Project Whirlwind
Memorandum L-9

6345 COST ANALYSIS

Jay W. Forrester

December 27, 1948

See copy only

Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: 6345 COST ANALYSIS

To: N. McL. Sage

From: Jay W. Forrester

Date: December 27, 1948

Introduction

The attached charts present by general area and by specific activity a breakdown of the yearly expenditures through the fiscal year 1948-1949 of Project Whirlwind - DIC Project 6345 and its predecessor Project 6295.

Content

Chart 1 lists the expenditures for laboratory operation. These are costs typical of this kind of work, associated with the setting up and servicing of a laboratory and its personnel but not dependent on any unique technical features of Whirlwind.

Chart 2 lists the expenditures for education and training. Included are costs of reports for outside use and of time taken to discuss project work with visitors, costs incurred for supervision of thesis research (other thesis costs are considered to be compensated by the technical results achieved and are therefore charged to other departments), and technical training (initial and continuing) for personnel (the first three months expenses for each new staff member are charged to education).

Chart 3 lists the expenditures for preliminary and aircraft analyzer work. The work first done on an aircraft analyzer was accompanied by a study of analog computation, which proved to be unsuitable and led to the change to digital computation.

Chart 4 lists the expenditures directly for Whirlwind I. These cover all labor, overhead and material specifically used for the design, construction, installation and testing of Whirlwind I, including the Sylvania subcontract.

Charts 5 and 6 list the expenditures for supporting engineering and for special supporting research, respectively, for Whirlwind I. These efforts were necessary for solution of basic technical computer problems and for completion of Whirlwind I, but the results are of general benefit and can be applied in many other cases. The supporting research of Chart 6 is work of a basic nature, necessary to Whirlwind I, which under other circumstances might have been the subject of separate research contracts.

Chart 7 lists the expenditures for storage tube research and development. Although this whole effort is undertaken to meet the needs of Whirlwind I, many of its results are of more general benefit.

Procedure

Cost figures for specific items were obtained in the following way. Certain costs could be estimated fairly satisfactorily as total sums; examples are the costs of central power supplies, commercial test equipment, and special materials for Whirlwind I. Others were best determined by estimating the number of man-months involved and then judging, on the basis of experience, the overall man-month cost; examples are military security, thesis supervision, editing, etc. The total of all these costs for each year was deducted from the total costs for the year. The remainder was distributed over all the fields not already charged for in proportion to the number of staff months (divided into two types, material-using and non-material using) devoted to each field as determined by a consideration of the work of each staff member in that field.

The breakdown of expected costs for 1948-1949 was used to obtain representative total staff-month costs. With the cost of all supporting activities charged to the primary activities, the figures obtained for 1948-1949 were $900 per month for a staff member using only incidental materials, and $1,850 per month for a staff member regularly using materials and laboratory equipment. This approximate ratio of 1:2 for the two kinds of work was maintained for the other years, even though the actual items assigned and allocated and therefore the actual cost per staff-month varied considerably.

JWF:RAN:ejw

Charts:
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Note:

To give a partial answer to an often-asked question, the asterisks on the charts indicate expenditures which it is estimated the Institute of Advanced Study has made for equivalent work. In this estimate, one year's expenditures at Project Whirlwind have sometimes been allowed to represent several years' expenditures at IAS (as the $5,000 for report editing and reproducing indicated in 1946-47). It is to be emphasized that the comparisons are for equivalent - not identical - activities; an example of this is the Whirlwind expenditure of $2,200 for liaison with Eastman Kodak on film reader-recorders in 1947-1949, probably equivalent to IAS's expenditure for liaison with the Bureau of Standards on teletype equipment.

The total estimate of IAS's expenditures is about $260,000, which may be substantially in error.

ACTIVITY	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		
SUMMARY	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
LABORATORY OPERATION #1				$22,500		$30,000		$126,100		$51,400			$230,000
EDUCATION & TRAINING #2						44,700		144,400		131,900			321,000
PRELIMINARY & AIRCRAFT-ANALYZER WORK #3		$75,000		173,100		110,700		54,400					419,200
WHIRLWIND I #4						21,200		320,400		808,200			1,149,800
SUPPORTING ENGINEERING #5						3,500		64,900		107,200			180,600
SPECIAL SUPPORTING RESEARCH #6						73,200		98,500		176,600			348,300
STORAGE TUBES #7						68,000		92,300		311,300			471,600
TOTAL		$75,000†		$201,600		$356,300		$901,000		$1,587,000	TOTAL FOR PROJECTS 6295 & 6345:		$3,121,000††
B-33255	(† CHARGED TO PROJECT 6295)										(†† TOTAL PROJECT FOR 6345 ALONE:		$3,046,000)

