OPERATIONS RESEARCH & SYNTHESIS

PROJECT REPORT No. 70

MECHANIZED BUDGET SYSTEM

GENERAL ELECTRIC
AIRCRAFT GAS TURBINE DIVISION
JET ENGINE DEPARTMENT

MECHANIZED BUDGETS SYSTEM

PROJECT REPORT
NO. 70

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I ABSTRACT

This report proposes a method for the application of data processing machines to manufacturing expense budgeting. It outlines the evolution of expense budgeting within the Manufacturing Section, Jet Engine Department; the problems brought about by the decentralization of budgeting responsibility; and a data processing technique to reduce the clerical burden.

The estimating technique employs linear estimators in manpower variables to provide expense projections. The estimators are obtained by a "Least Squares" fit of historical expense data.

The mechanization of the estimating technique is accomplished by utilizing the IBM 650 computer for a solution, through matrix operations, of the "Least Squares" problem.

II INTRODUCTION

The Jet Engine Department's Manufacturing Section is an organization designed for the developmental manufacture and test of jet engines. The Section is sub-divided into eight operating sub-sections; Assembly, Parts Manufacture, Materials, Manufacturing Engineering & Process Development, Test, Administration, Quality, and Facilities Engineering. Each of these sub-sections is directed by a manager having, in general, five or more unit supervisors reporting to him. (See Appendix A, for the Section Organization Chart.)

The budgeting activity of the Manufacturing Section has been subjected to many changes in its seven years of existence. For the most part, these changes can be attributed to organizational changes brought about by decentralization and to internal adjustments caused by "growing pains" in a new business.

Decentralization brought about a greater emphasis on the delegation of budgeting responsibility. Budgeting changed, placing the responsibility for budgeting and related clerical effort on operating management. The need to reduce the burden on operating management brought about the quest for a mechanical means of budgeting. This project report is concerned with budgeting in the Manufacturing Section as it has existed in the past, the methodology of budgeting by a mechanical means, and the application of the derived system.

III MANUAL BUDGETING

A. History of Manufacturing Section Budgeting

Mechanical budgeting within the Manufacturing Section came about by a natural evolution. Just as man matures with knowledge; so the Section's budget matured from an embryonic department budget to closely controlled unit budgets. This growth in manual budgets created the environment for the development of mechanized budgets. The growth began with the first section budgets.

Prior to 1952 the organization, now known as the Manufacturing Section, did not have a formal Indirect Manufacturing Expense or Direct and Applied Labor Budget. (Hereafter referred to as IME and DAL.) The Evendale jet engine business prepared budgets which were consolidated for submission to the general office. This Manufacturing function received an allocation of funds. Budgeting responsibility was difficult to assign; thus it was almost non-existent.

In May of 1951, in preparation for decentralization, there was an interim reorganization which created Project Operation - later to become known as the Jet Engine Department. During 1952 and 1953, the interim period, the financial section prepared budgets at the department level. Budgeting during this period was conducted with a minimum of assistance from the Manufacturing Section personnel.

In December of 1953 the Jet Engine Department was created and the Manufacturing Section established. A Budgets & Measurement Unit was formed within the Manufacturing Administration Sub-Section to act as a coordinating unit for all Manufacturing Section budgets. The 1954 budgets, the first budget under the new unit's guidance, extended the preparation of budget forms to the sub-section level. The Budgets and Measurements Unit took on the task of preparing intra-section budget forms, instructing sub-section

managers in the intricacies of accounting and budgetary methods, and consolidating all sub-section budgets into a section budget.

The 1955 Manufacturing budgets were extended to the unit level. This extension required the schooling of every unit supervisor in budget preparation. Though unit budgets were prepared in 1955, reporting against unit budgets was not begun until the following year.

The 1956, 1957, and 1958 manually prepared budgets were an extension of the 1955 approach with internal manufacturing reorganizations introducing some budget modifications. The trend over the years has been for greater budgetary coverage with better exhibits and details on the sub-section and unit levels. The increased emphasis on the education of all levels of management in budgeting has been rewarding when one compares budget realizations of earlier years with those of 1956 and 1957. The increased budgetary coverage has accented the need for a mechanized budgeting system.

B. Budget Procedure

The basis for all budgets is the department estimate of gross sales. Prior to the IME and DAL budgeting activity, the Marketing Section, Engine Projects Section, and the Budgets and Measurements Sub-Section review the funding situation. From the appraisal, a prediction of the next year's department gross sales is submitted to the department general manager who sets the Department Sales Budget.

A report is prepared which described the anticipated level of effort in each of the engineering sections. Each engineering section prepares an estimate of work to be done by the Manufacturing Section. From these estimates the Manufacturing Section prepares a document called the Product Plan. The Product Plan indicates the number of sets of parts, the number of assemblies, and the engine models and their scheduled tests.

