparison is given later in this section.

In the following pages the entire Whirlwind supporting organization is described in detail. The organization is flexible in some ways and would certainly be adjusted to some extent if total project budget were substantially increased or decreased.

SUMMARY SHEET

	Personnel	Total Cost
Laboratory Direction	(4)	$ 27,700
Publication	(1 3/4)	10,000
Librarian	(1)	3,300
Chief Draftsman	(1)	6,800
Standards and Specifications	(1 1/2)	11,000
Non-Staff and Services Supervision	(1 1/4)	9,600
Staff Supervision and Thesis Supervision	(1/2)	4,400
Military Security, Building Operation, Travel, and General Administrative Work	(1)	7,500
Print Room (Drawings, hectos, assembly of reports)	(3)	12,700
Procurement	(2)	7,300
Purchasing	(4)	15,900
Stock Room	(3)	14,400
Receiving and Shipping, Transportation Messenger	(2 1/2)	10,000
Instrument Repair and Calibration	(3/4)	3,700
Photographer	(1)	6,900
Telephone Operator	(1 1/4)	3,700
Typist-Receptionist	(1 1/4)	3,500
Guards	(4 1/2)	19,600
Electrician	(1)	5,000
Carpenter	(1)	4,100
General Operation	(1)	3,400
	38 1/4	$190,500
Maintenance and Cleaning	Paid by M.I.T.	

SUMMARY OF SUPPORTING ORGANIZATION:

Salaries and Wages	$126,800
Overhead	53,800
Materials and Services	9,900
Total	$190,500

Laboratory Direction (4)

Dr. G. S. Brown	10%		
J. W. Forrester	100%		
H. R. Boyd	25%	Salaries	$18,300
R. R. Everett	25%	Overhead	7,900
H. Fahnestock	25%	Materials & Services	1,500*
E. Galant (Sr. Secretary)	100%	Total	$27,700
R. Berry (Sr. Secretary)	50%		

* Principally telephone and travel expense

Forrester as Project Supervisor is full time on laboratory direction supporting all work in the laboratory. Forrester together with 1/4 of the time of Boyd, Everett, and Fahnestock constitute a planning group for the technical supervision of all work in progress and the assignment of engineering personnel and effort.

Publication (1 3/4)

H. Fahnestock	25%	Salaries	$ 6,900
Prof. Ulman	50%	Overhead	2,900
A. Monroe (Secretary)	100%	Materials & Services	200
		Total	$10,000

Complete recording of technical details have been made in engineering notes and memorandums for internal distribution and record purposes. For the past two years, at the request of the Navy, we have been increasing the number and quality of formal reports (approximately 25 yearly averaging 50 pages each) for outside distribution, and supplementing these with quarterly reports (50 pages), and preparing informal bi-weekly reports of progress by each technical person and service group (35 pages each). The quarterly reports are typed and printed by Jackson and Moreland at a cost of approximately $3,000 yearly for ONR and $2,000 yearly for the separate Air Traffic Control study quarterlies. Other costs properly chargeable to publications but included in other departments of this appendix are about $2,000 of the library cost, $8,000 of the print room cost, $3,000 of general administrative cost, $3,000 of photographic cost, and $1,000 of receiving and shipping cost. This estimate of $32,000 for publication includes only the cost of editing, printing, and distribution.

During the last six months we have received 94 separate requests from 49 different organizations for a total of 670 project publications. In addition to those publications specifically requested by title, we distribute 200 copies of our summary report quarterly.

Librarian (1)

A. Ryan	100%	Salaries	$2,200
		Overhead	900
		Materials & Services	200
		Total	$3,300

This is an increasing activity overloading one girl at present. She receives some help from secretaries and Osborne. The engineering group has recently begun to depend heavily on the library favoring a central, well-organized report file to haphazard personal files. The library has about one hundred books, more than one thousand outside reports, and from two to six copies as well as ditto masters for all reports. A single complete set of the more than 1500 reports, memorandums, and specifications fill two six-foot shelves.

Chief Draftsman (1)

A. Falcione	100%	Salaries	$ 4,700
		Overhead	2,000
		Materials & Services	100
		Total	$ 6,800

Supervises 11 draftsmen and 3 print room girls. Excellent administrator who schedules work thoroughly, keeps drafting output at high level, and of uniform quality. Keeping the records straight and modifications up-to-date for the 3000 WWI drawings is an important task in itself. The Chief Draftsman also checks drawings, establishes and revises Standards, and watches for possible engineering errors.

Standards and Specifications (1-1/2)

H.B. Morley	100%	Salaries	$7,500
B. Mitchell (Secretary)	50%	Overhead	3,200
		Materials and Services	300
			$11,000

Recognition of the importance of Standards work is steadily increasing, and this program has made a substantial contribution to WWI reliability. A standards book listing specifications on more than 3000 carefully selected parts has been prepared and is continually revised in view of technical developments and the latest information on reliability. Need for non-standard parts are reviewed. If found necessary, an attempt is made to select the most acceptable part obtainable to fulfill the requirements. A specification is written for all non-commercial items so that reorder is possible, and so that others may use the item to the best advantage. Copies of our specifications on pulse transformers have been sent to many other groups on request. All standard parts are stocked automatically. Copies of the two standards books are used by all engineers and tells him immediately which parts are acceptable and available in the stockroom and the tests and characteristic of each. This group also distributes all WWI test specifications.

Non-Staff Personnel and Services Supervision (1-1/4)

H.R. Boyd	75%	Salaries	$6,400
R. Berry (Sr. Secretary)	50%	Overhead	2,700
		Materials and Services	500
			$9,600

During the past eighteen months, the non-staff group has been reduced from 132 to 91. Part of these reductions were made by clearing out inferior workmen, resignations, and temporary employees, but the remainder had to be transferred to other projects or laid off within the frame work of the union contract. This involves a large administrative expenditure of time but many successful transfers have been arranged and it has been possible to maintain good morale despite the continued reductions. This group processes time cards, sick leaves, vacations, employments and terminations, employee ratings, and job descriptions. Detailed records are kept on all employees, work assignments are made. The cooperation with the union representatives is considered one of the most important tasks.

Staff Supervision and Thesis Administration (1/2)

J.C. Proctor	50%	Salaries	$3,000
		Overhead	1,300
		Materials and Services	100
			$4,400

Proctor assists the project supervisor in DIC Staff supervision and records, clearances, vacations, etc. He handles all details concerning research assistants and associates. This includes interviewing and selecting candidates, running a computer training program for them, and seeing that they make a satisfactory division of time between the classroom and the project. He gives guidance to students and staff where required in selecting theses, and administers all phases of the thesis work except the actual technical supervision.

Military Security, Building Operation, and General Administrative Work (1)
(Includes Library, Report Distribution, etc.)

J.C. Proctor	50%	Salaries	$5,200
R.A. Osborne	50%	Overhead	2,200
		Materials & Services	100
			$7,500

Problems of military security are usually heavy on the project partly because of a puzzling government policy which has seen the project twice classified and twice declassified and partly because of the large number of visitors. This group arranges visits to other projects including travel, details, and clearance; handles all non-technical project visitors and some technical ones; makes arrangements for group visits and in many similar ways reduces the load on the laboratory direction group. Building operation requires some time for such details as arranging for fuel deliveries, elevator repairs, meeting safety requirements, deciding on building repairs etc.

Print Room (3)

J. Gunn (In Charge - Clerk & Records)	100%	Salaries	$6,800
E. Randle (Clerk and Ditto)	100%	Overhead	2,900
A. Sullivan (Ozalid Operator)	100%	Materials & Services	3,000*
		Total	$12,700

* Includes all blueprinting and ditto supplies

Much of the cost of this group is attributable to publications. Ozalid operation is a full-time job and more than half of the hundred or more prints made daily are for reports. Reports are printed on a ditto machine and assembled by this group who also distribute mail and communications twice daily. Filing and records on the more than 8000 tracings requires considerable time. Other activities include the typing of parts lists and drafting reports, distribution of all copies at the 3000 registered WWI tracings, maintainance of library and engineering print files, and distribution of drafting supplies.