ACTIVITY	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		CHART 1
LABORATORY OPERATION	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
1. MATERIAL, COMPONENT } STANDARDS						$2,000*		$11,000		$7,000			$20,000
2. CENTRAL POWER SUPPLIES				$1,500		3,000		5,000		2,000			11,500
3. COMMERCIAL TEST EQ.				5,000		10,000*		20,000		7,000			42,000
4. OTHER LAB EQ. & FACILITIES				12,000		8,000		24,500		3,000			47,500
5. PERSONNEL MGT (STAFF AND NON-STAFF)						3,000*		9,600		6,400			19,000
6. MILITARY SECURITY (GUARDS, ETC.)				4,000		4,000		26,000		26,000			60,000
7 MOVING TO BARTA: LABOR ON BUILDING;								15,000				□	15,000
LOST TIME FROM WORK								15,000				□	15,000
□ SEE CHART 3													
TOTAL				$22,500		$30,000		$126,100		$51,400			$230,000

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ACTIVITY	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		CHART 2
EDUCATION AND TRAINING	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
1. REPORT EDITING AND REPRODUCING					4 SM + $1,000	$5,000*	12 SM + $5,000	$15,000	24 SM + $5,000	$24,000			$44,000
2. THESIS SUPERVISION					4	3,200	8	6,400	12	9,600			19,200
3. VISITORS					2	2,000*	7	7,000	10	12,000			21,000
4. SEMINARS FOR STAFF TRAINING. INCLUDES													
INSTRUCTION AND ATTENDANCE						1,500	18	14,400	21	14,300			30,200
5 TRAINING NEW STAFF (3 MONTHS													
EQUIVALENT EACH)					11 NEW STAFF	33,000	38 NEW STAFF	101,600	20 NEW STAFF	72,000			206,600
TOTAL						$44,700		$144,400		$131,900			$ 321,000

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ACTIVITIES	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		CHART 3
PRELIMINARY AND AIRCRAFT ANALYZER WORK	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
1. ANALOG COMPUTING METHODS	DIC 6295	$50,000		$35,700								☐	$85,700
2. SERIAL DIGITAL COMPUTER DESIGN STUDIES			50 40	65,000 23,200								☐	65,000 23,200
3. ARITHMETIC ELEMENT													
a. LAB. RESEARCH					36	$51,000*							51,000
b. BLOCK DIAGRAMS					12	8,500*	7	$3,800					12,300
c. LAB. MODEL-5 DIGIT MULTIPLIER DESIGN					30	42,700*							42,700
4. STORAGE TUBE STUDY, PRELIMINARY			27	33,800								☐	33,800
5. AIRCRAFT ANALYZER (COCKPIT & AIRCRAFT STUDY)		25,000	36	21,400	12	8,500	46	50,600				☐	105,500
TOTAL		$75,000		$179,100		$110,700		$54,400					$419,200

☐ EXPENSE FOR OPERATIONS NOT USED IN DIGITAL (PARALLEL) COMPUTER - $340,000
(SEE ALSO CHART 1)

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ACTIVITY	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		CHART 4
WWI DIRECT	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
1. ARITHMETIC ELEM. DESIGN							17	$18,700	11	$17,800			$36,500
2. CENTRAL CONTROL DESIGN							24	26,400	13	21,100			47,500
3. LIAISON WITH SYLVANIA							20	11,000	15	12,100			23,100
4. AIR CIRCULATION AND COOLING							3	3,300	2 + PURCHASE	23,200			26,500
5. POWER SUPPLIES (PURCHASE & INSTALL)							3	3,300	27 SM + $35,000	78,900			82,200
6. SYLVANIA SUB CONTRACT													
a. DESIGN								95,000		79,400			174,400
b. DRAFTING								22,000		52,000			74,000
C. PROTOTYPES								12,000		13,000	TOTAL BOTH YEARS		25,000
d. CONSTRUCTION								31,100		220,900	$558,952		252,000
e. FINAL TEST								5,200		28,300			33,500
7. CHECKING METHODS													
a. THEORY							12	6,600	5	4,100			10,700
b. DESIGN							11	12,100	15	24,300			36,400
8. CONTROL ROOM DESIGN							3	1,600					1,600
9. TEMPORARY CONTROL ROOM							3	3,300	6	9,700			13,000
10. TELETYPE IN-OUT							1	1,100*	2	3,200*			4,300
11. EASTMAN KODAK LIAISON							1	600*	2	1,600*			2,200
12. MATERIALS NOT IN ABOVE ITEMS								50,000		75,000			125,000
13. INSTALLATION							6	6,600	22	35,600			42,200
14. COMPUTER TEST									52	84,500			84,500
15 BLOCK DIAGRAMS					30	$21,200*	19	10,500	29	23,500			55,200
TOTAL						$21,200		$320,400		$808,200			$1,149,800