Upon completion of the Product Plan, the sub-section managers review it with their personnel, first to determine their workload and then to determine their manpower requirements. The labor accounts in the Manufacturing Section comprise approximately 80 percent of the IME and DAL expense. Extreme care must be taken not to over-estimate or under-estimate manpower since the setting of manpower will have a major influence on the level of expense.

The Manager of Manufacturing reviews each sub-section's manpower budget with the sub-section manager and if necessary requests modifications. When the section manager has approved the sub-section's manpower budget, the unit supervisors begin the preparation of their IME and DAL budgets.

The unit supervisor reviews his past expenses and relates manpower with these expenses to obtain a "feel" for his future expenses. Upon completion of this orientation, he then begins the clerical work of computing his base salaries and wages, overtime, employee benefits, telephone and telegraph, etc., and filling in the forms provided by the Measurements Unit. (See Appendix B budget forms.) This task usually takes him from one to three days with the assistance of the sub-section financial advisor.

The sub-section manager reviews each unit supervisor's budget to see if it is compatible with the anticipated sub-section business. If a unit budget is not in line it is returned to the unit supervisor for revisions and usually requires an entirely new set of budgets. When the sub-section manager is satisfied with all unit budgets, a sub-section consolidation is prepared. The sub-section budgets are forwarded to the Manufacturing Measurements Unit which audits each sub-section's budget and prepares the Section consolidation. The audit and consolidation takes approximately three days.

The consolidated IME and DAL budget is forwarded to the Section Manager for approval. The first Section budget is rarely compatible with the estimate of Department Sales; thus,

the budgets must be returned to the sub-sections for revisions. The number of revisions cannot be anticipated, but past experience has shown that more than two revisions can be expected.

Upon approval of the Section budget, it is forwarded to the Department Budgets and Measurements Sub-Section for a Department consolidation. Further revisions can be expected at this level.

The preceding outlines the current procedure for the preparation of IME and DAL manual budgets and is included here to enable the reader to have a better understanding of budgeting for the Manufacturing Section.

IV MECHANIZED BUDGETING

A. Conditions and Limitations

As in any mechanization, there were two conditions which had to be satisfied to justify and allow for the mechanization of budgets. First, there had to be a need for mechanizing the process; second, the process had to be adaptable to mechanization.

The first of these conditions was present. The great quantity of repetitive clerical effort necessary to produce the budget provided the stimulus to reduce the burden. Another factor indicating a need for mechanization was the excessive time spent by all levels of management in constructing a realistic budget.

The second of these conditions was the most difficult to recognize. There was data processing equipment available for use. The difficulty was converting the machine's potential into a working system for the production of budgets. The conversion would require that there be a data processing system devised which would standardize the clerical operations, be repetitive in its operational cycles, and yield acceptable output.

In addition to the basic considerations there were also certain project limitations which would effect the ultimate selection of a system. One of the major limitations was time. For the system to be of immediate value, the project had to be completed before the end of 1957. The commitment to a specific completion date required that certain short cut methods would have to be employed wherever possible and the scope of budgeting be limited.

A further limitation was the state of the raw data to be used in the study. The data contained in the manpower and accounting reports were in the form required for operating management's use and not in that form required for this project. Conversion of the data to a useful form was essential to the completion of this project.

B. Problem Definition

It became evident in the project's planning stage that the development of a mechanized budgeting system could best be approached as two different problems. One problem was to arrive at a method of estimating, the other, a means of estimating. The two problems were entirely different in work content. The first was a study directed toward the discovery of relationships existing in historical data which would allow inductive inference, the second was a study to determine if the available equipment was adaptable to budget preparation. The overall problem was one of the continuous integration of these two efforts.

C. Budget Estimator Study

1. Study Description

As previously stated, one objective of the project was to investigate the possibilities of, and the methods for, predicting expense dollars by account. It was believed that certain relationships did exist, could be ascertained, and were of such a nature as to allow the prediction of future expenses. The pursuit of this belief was referred to as the Budget Estimator Study. The Study encompassed: (1) an analysis of the basic data, (2) the constructing of a mathematical model, (3) the application of the mathematical model to fit the overall project requirements, and (4) an analysis of the output.

2. Basic Data and Analysis

The basic data consisted of monthly Indirect Manufacturing Expense Reports, Direct & Applied Labor Reports, and Manpower Reports. It was decided that data prior to 1954 should be deleted from the analysis because of its incomplete condition. A major task was gathering the data and putting it in a form which would be convenient for analysis. The reporting structure had changed from year to year. The forms

and the account structure had been changed and modified during the period selected for observation. In addition, the bulky and unwieldy nature of the reports was not conducive to analysis. Observing one account over a period of a year was difficult and costly in time.

To overcome this handicap, a Basic Data Sheet was designed. (See Appendix C). This sheet provided the observer with two years of data in a form that could be conveniently analyzed. That which had formerly been on twenty-four sheets, was now on one.