Procurement (2)

H. Hodgdon (Administrative Assistant)	50%	Salaries	$5,000
C. Shay (Clerk)	100%	Overhead	2,100
B. Mitchell (Secretary)	50%	Materials & Services	200
			$7,300

Engineers request needed material from this group. Checks are made on existing stocks and purchase requisitions are written for special or out-of-stock items. Frequently, much time must be spent in locating a supplier for the item and working out the ordering details. About 200 purchase requisitions per month are being placed at present. Several file cabinets of catalogs are maintained for engineering use. A Kardex record is kept of all orders which supplies information on deliveries, stockroom inventories, costs, and rate of usage. Knowing price and usage information allows quantity purchase where feasible from the least costly vendors saving thousands of dollars yearly and maintaining adequate stocks on hand.

Purchasing* (4)

G. Hudson (Purchasing Agent)	60%		
J. Breen (Asst. Purchasing Agent)	60%		
A. Tailby (Asst. Purchasing Agent)	60%	Salaries	$11,000
D. McGrath (Accounting)	60%	Overhead	4,900
N. Rice (Secretary)	60%	Materials & Services	none
R. Walker (Secretary)	60%	Total	$15,900
R. Zussman (Secretary)	60%		

Actual purchasing, payroll preparation, and invoice processing is carried out by this group at building 32 which serves all of the Servomechanisms laboratory.

Stock Room (3)

H. Hodgdon (Administrative Assistant)	50%	Salaries	$9,600
R. Pugliese (Sr. Stock Clerk)	100%	Overhead	4,000
F. Powers (Stock Clerk)	50%	Materials &	
F. Hannon (Incoming Material Inspection)	100%	Services	800*
			$14,400

* Includes cost of stock cabinets, drawers, and other supplies needed for stockroom operation.

This group is under manned but it is considered to be an activity where economical operation requires that people be over-loaded at times.

The glass and chemical stockrooms are operated in informal fashion by storage tube technicians. While this group operates the three remaining stockrooms of which 1 is at Fort Heath for large and infrequently used materials and equipment . A small basement stockroom contains overflow and special items such as storage tubes. The main stock room contains more than a half million total and 10,000 different kinds of items. There are 3,000 different standard items for which an adequate stock must be maintained. One man is occupied nearly full-time in incoming material inspection. For example, nearly 25,000 crystal tests have been made. This includes inspections on each incoming item as well as tests before issuing since shelf life is a problem. Keeping track of more than 5000 equipment and instrument items is also a substantial job. Other jobs include the maintenance of an assigned stock section, filling parts lists and individual testing of the parts for delivery to the shops, tool records, sending instruments out periodically for calibration and repair, salvage of used parts, and disposal of scrap and surplus items.

Receiving and Shipping, Transportation, Messenger (2 1/2)

F. Powers (Receiving & Shipping Clerk)	50%	Salaries	$ 6,500
F. Cowie (Pt. Time Driver & Receiving and Shipping Clerk)	100%	Overhead	2,700
		Materials & Services	800*
T. Annetti (Messenger & Driver)	100%	Total	$10,000

* Includes cost of operating vehicles

Annetti makes two inside mail pickups and deliveries daily, and two trips to Building 32. Trips to other institute buildings are made as required. He also makes pickups from painters, silk-screeners, and other material suppliers.

Cowie and Powers receive all incoming material, do crating and report mailing, keep records on all materials leaving or entering the building, make twice-weekly trips to the stockroom at Fort Heath, do other driving as required and help in the stockrooms as time permits.

Instrument Repair and Calibration* (3/4)

B. Lane	35%	Salaries	$ 2,400
J. Pope	30%	Overhead	1,000
		Materials & Services	300
		Total	$ 3,700

* Building 32 service

Lane is an excellent instrument repair man and Pope is his assistant. Located in Building 32, they have a steady backlog of work from other laboratories. Instrument repairs may be done outside although not too successfully, but we believe that good research requires the periodic, accurate calibration of meters and equipment by dependable people. Lane is also able to alter meters on short notice for special purposes.

Photographer (1)

L. Sanford	100%	Salaries	$ 4,000
		Overhead	1,700
*Includes cost of all photographic supplies and equipment except film supplies for Whirlwind I operation.		Materials & Services	1,200*
		Total	6,900

A photographer might be considered a luxury except for the quantity that we require and the distance from photo service. Actually, the photographs of equipment and operations requires only a small amount of time. Most of the time is spent in engineering photography, developing, and printing. All storage tube surfaces as well as pictures of TV presentations of tube tests are photographed and these pictures have been very useful in locating trouble. Scope pictures are the only means of doing quantitative work on high-frequency pulse circuits, and it is expected that scope pictures will prove to be an excellent method of delivering WWI answers to many engineering problems. The Eastman film input-output equipment requires a great deal of film processing. Last summer, this group was reduced from two to one for economy reasons, and is badly overloaded at present.

Telephone Operators (1 1/4)

R. Burbank	100%	Salaries	$ 2,600
A. Gabbe	25%	Overhead	1,100
		Materials and Services	Negligible
		Total	$ 3,700

Six institute and four outside lines are connected through the switchboard to more than sixty building extensions. Switchboard operation is continuous during the day and requires a quarter time relief and lunch-time operator. All building intercommunication is handled by this operator through the board and a PA system. If sufficient lines and institute switchboard space were available for direct service the cost would be somewhat lower although institute lines cost $6.00 per month against $1.00 for building extensions, and the saving would be small. Such a move would give less satisfactory service, and leave a formidable building intercommunication problem with our three floors, and ~~hundred~~ eighty rooms. The load is heavy for one operator compared to loads at other boards.

Typist-Receptionist (1 1/4)

S. Rounds	100%	Salaries	$ 2,500
A. Gabbe	25%	Overhead	1,000
		Materials & Services	Negligible
		Total	$ 3,500

The steadily increasing flow of computer and laboratory visitors requires someone on duty at the door. Our typist-receptionist has been much cheaper and more satisfactory than a guard since we are able to use the larger percentage of her time for required typing of various kinds. Having a person for this task is customary in most Navy and MIT offices.

Guards (4½)

W. Wiercinski (Foreman)	50%		
P. Flynn	100%	Salaries	$13,800
W. Legras	100%	Overhead	5,800
F. Carroll	100%	Material & Services	
W. Williams	100%	Total	19,600

The four guards are on duty from 4:30P.M. until 8:00 A.M. Monday through Friday and on a 24-hour basis on weekends and holidays. It is possible to get along with three guards if they work 48 hours as is done at Building 32. Two years ago, Hilley in the Boston ONR office requested that we not work more than 44 hours except on holidays which is being done. Hourly rounds of the building are made. Guards also watch life-tests and tube-processing equipment which operates on a 24-hour basis, admit and check-out the many off-hour workers, and in their spare time, help with the building cleaning. We believe this practice helps prevent indolence and carelessness, although most guards at the Institute do not do such work.

Electrician (1)

G. Bent	100%	Salaries	$ 3,300
		Overhead	1,400
		Materials & Services	300
		Total	5,000

A large electronics and electrical research program such as ours requires continuous extensions, modifications, and repair in the electrical system. Use of separate central d-c power supplies for the laboratory and for Whirlwind introduce many of these problems but save a great many small supplies and much technician time. The main power distribution system has been installed by outside contractors paid by the Institute. However, extensions and modifications are considered a technical activity and occupy much of the electrician's time. He also services the numerous motor-generator sets, and power-supply equipment, P.A. system, and does electronic construction if time permits.