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ACTIVITY	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		CHART 5
SUPPORTING ENGINEERING	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
1. LABORATORY VOLTAGE REGULATION							3	$3,300	3	$4,900			$8,200
2. A-C COUPLED CIRCUITS					6	$8,500	3	3,300					11,800
3. PULSE DELAY STUDY IN LONG CONTROL CHAINS							5	5,500	3	4,900			10,400
4. CIRCUIT RESPONSE TO NON-REPETITIVE PULSE GROUPS							6	6,600	4	6,500			13,100
5. LIFE AND RELIABILITY, 5-DIGIT MULTIPLIER							12	13,200*	6	9,700			22,900
6. TEST EQUIPMENT, COORDINATED SYSTEM FOR COMPUTER RESEARCH							17	18,700	32	52,000			70,700
7. BASIC CIRCUITS							13	14,300*	18	29,200			43,500
TOTAL						$8,500		$64,900		$107,200			$180,600

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ACTIVITY	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		CHART 6
SPECIAL SUPPORTING RESEARCH	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
1. PULSE TRANSFORMERS					12	$17,000	10	$11,000	2	$ 3,200			$31,200
2. VACUUM TUBE LIFE IN PULSE CIRCUITS							7	7,700	9	14,600			22,300
3. HIGH SPEED FLIP–FLOPS					11	15,600	22	24,200	21	34,000			73,800
4. MATHEMATICS AND APPLICATIONS RESEARCH					23	16,400*	29	16,000	69	56,000			88,400
5. CRYSTAL STUDIES AND TESTING METHODS					5	7,100	3	3,300	1	1,600			12,000
6. MAGNETIC RECORDING							12	13,200*	12	19,400			32,600
7. SAMPLING SERVO THEORY							4	2,200	9	7,300			9,500
8 DATA CONVERSION, ANALOG – DIGITAL							6	6.600	11	17,800			24,400
9 VIDEO AMPLIFIER (25mc BAND) & PROBE							10	11,000	6	9,700			20,700
10 IN–OUT (MISC.)					12	17,100*	3	3,300*	8	13,000*			33,400
TOTAL						$ 73,200		$98,500		$176,600			$348,300

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ACTIVITY	JULY '44 – JUNE '45		JULY '45 – JUNE '46		JULY '46 – JUNE '47		JULY '47 – JUNE '48		JULY '48 – JUNE '49		JULY '49 – JUNE '50		CHART 7
STORAGE TUBES	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	STAFF MONTHS	COST	COST TO JUNE '49
A. TUBES													
1. TUBE CONSTRUCTION (193 TUBES, ALL TYPES TO DEC. '48					6	$8,500	23	$25,200	39	$63,300			$97,000
2. BASIC STUDIES (LIFE STORAGE BEHAVIOR)					5	7,100	7	7,700	24	38,900			53,700
3. TUBE TESTING					24	34,000	17	18,700*	33	53,600			106,300
4. TUBE DESIGN (MECHANICAL)					4	5,700	9	9,900	16	25,900			41,500
5. LAB. & PROCESSING EQUIPMENT							16	17,600	20	32,400			50,000
6. DEV. CONST TECHNIQUES					3	4,200	4	4,400	6	9,700			18,300
7. HOLDING GUNS							2	2,200	12	19,400			21,600
B. CIRCUITS													
1. DEFLECTION					6	8,500	6	6,600	6	9,700			24,800
2. OUTPUT									18	29,200			29,200
3. RELIABILITY TESTS OF TUBES									18	29,200			29,200
TOTAL						$68,000		$92,300		$311,300			$471,600

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