The Basic Data Sheet enabled the recasting of accounts and manpower records into compatible form. The structure of manpower classifications was not stable. For example, maintenance men were at one period considered overhead labor and the following year reclassified as direct labor. This type of change affected the manpower, IME and DAL reports. In order to make the basic data compatible for analysis, 1954, 1955 and 1956 data were recast in the 1957 report structure.

3. Mathematical Model

The objective of constructing a mathematical model was to formulate those relationships which would enable the estimation of labor and material accounts and, at the same time, satisfy the conditions for mechanization.

a) Labor Accounts

It can safely be assumed that the total wages paid in a given period are equivalent to the sum of the individual payments made in that period. Let the amount paid to individual i in manpower category j (hourly, salaried, exempt, etc.) be p_{ij}. Total wages W_t for period t, where x_{tj} is the number of men in category j for r categories, can be expressed:

$$W_t = \sum_{j=1}^{r} \sum_{i=1}^{x_{tj}} p_{ij} \qquad (1)$$

The mean or average rate of payment in class j, denoted by a_j, is then defined by the relation;

$$\sum_{i=1}^{x_{tj}} p_{ij} = x_{tj}\, a_j \qquad (2)$$

Using this definition, (1) becomes:

$$W_t = \sum_{j=1}^{r} a_j\, x_{tj} \qquad (3)$$

If we estimate a_j, (3) provides a linear form for estimating wages, W_t, from the manpower by categories, x_{tj}. The problem is thus reduced to that of determining whether the a_j's are sufficiently stable, historically, to be estimated. This is taken up in Sections 4 and 5 following.

b) Material Accounts

The term material is used to designate those accounts which are not pure labor. Examples of material accounts are telephone expense, IBM rental expense, employee transfer expense, etc. In order to estimate material accounts from a simple relation, as in the case of wages, it had to be determined whether expenditures of some material accounts also varied closely with manpower. If so, then for budget estimating purposes, total expenditure could be considered uniformly distributed among the men.

An analysis similar to that in section (a) would yield, as in the labor accounts, a linear form of the type:

$$M_t = \sum_{j=1}^{r} a_j x_{tj} \tag{4}$$

where a_j now represents the average amount of expense per man in category j.

c) General Estimator Form

If the foregoing method of estimating is found to be satisfactory, the conditions of mechanization are satisfied. A single linear form can be employed on all accounts where practicable. By letting b_t be the budget item for the monthly period t, a_j the average rate of expense per man in a manpower classification j, and x_{tj} the number of men in classification j for month t, the general form becomes:

$$b_t = \sum_{j=1}^{r} a_j x_{tj} \tag{5}$$

In those accounts defying relation to a convenient variable, or those accounts of a fixed nature, an average expense will be used. If now we let a_k denote this expense, the estimate can be expressed in the general form;

$$b_t = a_k \tag{6}$$

where any one variable is held fixed (with value one) and the others are eliminated (with value zero).

The general formula relates only to one account for one month. To cover all accounts for the sub-section and section for the entire year the notation is expanded;

$$b_{t,m,n,} = \sum_{j} a_{j,m,n,} x_{t,j,n} \tag{7}$$

where m refers to account and n the sub-section for month t. The sub-section and section budgets are as follows:

$$B_{m,n} = \sum_{t} b_{t,m,n} \tag{8}$$

the annual expenditures for item m in sub-section n,

$$B_{m} = \sum_{n} B_{m,n,} = \sum_{n} \sum_{t} b_{t,m,n} \tag{9}$$

the annual expenditures in item m for the section, and

$$B = \sum_{m} B_{m} = \sum_{m} \sum_{n} \sum_{t} b_{t,m,n} \tag{10}$$

the annual expenditures in all items for the section.

The mathematical model is based on the assumption of linearity, within a given range, between the dependent variable expenditures and the manpower variables. With this condition the problem remained to select the method of estimating the actual relations that existed in the data. The best known, and the one that would best lend itself to mechanization, was the method of "Least Squares." The selection was sound in that it would permit for future multiple regression analysis, when time permitted and when further study of the parameters of estimating would be desired. (See Appendix D for the mathematics of "Least Squares" method.)

4. Application of the Mathematical Model

The application of the theoretical mathematical model to form the actual system required the selection of the scope of budgeting, the selection of independent variables, and the selection of representative data. The selection of the scope of budgeting entailed the determination of the type of expenses to be mechanized. The selection of the independent variables was the determination of which manpower categories

were best related to the expense. The selection of representative data required the choice of the period of time upon which the estimator would be based.