Carpenter (1)

W. Reardon	100%	Salaries	$ 2,700
		Overhead	1,100
		Materials & Services	300
		Total	$ 4,100

Building repair is done by an institute-paid building maintenance and cleaning group. However, both the computer and storage tube program have required frequent building alterations and construction of special equipment. Reardon is an inexpensive but capable carpenter, sheet metal worker, and handyman who helps technical groups requiring such services. He works in the shop on the infrequent occasions when he is not needed elsewhere.

General Operation (1)

Mrs. Fay	50%	Salaries	$ 2,400
E. Cantrell	50%	Overhead	1,000
		Materials & Services	Negligible
		Total	$ 3,400

Mrs. Fay is a matron who dusts during the day, looks after the lunchroom, and cleans the ladies' rooms. Actually, about half of her time is spent in cleaning which is an institute overhead item. To balance this, part of Cantrell's time, which is charged to institute overhead, is used directly on the projects for running errands, moving equipment, etc.

Many of the jobs, such as moving, which are performed by Cantrell, are purchased as services through buildings and power by on-campus projects.

Maintenance and Cleaning (3 1/2)
(Paid by M. I. T.)

W. Wiercinski (Foreman)	50%	Salaries	$ 9,600
E. Cantrell (Painter)	100%	Overhead	
P. Sinewsky (Cleaner)	100%	Materials & Services	3,100
M. Christinakos (Cleaner)	100%	Total	$12,700

This group is paid for by M.I. T. and do the cleaning and maintenance of the building. The group is barely adequate for this purpose as an old building requires much repair and this one is cut up so badly that it is difficult to clean.

APPENDIX C

Whirlwind Status on July 1, 1950

In order to discuss the items of Attachments I and II of the December 2 letter to Captain Pearson in their proper light, it is first necessary to discuss the status of Whirlwind I as of July 1, 1950.

Briefly, the computer will exist in the Barta Building. It will be complete in the sense that it should be working and usable within its limitations. It will be incomplete in the sense that the necessary detailed thorough study of its operation will still be in progress, incomplete in that the high order of reliability which is needed for its purpose and which we believe we have built in will not yet be achieved. (See Appendix A.) Lastly, Whirlwind I will be incomplete in that more and faster storage and a greater diversity of terminal equipment must still be added. This unfinished work is that deferred from the present fiscal year in response to the ONR request that work be slowed down and extended over a longer time. The major elements of Whirlwind I with their predicted status as of July 1, 1950 are listed below:

(a) The Arithmetic Element - The arithmetic element will have been installed and operating for nearly 1-1/2 years. Study of this part of the computer will have been very thorough. Lacking will be instruction books plus the detailed maintenance and trouble-location procedures which will allow medium grade personnel to keep the arithmetic element at peak efficiency. As of July 1, 1950 the arithmetic element and, for that matter, the entire computer will still be in the care of high-grade engineers, many of whom did the actual design and all of whom were involved in the subsequent installation. It is neither efficient nor even possible to leave the care of the computer to these people. Men of such calibre lose interest in routine work after a year or two. There are two ways of providing new people: one is to continue to obtain high quality engineers and put them through an expensive training under the existing crew until they too have the necessary "feel" to maintain the complicated computer. The other is to reduce the maintenance and trouble-location process to the point where it can readily be taught to and applied by research assistants and routine personnel. This latter procedure is the one we would like to use, not only because we feel it to be economical in the long run with this one computer, but because it will be the only possible procedure when large numbers of computers will be in use. It is one of the basic purposes of Project Whirlwind to consider the computer reliability needed for computer operational use -- not merely laboratory use.

To be sure, considerable progress will have been made toward stereotyped procedures by July 1 but much will remain to be done.

(b) The Central Control - The central control will be in about the same state as the arithmetic element, perhaps not quite so well understood, since it will have been in operation less than a year.

(c) The Electrostatic Storage - The equipment for ES Row is now built but the final d-c wiring installation will not be complete until April. The entire storage will be tested and operated separately from the rest of the computer until its operation has reached a high degree of reliability. We expect to tie the storage into the computer before July 1, 1950. There will still remain a long period of study before the electrostatic storage will have reached the stage already obtained by the arithmetic element and central control.

The storage available on July 1 will consist of 256 words of 16 binary digits each with an access time of about 25 micro-seconds. These characteristics are sufficient for study purposes and even for the solution of substantial problems. They are not sufficient for the efficient use of Whirlwind I. It is of great importance to increase this storage capacity and of lesser but still substantial importance to decrease the access time.

(d) Terminal Equipment - Sufficient terminal equipment will be available on July 1 to allow operating the entire computer with electrostatic storage. It will be possible to insert problems and to remove results. The equipment will be adequate for the needs of Whirlwind I at that time; it will not be adequate on a long term basis when Whirlwind I is put into productive use. Four out of the six EK units will still require testing and alterations; auxiliary stepping registers must still be designed and built. If Whirlwind I is to be widely used for scientific and engineering calculation, then magnetic tape units must be procured and the equipment for connecting them to the computer and controlling them from the computer must be designed and built.

In this area of terminal equipment a substantial amount of electronic design and construction is still required to bring Whirlwind I up to its scheduled level of efficiency. Since this equipment must have reliability equivalent to the rest of the computer, it must have periods of debugging, study, and maintenance procedure development.

There is really a fifth part of the computer that does not appear in the logical diagrams. This part is service equipment for the first four; its contributions are not readily visible, but without it the computer is helpless. Included are the following parts:

(a) Power Supplies - These include motor-generator sets with regulators and controls, d-c power supplies, power distribution with switching, interlocks, fuses and fuse indication, metering, and d-c wiring. This system contains 1500 relays and represents an investment of $150,000.

(b) Air Conditioning - 60 kw of filament, plate, and relay power are dissipated in the computer room. This heat is removed by a mechanical air conditioning system which includes a precipitron air cleaner.

(c) Test Equipment - A large amount of both commercial and laboratory built test equipment is needed for the study, control, and trouble location of the computer.

Although this service equipment is available and is largely of well known types, it still requires preventive maintenance if it is not to contribute appreciably to computer failures.

To recapitulate, the computer will exist in a minimum form on July 1, but substantial study, storage development, and terminal equipment development will be needed to bring it to a state of full efficiency.

APPENDIX D

Detailed Breakdown of Budget in Letter to Captain Pearson, not including Supporting Organization of Laboratory

In the light of the discussion of Appendix C we can now proceed to examine the items in the December 2 letter to Captain Pearson. Only those items are included here which were agreed upon as immediately desirable in discussion with ONR representatives. Of the original items, B-2 has been dropped and combined with an increased B-4, B-5 has been reduced from eight to four magnetic tape units, and B-6 and C-3 and C-4 omitted, and C-2 reduced to a fifth its earlier level.

The figures on the following pages are usually less than the corresponding figures in the Pearson letter because all the so-called "supporting organization" has been taken out and is handled as a separate item in Appendix B. In the following pages, only personnel and materials assigned and used directly on the technical work are charged to the technical tasks.

A-1 Routine Whirlwind I Maintenance Including Storage Tube and Other Part Replacement

This item represents the effort required to keep WWI operating on a one shift basis at the stage of development reached by July 1, 1950.

No provision is made for new design or even for continued debugging of existing equipment. There is no provision for an active program for improving maintenance procedure beyond what might be expected as a by-product from the crew doing the routine work. As long as the computer voltages are on, even if the computer is doing no useful work, there will be need for a steady replacement rate of storage tubes, ordinary vacuum tubes, germanium crystal diodes, and other components. These replacements, particularly storage tubes, represent a considerable part of the cost. The routine maintenance and repair of the power supplies, motor generator sets, air conditioning system, and test equipment represent another cost.