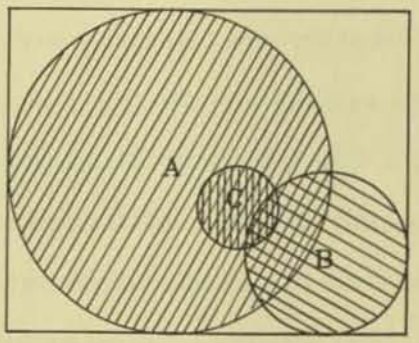
a) Selecting Scope

The decision as to which of the budgeting areas would be mechanized first was not difficult. Indirect Manufacturing Expense and Direct and Applied Labor were chosen for the following reasons:

(i) Of the total dollars budgeted for labor and overhead in the Manufacturing Section, approximately seventy per cent is IME and twenty-six per cent is DAL not chargeable to IME. The sum of IME and DAL, therefore, comprise ninety-six per cent of budgeted labor and overhead.

The Venn Diagram, see Figure 1, shows the relative proportion of section budgets that would be included by selecting IME and DAL for the scope of the mathematical model. It also illustrates the relationships of IME to DAL. IME (A) intersects with DAL (B); since (A) cannot be selected without considering (B), and vice versa, both should be selected.

Figure 1



A : Total IME

B : Gross DAL

C : Appropriated IME

It further illustrates that Appropriated IME (C), although random in nature from year to year, is included in IME (A) and intersects with DAL (B), and by necessity must also be provided for in the mathematical model.

(ii) The scope was limited by the time available for producing a 1958 test budget. By limiting the scope, it would afford a concentrated effort in the chosen areas of IME and DAL budgets.

(iii) The burden of clerical and managerial effort expended on the preparation of the entire Manufacturing Section budgets was in the area of IME expenditures. Since reduction of this burden was the prime objective of the project, it was logical that this factor be given first consideration.

(iv) The basic data were available and adaptable for analysis. By choosing an area of budgeting where the basic data were readily available, the time for collecting data was reduced.

b) Selecting Independent Variables

Manpower categories, defined by department policy, limited the use of data for independent variables. The manpower categories were consistent for the period of observation. They were:

(i) IME Exempt Manpower
(ii) IME Salaried Manpower
(iii) IME Hourly Manpower
(iv) Direct Hourly Manpower
(v) Direct Salaried Manpower

This introduced the possibility of forming thirty-one different combinations of one or more of the five variables. The magnitude of the problem can be appreciated when

one considers the possibility of matching any of these thirty-one combinations with approximately 20 different accounts, for all sub-sections. The inclusion of additional variables such as total IME manpower, total direct labor manpower, and total section manpower further increases the selective possibilities.

Time did not allow for an exhaustive study in the area of variable selection and intuitive shortcuts had to be employed. Examples of some of the intuitive judgments made were that:

(i) Traveling and Living Expenditures are linearly related to IME exempt manpower,

(ii) IME Base Salaries and Wages are linearly related to IME Manpower categories,

(iii) Employee Benefits Expenditures are linearly related to Manpower categories,

(iv) Utilities, although bookings are made to one of the eight sub-sections, are linearly related to all categories of the Manufacturing Manpower.

A battery of tests were run using different intuitive combinations of independent variables. (These tests were also used to "debug" the computer programs). It was found that if more than one variable of the type defined above was used, the test results, on the whole, had poor correlation with the control data. This phenomenon was attributed to the state of the data. Single variable estimators using combined samples of the original manpower data were chosen for the 1958 Test Budget to control the effect of erratic fluctuations while leaving natural patterns undisturbed. The actual independent variables selected for the final 1958 Test Budget were as

shown in Figure 2.

Admittedly, the use of these variables was an expediency, but it must be emphasized that the purpose of this study was to provide management with immediate assistance in budgeting.

c) Selecting Representative Data

Previous analyses of the basic data had revealed characteristics that would obviously have to be considered in the selection of the basic data. Great care would have to be taken to make certain that misrepresentative data would not negate true relationships.

Manpower reports had a fallacy that had to be corrected if more accurate relationships were to be found in the future. The manpower reports reflected the manpower at one point in time at the end of the fiscal month, causing variations in manpower-expenditure relationships.

For this project the selection of the dependent variable base period, by necessity, dictated the comparable selection of the independent variables.

The mechanization process required the data to cover a uniform base period. A decision had to be made whether the base period would cover one or more years' data. Cursory analysis of earlier years' data indicated a lack of continuity in the variables. Economic and administrative changes caused a disturbance in the correlations if the base period was not the annual period immediately preceding the estimating period. Most administrative changes had been instituted annually at budget time and would thus minimize the recasting.