In the maintenance program, one of the research assistants is essentially a trainee. The staff group will rotate with any one man staying three years. This will provide variable training and will prevent stagnation and loss of interest that would follow prolonged assignment to this single job.

Storage tube cost estimates throughout this memo are based on the declining cost per tube which are resulting from improved organization of the work and the procurement of certain new pieces of equipment to improve personnel efficiency. Tube cost in the third quarter of 1949 (including proration of supporting charges) was $2250 each. At present on the same vasis it is $1500 and the cost is expected to decrease toward $1000 each.

It can be expected that maintenance costs in the year after next will decline in the same way that storage tube costs are declining. After the work on item A-2 has been completed, the maintenance staff may not require the number of personnel scheduled for next year. Storage tube life and the replacement rate of tubes and components are unknown and in later years may be more favorable than one can now depend on. The indicated tube and crystal replacement rate in the following budget is larger than now being experienced in the Whirlwind computer but there is real likelyhood that the present rate may go up as components age. The following tube replacement budget assumes that receiver-type tubes will operate about two years on the average. The budget represents our best realistic estimate for the year 1950-51. It may become substantially different after a year's experience is gained and after the results of section A-2 are available.

A-1 Routine Whirlwind Maintenance
(Including storage tube and other replacements)

Assigned Personnel

1 Engineer @ $5,200/yr Technical supervision of group plus trouble-location and repair	$ 5,200		
2 Research Assistants @ $2,400/yr 1 for routine checking of computer - assist in trouble-location and repair 1 for power supplies, bench testing of spares, terminal equipment. Both research assistants are in training for engineer's job.	4,800		
4 Technicians @ $3,500/yr These people are on a permanent basis and perform the bulk of the routine work. 1 for preventive maintenance on relays and power distribution. 1 for terminal control room equipment and maintenance. 2 to assist in computer routine maintenance, trouble-location, repairs, minor changes	14,000		
1 Clerk @ $2,100/yr To keep the log with records of performance, changes and repairs, ordering parts, etc.	2,100		
Total Salaries and Wages		$26,100	
Overhead @ 42%		11,000	
Total Personnel and Overhead		$37,100	
Materials not including storage tubes			
2,500 vacuum tubes @ $3.00	$7,500		
3,000 crystals @ $1.30	3,900		
Other components, transformers, etc.	3,000		
		$14,400	
Total Excluding Storage Tubes			$51,500

Storage Tubes

It is difficult to compute the cost of storage tube replacements since the tubes are not purchasable items and their life under computer conditions is unknown. The approach used here is to estimate the minimum organization that could maintain the present facilities and build tubes with reasonable efficiency. Such an organization could probably produce one acceptable tube per week. This rate could supply replacements for one 16 tube bank of tubes with an 800 hour life. It would supply replacements to a 32-storage tube machine with tube life of 1,600 hours. Life is expected to be this good or better. The estimate is generous, and consideration will be given to this fact when figuring ST research budgets in later items.

Assigned Personnel

1 Engineer @ $5,200/yr Supervise construction and test - overcome production troubles	$ 5,200	
1 Research Assistant @ $2,400/yr Routing static and dynamic test of new tubes including test equipment maintenance - mount adjustment	2,400	
1 Glassblower @ $4,800/yr Glasswork for storage tubes and evaporation tubes, make stems, maintain vacuum systems	4,800	
3 Technicians @ $3,500/yr 1 for tube processing on the vacuum systems 1 for gun assembly and evaporation tube assembly including cathode spraying	10,500	
(Total)		$22,900

Total Brought Forward	$22,900		
(Technicians continued)			
1 for storage tube assembly including chemical cleaning. The latter 2 technicians supplement each other in an organization that is already dangerously close to disaster in case of losing any one man.			
1 Machinist @ $3,500/yr To make tube parts	3,500		
Total Salaries and Wages		$26,400	
Overhead @ 42%		11,100	
Storage Tube Personnel and Overhead		$37,500	
Materials The materials include glass, mica, stainless steel, processing gases, and chemicals		5,000	
Total Storage Tube Personnel and Materials			$42,500
Maintenance, Excluding Storage Tubes			51,500
Total for Item A-1			$94,000

A-1 SUMMARY

Direct Salaries and Wages	$52,500
Overhead	22,100
Materials and Services	19,400
	$94,000

A-2 Developing the Maintenance and Operating Procedures for WWI

(Preferable Name - Developing Available Whirlwind Equipment into a Well-Understood and Reliably Operating Computer)

A-1 estimates the cost of keeping Whirlwind at the level of development attained by July 1, 1950: A-2 estimates the cost of continuing that development until Whirlwind can truly be said to be in reliable operation except for equipment additions. The work under this item is almost entirely deferred activity resulting from the 1949-50 reduction of Barta Building budget to 50% of the previous year (not including the reduction effected by ending outside sub-contract work).

This A-2 development includes:

The additional test and study required to bring the electrostatic storage system to a level of reliability equal to that of the arithmetic element and the central control.

A like task with the input-output registers and control.

Completion of the work presently in progress of measuring and improving operating margins throughout the computer.

The redesign and modification of troublesome parts of the computer.

Reliability runs on the computer in whole and in part.

The collection and correlation of computer performance data.

The design of checking and trouble-location problems for the entire computer.

The continued development of marginal checking procedures.

The establishment of maintenance methods and schedules.

The writing of instruction books covering machine operation and maintenance.

The documenting of all modifications made in the computer with drawing changes, specifications, and other records kept up to date.

It is this item A-2 which more than any other is representative of the project's attitude toward reliability and the definition of the word complete. This expenditure of time and money will be made on equipment already assembled, reasonably well debugged, and presumably complete. This expenditure will be necessary if the full measure of reliability available from WWI is to be realized, if full information on computer reliability is to be obtained for use here or elsewhere, and if the maintenance procedures are to become stereotyped so that the machine will not require the continuous attention of a few specific people.

This item does not represent a level effort throughout the year. Instead the effort will be larger at first, tapering as the work is completed until it reduces to instruction book writing, data correlation, and possible reliability testing at the end of the year. The staff released as the year progresses will transfer to terminal equipment A-3 and B-5 with some going to Air Force and Fire Control studies.

The work of this item is somewhat equivalent to the four years spent in bring the ENIAC or MIT differential analyzer up to a satisfactory performance level after initial assembly.

It is difficult to dissociate A-2 personnel from A-1 personnel since the efforts will necessarily be combined. The breakdown assumes, therefore, that A-1 personnel are available for routine maintenance and test.