Figure 2

1958 Test Budget Variables

CODE:

X_1 = Total Direct Labor Manpower
X_2 = Constant One
X_3 = Total IME Manpower
X_4 = Total Sub-Section Manpower (IME & DAL)
X_5 = Zero or Total Section Manpower (IME & DAL)
Q_1 = New 1958 Accounts
Q_2 = Did Not Incur Expense in 1957

Account \ Sub-Section	Assembly	Parts	Materials	Mfg. Engrg.	Test	Admin.	Quality	Fac. Engrg.
Direct Labor	X_1	X_1	Q_2	Q_2	X_1	Q_2	X_1	X_1
IME Base Salaries	X_3	X_3	X_3	X_3	X_3	X_3	X_3	X_3
DAL O.T. Prem.	X_1	X_1	Q_2	Q_2	X_1	Q_2	X_1	X_1
IME O.T. Prem.	X_3	X_3	X_3	X_3	X_3	X_3	X_3	X_3
Non Prod. Labor	X_1	X_1	Q_2	Q_2	X_1	Q_2	X_1	X_1
Training	X_1	X_1	Q_2	Q_2	X_1	Q_2	X_1	X_1
Employee Benefits	X_4	X_4	X_4	X_4	X_4	X_4	X_4	X_4
Other Pay Prem.	X_4	X_4	X_4	Q_2	X_4	Q_2	X_4	X_4
Tools & Supplies	X_4	X_4	X_4	X_4	X_4	X_4	X_4	X_4
Office Supplies	Q_1	Q_1	Q_1	Q_1	Q_1	Q_1	Q_1	Q_1
Maintenance	Q_2	Q_2	Q_2	Q_2	X_4	Q_2	Q_2	X_4
Appropriated	Q_1	Q_1	Q_1	Q_1	Q_1	Q_1	Q_1	Q_1
Utilities	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	X_5
Data Processing	X_2	X_2	Q_2	Q_2	X_2	X_2	X_2	X_2
Employee Ed.	Q_2	Q_2	Q_2	Q_2	Q_2	X_5	Q_2	Q_2
Rearrangement	Q_2	Q_2	Q_2	Q_2	X_2	Q_2	Q_2	X_5
Telephone	X_3	X_3	X_3	X_3	X_3	X_3	X_3	X_3
Travel & Living	X_3	X_3	X_3	X_3	X_3	X_3	X_3	X_3
Other Misc. Cont.	X_2	X_2	X_2	X_2	X_2	X_2	X_2	X_2
Rent	Q_1	Q_1	Q_1	Q_2	Q_2	Q_1	Q_1	Q_1
Tax & Insurance	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_1
Depr. & Amort.	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_1
Gen. Co. Asses.	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2
A.S.D. Asses.	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2
AGTD Asses.	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2
Other Assess.	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_2	Q_1
Expense Credits	Q_2	Q_2	X_2	Q_2	X_2	Q_2	X_2	X_2

5. Analysis of Estimator Output

The objective of the estimator study was to devise a method of predicting future expenditures by searching historical data for expenditure patterns. Obviously, the success of the study would be reflected in the accuracy of the predictions.

The method used to determine the acceptability was a series of tests using 1954, 1955, 1956 data. By using actual manpower of the year to be estimated and the prior year actual expenses, it was possible to simulate conditions of future budget estimators. The accuracy of the output could then be compared with actual expenses to determine the accuracy of the predictions. The final test was run based on 1957 actual expenses using the 1958 budget as a control. Comparisons for this test would be made initially against the manual budget and later, as the reports were made available, against actual 1958 expenditures.

The use of prior year expenses to derive coefficients does not take into consideration the economic and administrative changes that could occur in the coming year. For purposes of this project, economic and administrative changes are defined as "those changes in the cost of doing business which are explainable deviations from past performance." Examples of these type changes are:

1. Increases or decreases in the Labor Accounts resulting from Productivity Increases, Cost of Living Increases, Merit Increases, etc.

2. Increases or decreases in Material Accounts resulting from changes in market price, etc.

3. Increases or decreases to both Labor and Material Accounts resulting from reorganizations, changes in billing or assessment routines, changes in account structure, etc.

Adjustments are required to reflect the changes upward or downward in expenses that the economic or administration changes would affect. Budget responsibility, so necessary to a controlled budget, is retained by requiring the sub-section manager to provide these economic and administrative changes.

In practice, the first mechanized budget is a projection of the prior year level of expense using the coming year estimated manpower. The manager then makes an intuitive evaluation of the economic and administrative conditions for the coming year.

The managers intuitive evaluation is expressed as a percentage increase or decrease from the unadjusted budget run or as a specific monthly dollar substitution for each account to be adjusted. Percentages are used if there is agreement with the rate of expenditure but a higher or lower level of expenditure is desired. (e.g. 5% increase in the labor account for anticipated average wage increases.) Dollar substitutions or additions are used when there is a lack of agreement with the rate, level, and/or distribution of expenditures between sub-sections or there is no previous historical data (e.g. a change in accounting procedure billing assessments not previously billed to the Section).

The manager's intuitive evaluation requires, in most cases, from 15 to 30 minutes to complete the form, Figure 3. These modifications to the unadjusted budget are applied to the adjusted budget by a computer multiplication in cases of percentage adjustments and by substitution or addition to the unadjusted budget in cases of specific dollar changes.