A-2 Continued Whirlwind Development

Assigned Personnel

1 Senior Engineer @ $7,200/yr Direct technical supervision	$ 7,200		
4 Engineers @ $5,200/yr 1 for redesign and developing electronic trouble-location methods 2 to design trouble-location problems, check problems, and correlate these problems with marginal checking 1 for instruction book preparation	20,800		
2 Research Assistants @ $2,400/yr 1 for routine measurements and detailed trouble investigation and design 1 to assist in the preparation of instruction books	4,800		
3 Technicians @ $3,500/yr 1 for modification and construction 1 for breadboard construction and circuit test 1 to assist in routine computer testing	10,500		
2 Draftsmen @ $3,200/yr These men are required to keep drawings and specifications up to date and to work on instruction book illustrations	6,400		
2 Secretaries @ $2,200/yr 1 for change notices and records 1 for instruction book typing	4,400		
1 Administrative Assistant @$3,900/yr To keep all records up to date	3,900		
Total Salaries and Wages		$58,000	
Overhead @ 42%		24,400	
Total Personnel and Overhead			$82,400

Total Personnel and Overhead	$82,400	
Materials and Services Estimated to cover modification materials, and instruction book printing in addition to normal requirements	10,000	
Total Personnel and Materials for A-2		$92,400

A-2 SUMMARY

Salaries and Wages	$58,000
Overhead	24,400
Materials and Services	10,000
	$92,400

A-3 Terminal Equipment Development

As of July 1, 1950 only a bare minimum of terminal equipment will be available. A-3 covers the extension of this minimum by debugging and putting into operation the remaining 4 EK units (for a total of 6), the design, construction and test of the stepping registers to go between paper units and EK units without the use of the Whirlwind in-out register, and the design, construction, and test of the switch with which the computer can select among the various available pieces of terminal equipment. Also included here is development of scope display circuits allowing the computer to show points, circles, ellipses, and lines on a cathode ray tube for displaying friendly and enemy target and circles of probable position in certain types of real time work. This scope display equipment will also be valuable in the rapid plotting of scientific results. As part of the terminal equipment program, it will be necessary to prepare the present storage tube laboratory as a terminal equipment and control room. The room will need an air conditioning unit to extract heat from the equipment and to control dust and humidity for the EK film units. The storage tube laboratory is to be moved to the basement.

A rough breakdown of the total by the different subsidiary items is:

Debugging EK units	20%
Stepping registers -- contain about 50 relays and 75 vacuum tubes -- design, construct 3 and test	30%

Scope display equipment	20%
Selector switch -- 150 vacuum tubes -- design, construct, test	20%
Moving storage tube lab and preparing control room	10%

A-3 Personnel

1 Senior Engineer @ $7200/yr. Direct technical supervision and planning	$ 7,200	
3 Engineers @ $5200/yr. 1 to design the selector switch 1 to design the stepping registers 1 for research and design of scope display	15,600	
4 Research Assistants @ $2400/yr. 2 to debug EK units 1 to assist with stepping register design and test 1 for research and design of scope display	9,600	
6 Technicians @ $3500/yr. 1 to assist with EK units 1 to assist with switch and stepping registers 1 for work on scope display 2 for construction 1 for average time allotted to storage tube lab move	21,000	
2 Draftsmen @ $3200/yr. Layout and mechanical design of switch and stepping registers	6,400	
1 Secretary @ $2200/yr. Assigned to senior engineer for reports, modification sheets, and general work	2,200	
Total salaries and wages		$62,000
Overhead @ 42%		26,000
Total personnel and overhead		$88,000

Total personnel and overhead		$88,000	
Materials and Services			
Stepping registers	$ 5,000		
Materials for scope display	2,000		
Switch	2,000		
Air filter & cooling control room	5,000		
Breadboards and EK	3,000		
Total Materials and Services		$17,000	
Total direct cost of A-3			$105,000

A-3 SUMMARY

Salaries and wages	$62,000
Overhead	27,000
Materials and Service	17,000
	$105,000

A-4 WWI Operation

This item might be dropped as a separate category for next year. It is logically distinct from both A-1 (maintenance) and A-5 (problem preparation) and should eventually require a substantial yearly expenditure. It is questionable, however, whether it would not be preferable to combine the duties of this group with those of A-1 and A-5 organizationally and to so budget them in the future. In any event, in this coming year there should be relative little of this work, while the computer is swarming with A-2 people. Since it does not seem reasonable that WW should work problems, undergo performance testing, and require maintenance all at one time it should be possible to divert some of the A-1 and A-2 people to operation when needed. We therefore suggest that item A-4 be dropped.

A-5 Basic Group for Applications and Mathematics

This covers a small group of 9 staff members, etc.

This group is essentially mathematical and is of arbitrary size. 8 staff members preparing problems can in no way keep up with the computing capacity of a machine such as Whirlwind. Since a large part of this group's effort will be preparatory -- the design of library programs, discussion with visitors and potential users, education of themselves and others, studies in applied mathematics -- the amount of actual problem preparation will be small.

It is doubtful if a competent group of the right character can be fully gathered by July. Instead, an initial group of engineers will be drawn from present staff for work on the ONR fire control study. To this will be added capable people as they can be obtained. If there is reasonable expectation of continued support in fiscal 1951-52 then the basic group could be much larger than 8 at the end of this year.

Some saving could be effected in this item but only with the risk of seriously delaying the effective use of WW for scientific and engineering computation. This item does not cover the staff of persons generating the need for computing work. The staff of this group will work with members of the M.I.T. faculty who wish to use the computers. In other words they are consultants, advisors, and coaches as well as preparing basic library programs and computing sequences of general usefulness. During this next year is here included the small study on fire control applications of digital computers which has been requested by ONR. The original section A-4 has been combined with this work.

A-5 Basic Group for Applications and Mathematics

Personnel

The group will start smaller than that described and end up larger: an average is shown.

1 Senior mathematician @ $7200/yr. Supervision and research	$7,200		
2 Mathematicians @ $5200/yr. Mathematical formulation	10,400		
2 Engineers @ $5200/yr. Fire control studies	10,400		
2 Research assistants in mathematics @ $2400/yr. Coding	4,800		
2 Research assistants engineering @ $2400/yr. Coding	4,800		
2 Computers @ $3200/yr.	6,400		
2 Typists @ $2200/yr. Machine tape code preparation	4,400		
2 Secretaries @ $2200/yr. Reports and general	4,400		
Total salaries and wages		$52,800	
Overhead 42%		22,200	
Total personnel and overhead		$75,000	
Materials and services Travel, supplies, publications		4,000	
Total A-5			$79,000

A-5 SUMMARY

Salaries and wages	$52,800
Overhead	22,200
Material and service	4,000
	$79,000

B-1 Vacuum Tube Life Studies and Performance Records

All vacuum tubes used in the Whirlwind I computer and associated test equipment have been given individual serial numbers and card records have been kept of manufacturer, production lot number, circuit in which the tubes are used, filament hours, and plate hours. Static and dynamic tests are made on the tubes after an initial preburning period and again after the tubes are rejected from normal service. This program is unusually complete by comparison with any others in the vacuum tube industry and is providing unique data on tube life and reliability and information on how to improve vacuum tubes.

B-1 Itemizing

1/4 Senior Engineer Supervise and analyze results	$1,800		
1 Research Assistant @ $2400/yr Supervisor of routine test, special testing, and reporting	2,400		
1 Technician @ $3500/yr Routine tube test	3,500		
1 Secretary @ $2200/yr Keeping records	2,200		
Total Salaries and Wages		$ 9,900	
Overhead at 42%		4,200	
Total Personnel and Overhead		$14,100	
Materials and Services (Does not include tubes)		3,000	
Total direct			$17,100

B-1 Summary

Salaries and Wages	$ 9,900
Overhead	4,200
Material and Service	3,000
	$17,100

B-3 Research to Develop a Storage Tube for 1024 Binary Digits

Although the heading of this item is very specific, it represents only the primary target for the storage tube development group covered in the estimate. Whirlwind I will be a relatively inefficient machine with only the 256 storage registers provided in the electrostatic storage presumed to be operating July 1, 1950. Although we have high hopes for the success of our development group in substantially increasing the storage capacity of our tubes by July, it will be necessary to continue this development in order to ensure the existence of 1024 digit tubes within the next year.

This research will not be a constant effort throughout the year. In the first place, we do not expect it will take that long to reach the primary objective; in the second place, there is a necessary lapse of about 6 months between the approval of a fully tested new tube and the existence of 2 banks of operating tubes in Whirlwind I. It is therefore of great importance to accomplish the development as soon as possible in order to obtain the advantage of 2048 registers of Whirlwind I storage within the year.