Figure 4 is a comparison sheet of the final 1958 Section Mechanized Budget. (Comparisons for each sub-section are included as Appendix E.) The first, (1), column of data indicates the amounts budgeted manually for 1958. The second column, (2), is the amounts arrived at by mechanized means using 1957 as the base period and 1958

Figure 3

MECH. BUDGET ECONOMIC & ADMINISTRATIVE CHANGES

Sub-Section _____ By _____ Date _____

ACCT. NO.	ACCOUNT TITLE	PER CENT INCREASE OR DECREASE	MONTHLY DOLLAR SUBSTITUTIONS OR ADDITIONS											
			JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
199	OVERHEAD SALARIES													
211	O. T. PREM. - DAL													
213	O. T. PREM. - OTHER													
230	NON-PRODUCTIVE LABOR													
240	TRAINING													
270	OTHER PREMIUMS													
399	EMPLOYEE BENEFITS													
421	TOOLS & SHOP SUPPLIES													
422	OFFICE SUPPLIES													
445	MAINTENANCE													
449	APPROPRIATED EXP.													
459	UTILITIES													
464	ADVERTISING & PUBLIC													
468	DATA PROCESSING													
472	EMPL. EDUCATION													
473	REARRANGEMENTS													
478	TELEPHONE & TEL.													
481	TRAVEL & LIVING													
482	EMPLOYEE TRANSFERS													
499	OTHER MISL. CONT. EXP.													
519	RENT													
529	TAXES & INSURANCE													
549	DEPRECIATION & AMORT.													
710	GEN. CO. ASSESSMENTS													
720	A. S. D. ASSESSMENTS													
731	A. G. T. D. ASSESSMENTS													
749	OTHER ASSESSMENTS													
799	EXPENSE CREDITS													

Figure 4

MANUFACTURING SECTION

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
	(1)	(2)	(3)	(4)	(5)
OVERHEAD SALARIES	5891	5472	- 7	5960	+ 1
O.T. PREM. - DAL	84	257	+206	142	+69
O.T. PREM. - OTHER	78	140	+ 79	97	+26
NON-PRODUCTIVE LABOR	110	152	+ 38	152	+38
TRAINING	221	270	+ 22	270	+22
OTHER PREMIUMS	863	833	- 3	875	+ 1
EMPLOYEE BENEFITS	1209	1060	- 12	1167	- 5
*TOOLS & SHOP SUPPLIES	807	{		791	- 2
*OFFICE SUPPLIES	335	{ 905	- 26	335	+ 9
MAINTENANCE	637	787	+ 24	709	+11
**APPROPRIATED EXPENSE	922			922	0
UTILITIES	1000	931	+ 7	931	- 7
DATA PROCESSING	116	30	- 74	89	-25
EMPLOYEE EDUCATION	109	81	- 26	83	-26
REARRANGEMENTS	148	133	- 10	133	-10
TELEPHONE & TELEGRAPH	145	149	+ 3	149	+ 3
TRAVEL & LIVING	146	152	+ 4	152	+ 4
**EMPLOYEE TRANSFERS					
OTHER MISL. CONT. EXP.	307	376	+ 22	295	- 4
TOTAL CONTROL EXP.	13132	11728	- 11	13252	+ 1
***RENT	88	{ 1381	- 14	87	0
***TAXES & INSURANCE	165	{		165	0
***DEPRECIATION & AMORT.	1333	{		1333	0
**OTHER ASSESSMENTS	200			200	0
GROSS EXPENSE	14918	13109	- 12	15037	+ 1
EXPENSE CREDITS	1307	1411	+ 8	1373	+ 5
NET EXPENSE	13611	11698	- 14	13664	+ 1
DIRECT & APPLIED LABOR	4251	4196	- 1	4196	- 1
TOTAL IME & DAL	17862	15894	- 11	17860	0

* Reported as one account in 1957.

** New accounts for 1958.

*** Reported as "Fixed Expenses" in 1957.

estimated manpower as the independent variables. The fourth column, (4), differs from the second column in that economic and administrative changes have been included.

The current success of the estimating method is evidenced by the per cent of variation from the manual budget. The true measure of success can be established during 1958 by a comparison with actual expenses.

D. Machine Applications

The success of the Mechanized Budget Project was to be measured by the degree to which clerical effort could be reduced and the accuracy of its predictions. The results of the budget estimator study could be used to advantage in the manual preparation of budgets. In order to have a mechanized system, it was necessary to apply data processing equipment. The mechanization phase of the project can be presented in three steps: (1) a preliminary study to determine the feasibility of mechanization from an equipment and technique standpoint, (2) the adaptation of the Mathematical Model to the data processing system, and (3) the programming required to make the system operational.