Fortunately the storage tube development and production efforts are interchangeable to a large extent. The expectation is that the bulk of the storage tube effort (except for a percentage roughly equivalent to that listed in A-1 and needed for replacement of Whirlwind I tubes) will be applied to storage tube development work including the design and construction of research tubes and the planning and carrying out of tests. When a thoroughly proven and reliable new design is available, the bulk of the effort will shift to the construction of tubes for Whirlwind.

The technicians who had been building research tubes will start building production tubes. The design group will turn to fixture design, specification writing, and records. The test group will turn to production static, dynamic, and life test and Whirlwind I tryout. That part of the development group that is too valuable for routine test will continue the development group on a reduced scale and possibly with more fundamental objectives. The sequence will be first to apply the effort to new development with a minor effort on Whirlwind tube replacement, then to put on a burst of production effort lasting about 6 months which should see Whirlwind fully equipped with new tubes, then a return to development work and tube replacement, and so on. The interval of the cycle will depend on the size of the group and the intangibles of vacuum tube development. If, as we fully expect, the new tubes will operate in combination with the old, then the replacement can be on a gradual rather than all at once basis, smoothing out the cycle somewhat but not really affecting the time schedule, since the improved performance of the new tubes cannot be realized until at least one full bank is available.

This item does not include the costs of the entire organization outlined above. The production effort required is properly chargeable to the construction of 2 banks of 1024 digit tubes for Whirlwind I and is covered under item B-4. Most of the construction is covered under B-4, most of the test group under B-3.

B-3 Itemization

1 Senior Engineer @ $7200 Direct technical supervision of the development program	$ 7,200		
2 Engineers @ $5200 1 for development test work 1 for mechanical design	10,400		
2 Research assistants @ $2400 For general test work	4,800		
2 Technicians @ $3500 1 to assist test engineers and construct test equipment 1 to build research tubes	7,000		
1 Draftsman @ $3200 Design and drawings	3,200		
1 Secretary @ $2200/yr	2,200		
Total Salaries and Wages		$35,000	
Overhead at 42%		14,700	
Total Personnel and Overhead		$49,700	
Materials and Services			
Research tube materials	5,000		
General lab supplies	5,000		
		10,000	
TOTAL			$59,700

B-3 Summary

Salaries and Wages	$35,000
Overhead	14,700
Material and Service	10,000
	$59,700

B-4 Change to 1024 Digit Storage Tubes in Whirlwind I

This item covers the cost of the construction and production test groups during the period required to build and test 32 storage tubes. The item presumes that one complete tube bank is operating in Whirlwind I, using tubes of reduced capacity, and the equipment for the second bank has been built prior to July 1, 1950, but is not yet in operation. Some time is assumed to cover the cost of putting the second bank in operation using the new tubes. The first bank will still be in operation during this time. When the new bank is operating, the first bank will be taken out of service and new tubes installed. This is essentially a routine operation covering bench testing and adjustment of storage tube mounts.

The personnel listed will not be assigned to this effort for the entire year. Instead, a larger group will work on it for a shorter time as discussed in B-3.

The construction group available under items A-1, B-3, and B-4 can produce 2 usable storage tubes per week of the present type, plus an occasional research tube. During the production run, about 1/2 tube per week will be needed, as an estimate, to provide replacement for the operating bank in Whirlwind I. About 1 1/2 new tubes per week will become available requiring a total of 5 to 6 months to construct 2 full banks. Since this construction group can probably build tubes at a rate faster than required during the development period, it may be possible to build up a backlog of replacement tubes adequate to supply the computer during the tube production period. In this case, a full 2 tubes per week will become available, reducing the changeover time to perhaps 4 months.

B-4 Itemization

1 Engineer @ $5200/yr. Supervise tube construction	$ 5,200		
1 Research Assistant @ $2400/yr.	2,400		
3 Technicians @ $3500/yr. 1 for gun construction and ET assembly 1 for ST assembly 1 for making ST parts	10,500		
2 Student technicians @ $2200/yr. 1 glass blower's helper 1 vacuum system technician	4,400		
Total salaries and wages		$22,500	
Overhead at 42%		9,500	
Total personnel and overhead		$ 32,000	
Materials and Services		8,000	
Storage tube materials	$ 6,000		
Tools, jigs, fixtures and general	2,000		
Total Direct			$ 40,000

B-4 SUMMARY

Salaries and Wages	$22,500	
Overhead	9,500	
Materials and Services	8,000	
		$ 40,000

B-5 Magnetic Tape Units

Magnetic tape units can serve not only as a means of inserting and removing computer information but also as a large-capacity slow-speed erasable memory supplementing the internal memory of the machine. The need for film development between recording and reading restricts the use of film equipment for that purpose. For real-time work this slow speed supplementary memory is not essential except in special cases; if available, it will almost certainly be used for various reference information. In scientific and engineering calculation, however, particularly in partial differential equations, and in logistics and other work requiring sorting and collating the slow-speed erasable memory is of great value. It is therefore proposed to add such equipment to Whirlwind in the next year.

The estimated cost included $50,000 for the purchase of 4 tape drives from the Raytheon Manufacturing Company. These drives have already been developed for use with the Hurricane computer; the price given is an estimate of the cost of adding 4 units to their production run which has not yet started. The drives as delivered are assumed to include the servo controls and magnetic heads but no amplifiers, discriminators, hunting circuits, or circuits for connecting the units to the computer or controlling the units from the computer.

The estimate of the cost of developing, constructing, and installing the necessary control and connecting equipment is necessarily rough. Detailed block diagrams and preliminary circuit studies will be necessary before a firm estimate can be made. Raytheon will have developed circuits for this purpose, but it is doubtful if Whirlwind can use them for a combination of computer logical checking, packaging, and other reasons.

A preliminary study, subject to considerable revision, indicates the probable necessity for building double, 6-digit binary shifting registers to go with each tape unit. It will be necessary to build 6 channels of amplifier and discriminator as well as writing circuits for each unit. A substantial addition to the present in-out control will be needed to satisfy the special shifting requirements of the magnetic units. Some revision, probably slight, will be needed in in-out control and in-out register and comparison register. The terminal equipment selection switch covered in A-3 will have to be made somewhat larger.

The above equipment provides only for operating the magnetic tape units as a supplementary memory with the computer. The use of the magnetic tape units as terminal equipment in place of, or in addition to, EK film units will require special equipment to allow using them with paper tape and typewriter equipment. Insofar as possible, these needs will be met in the equipment to be designed under A-3. The operation of the magnetic tape units with Whirlwind as auxiliary storage is of the greater importance and will be given first priority.

Substantial design work may be required under this item since the shifting registers should be direct-coupled and cannot, therefore, be of standard Whirlwind design. The other circuits are also of different types.

We do not expect that the sum requested under this item will more than cover the development, design, prototype, construction, and initial test of the needed circuitry. The reduction of the entire equipment to Whirlwind working reliability standards will remain to be done in the next fiscal year.

B-5 Itemization

1/2	Senior Engineer @ $7200/yr Technical supervision and planning to be coordinated with A-3	$ 3,600	
3	Engineers @ $5,200/yr. 1 for shifting register development 1 for development of in-out control additions 1 for packaging, mechanical design, production control	15,600	
2	Research Assistants @ $2400/yr. 1 for amplifiers and discriminators 1 for in-out register and in-out control modifications and to assist in register and control design	4,800	
2	Technicians @ $3500/yr. Breadboard construction and test assistance	7,000	
5	Technicians @ $3500/yr. Final construction	17,500	
2	Draftsmen @ $3,200/yr. Layouts and mechanical design	6,400	
1	Secretary @ $2,200/yr. General office	2,200	
	Total Salaries and Wages		$57,100

Total Salaries and Wages		$57,000	
Overhead @ 42%		24,000	
		$81,000	
Materials and Services			
Experimental Construction	$5,000		
Materials Production	16,000		
4 Tape Drives	50,000		
Total Materials and Services		71,000	
			$152,000

B-5 SUMMARY

Salaries and Wages	$57,100	
Overhead	24,000	
Materials & Services (including $50,000 to Raytheon)	71,000	
Total		$152,000

C-1 Advanced Storage Tube Research

B-3 and B-4 presume a storage tube group level that will be unable to support any large amount of development during the period when the changeover tubes are being built and tested. This item will strengthen the development and construction groups to the point where development continuity can be maintained throughout the year. Presumably the 1024 digit tube development can be somewhat hastened and the increased storage made available to Whirlwind earlier in the year.

The development of the 1024 digit tube is the first but by no means the final objective of the Whirlwind storage tube development program. The next objective will be to reduce the access time to the final specification of 6 microseconds where the storage tubes will be in balance with the rest of Whirlwind. This development will make Whirlwind about 3 times as fast as at present and will require no circuit changes. The higher speed will soon become important in such work as air intercept application studies with the computer.

The next objective (although work in most of the fields to be mentioned will be carried out in parallel but with varying emphasis) will be to reduce tube cost. One approach will be to reduce initial cost by simplified design and construction techniques. The other and perhaps more lucrative approach will be to increase tube life, largely as a result of the cathode studies now underway at a low level.

Considerable work of a research nature is also needed on the more fundamental aspects of storage tubes of the Whirlwind type.

Further objectives are the increase in storage densities beyond 1024 digits, further reduction in access time and the investigation of mosaics other than beryllium.

The assignments given below provide some increase in the construction group but more of an increase in the engineering group for the study of research tubes.

The total storage tube effort represented by this budget (Items A-1, B-3, B-4, C-1) is about equal to that maintained during fiscal 1949-50. It is most desirable to maintain this highly trained group particularly in the construction crew and higher staff levels. A substantial part of the storage tube research has always been carried on by research assistants and associates and by thesis work. This budget provides for maintaining this group by new students as the present ones complete their work and leave.

C-1 Itemization

2 Engineers $5,200/yr. 1 for research on higher speed and tube life research 1 for analysis and test	$10,400		
3 Research Assistants $2,400/yr. 1 for cathode studies 1 for general test 1 for tube design improvement	7,200		
2 Technicians $3,500 1 for laboratory assistance and construction, routine life testing 1 for special work in tube construction	7,000		
1 Secretary $2,200/yr. Reports and general	2,200		
Total salaries and wages		$26,800	
Overhead 42%		11,300	
Total Personnel		$38,100	
Materials & Services Special equipment, research tube material, general		6,000	
Total direct			$44,100

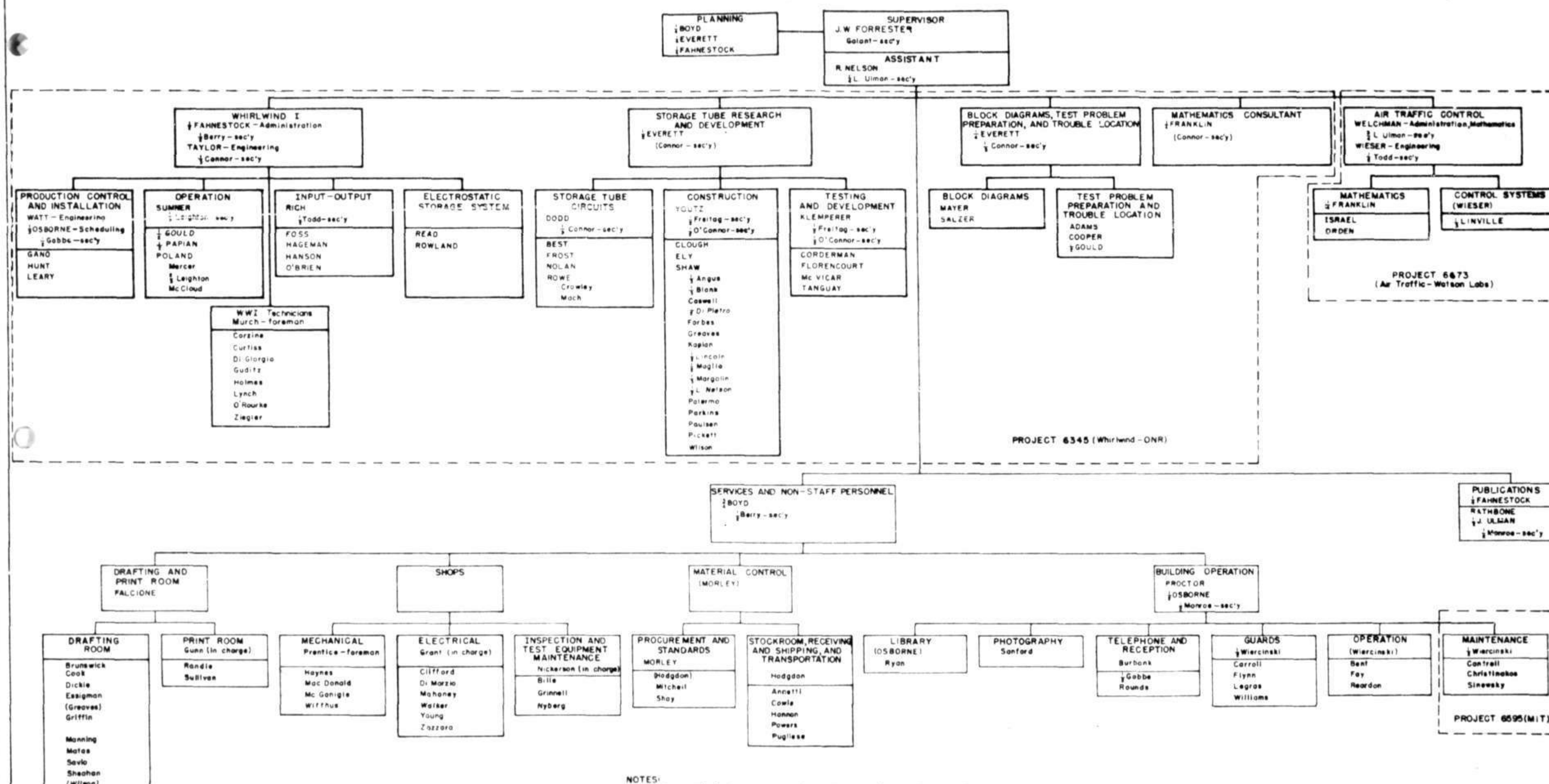
C-1 SUMMARY

Salaries and Wages	$26,800	
Overhead	11,300	
Material and Service	6,000	
		$44,100

APPROVED FOR PUBLIC RELEASE. CASE 06-1104.