1. Study of Feasibility

The study conducted to determine feasibility was begun many months in advance of the project. The idea was conceived at the time the Jet Engine Department introduced electronic data processing. The problem was discussed with an IBM representative and he indicated confidence that a mechanized budget could be devised.

This portion of the project became active in May 1957 when a meeting was held with the Jet Engine Department Data Processing personnel. Discussions relative to the system to be devised, the machine capabilities, and the availability of programs and

programmers provided the basis for discrete steps to be taken toward the development of a mechanized process.

The mechanized process would require the utilization of the 650 computer and auxiliary equipment for computation along with machines for keypunching, reproducing, sorting, and tabulating. Scheduling of the 650 was critical. The project required high utilization and the current load left only a minimum of surplus capacity. Agreements were made with Data Processing to sandwich operating time in between their periods of high utilization. Additional time could be obtained by using the machine during the second shift when, for the most part, it was not scheduled. The machines other than 650 were available on demand. It was also agreed that Operations Research & Synthesis personnel would operate the machines because of the developmental nature of the work.

The next problem was to determine how a working program would be obtained that could be applied to the available equipment. The desire was to minimize the programming cost while maximizing the use of existing programs. After a series of discussions with IBM Applied Science Representatives, there seemed to be four alternative approaches. These were (1) utilize the programming and services of the Flight Propulsion Laboratory 704 Computer organization, (2) employ, with modification, the IBM 650 Library Programs for Multiple Linear Least Squares Curve Fitting, or regression analysis, (3) self-program the entire 650 computer application, and (4) integrate IBM Library Sub-Routines into a self-programmed 650 Computer Application.

The first of the alternatives was rejected due to the excessive cost for rental of a 704 Computer. The second was rejected on the advice of the Applied Science Representative, who anticipated difficulty in using this "canned" program. The third alternative was rejected in that it did not take advantage of the available programming resources.

The last of these alternatives was chosen for two reasons. First, an agreement with IBM made available an experienced programmer who could assist in solving programming difficulties; second, this agreement made it economically feasible and technically possible to organize a working program of IBM Sub-Routines.

The programming began with the selection of Sub-Routines and the outlining of supplemental programming that would perform the necessary mathematics. (See Appendix F.)

2. Programming and Operation

The complete cycle of mechanized budget operation can be best understood by referring to the flow chart, Figure 5. The areas within the dotted lines details computer operation by pass and can be related to the explanation to follow.

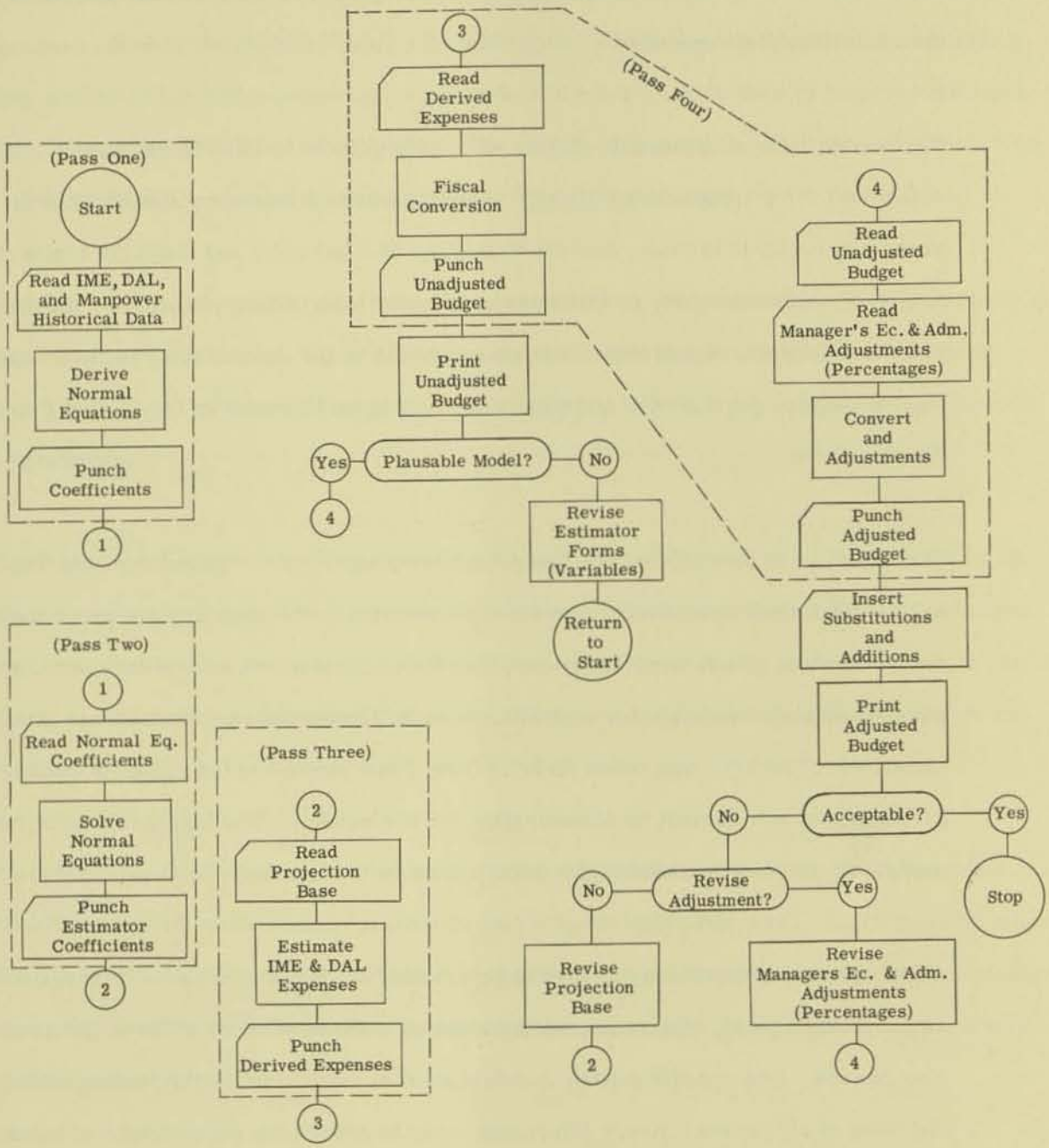
The complete program for deriving the estimators and evaluating the estimators involves four distinct phases and computer passes. The organization is dictated by the nature of the Library Programs utilized.