D-32267-4

ORGANIZATION
ELECTRONIC COMPUTER DIVISION
SERVOMECHANISMS LABORATORY
MARCH 1, 1950

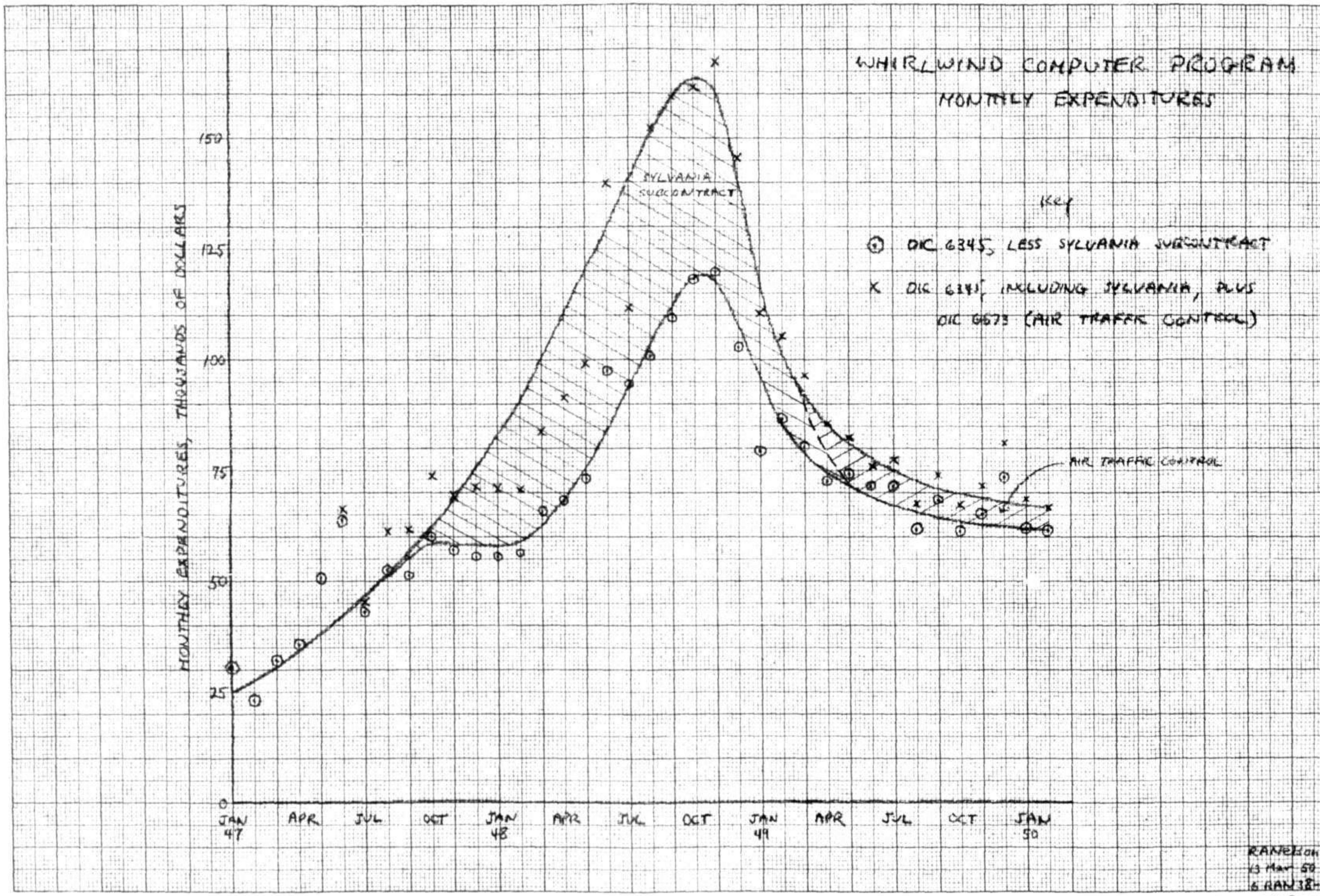


NOTES:
1. Primary activities are shown in heavy boxes; and supporting activities in light boxes.
2. Staff members are shown in capital letters and non-staff in small letters.
3. Fractions indicate the way in which the time of some persons is charged to the activities in which they participate.
4. Accounting and payroll handled in Building 32 and allocated to projects.

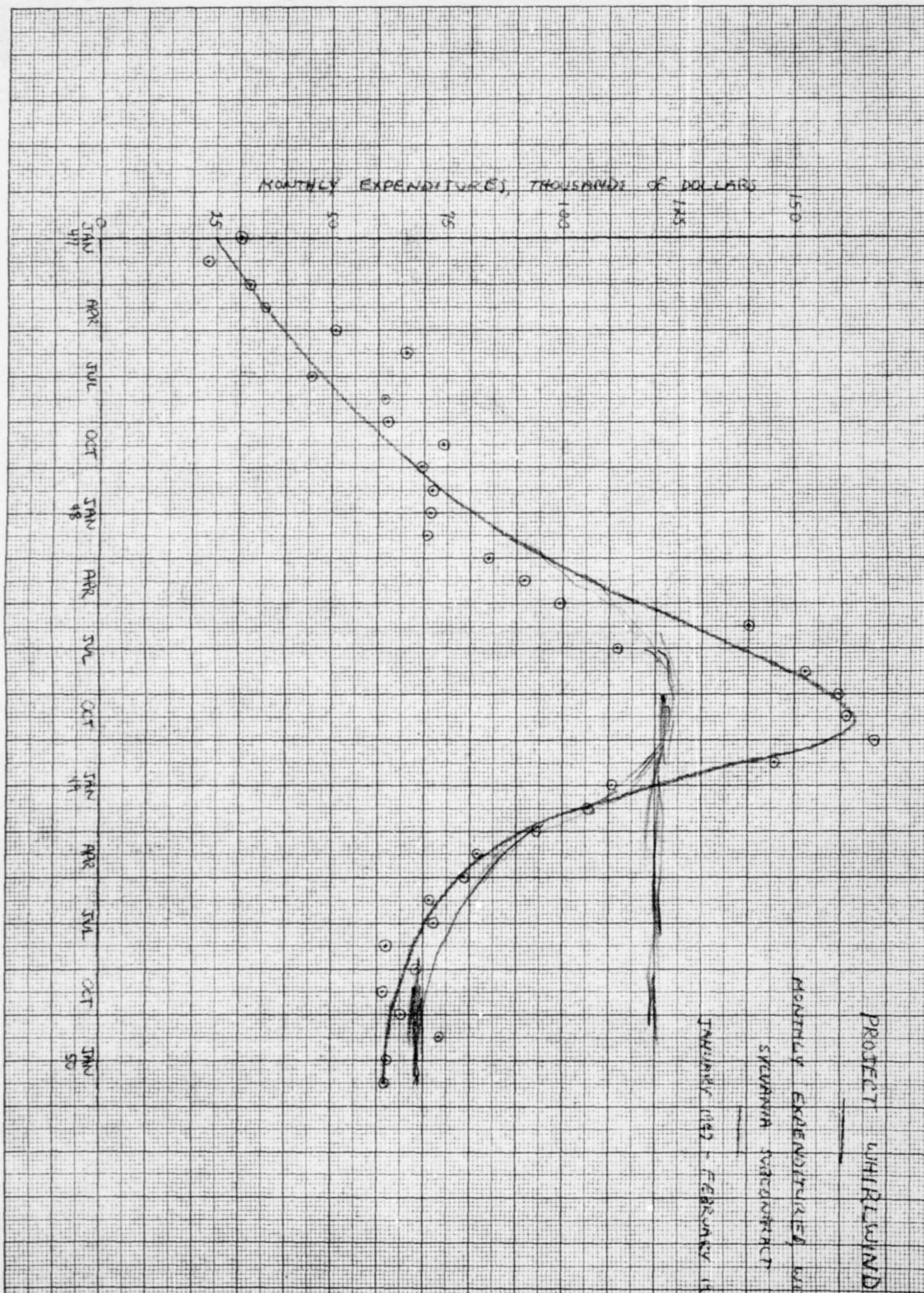
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO.
ORGANIZATION CHART
D.L.S.
D-32267-4
B-REDUCTION

APPROVED FOR PUBLIC RELEASE. CASE 06-1104.

SB-38922



SB-38922


PROJECT WHIRLWIND
MONTHLY EXPENDITURES, WITH SYLVANIA SUBCONTRACT
JANUARY 1947 - FEBRUARY 1950
MONTHLY EXPENDITURES, THOUSANDS OF DOLLARS
0
25
50
75
100
125
150
JAN 47
APR
JUL
OCT
JAN 48
APR
JUL
OCT
JAN 49
APR
JUL
OCT
JAN 50