In Pass One (See Appendix G for program description) the observed data must be loaded, converted to floating decimal form, adjusted for calendar variations, and placed in the proper location and form dictated by the matrix multiplication subroutine. The loading program was designed to include many identification codes and checks to insure valid results. The Library Routine was modified to preserve this identification and prepare the output for the next operation. This pass produced the coefficients of the normal equations.

The output of Pass One (See Appendix H for program description) feeds directly into Pass Two. The input must be identified and located for inversion as dictated by the

Figure 5

MECHANIZED BUDGET OPERATION



matrix inversion sub-routine. Minor changes in this library program modified the output and again preserved identification. The selected output included only identification and the vector of "Least Squares" coefficients in a form readily adaptable to the evaluation of estimators.

The matrix multiplication sub-routine was again utilized in Pass Three (See Appendix I for program description) the evaluation of estimators. A loading program was required to read, convert to floating decimal form and properly locate the manpower projection base preparatory to a vector matrix multiplication by the derived coefficients. Again identification was added to the normal sub-routine's output. This pass provided the monthly estimated expenditures in an unadjusted floating decimal form.

The objective of Pass Four (See Appendix J for program description) was the conversion of budget expenditures into fixed decimal form and their adjustment to calendar variations. Each output card contained the current month expenditure and the year-to-date accumulation for a given account in a given sub-section and was so identified. The input was taken directly from Pass Three and the output is ready for listing by sub-section or accumulation for the section. The manager's intuitive modifications were included in the fiscal adjustment process.

All of the programs were optimized and condensed to "seven per card" form. A single control panel, with minor wiring changes between passes, suffices for all four passes. One console setting is established to accommodate the loading and checking of all passes. Every effort was made to reduce the consumption of valuable computer time.

V RECOMMENDATIONS AND CONCLUSIONS

The development of a system for mechanical IME & DAL budgeting has been completed and has been given to the Manufacturing Administration, Measurements Unit, for its operation. The system is not self-sustaining. A great deal of work must be done to improve the input data, to test the reliability of the predictions, and to optimize the operating technique. The following recommendations are offered to the operating personnel.

Current manpower reports reflect the manpower count at one point in time, approximately at the end of the fiscal month. It is recommended that reporting be changed to a four point monthly average. This would provide a more realistic base for determining manpower-cost relationships.

The cost reporting structure must be standardized and stabilized to allow for studies of the behavior of the accounts over longer periods of time. If the reporting structure is changed, the data to be used as the base period should be revised immediately while the changes can be easily ascertained. Accounting adjustments affecting prior months' data should also be re-cast immediately.

The search must be continued for more sensitive independent variables. Variables other than manpower should be tested for possible inclusion in the estimator form. Care must be taken that changes in the economy do not affect the predicting accuracy of the independent variables now being used. Every effort must be directed to the investigation of a system using a multi-variable selection pattern.

Correlation and regression analysis necessary for the establishment of statistical controls has not been completed at this time. It is suspected that such analysis would reveal behavioristic manpower-cost relationships that would be helpful in future budgeting.

Further testing, by making simulated budget runs, is essential to the successful operation of the system. Improper usage of the system producing inaccurate budgets will negate present managerial confidence and lead to its complete rejection.

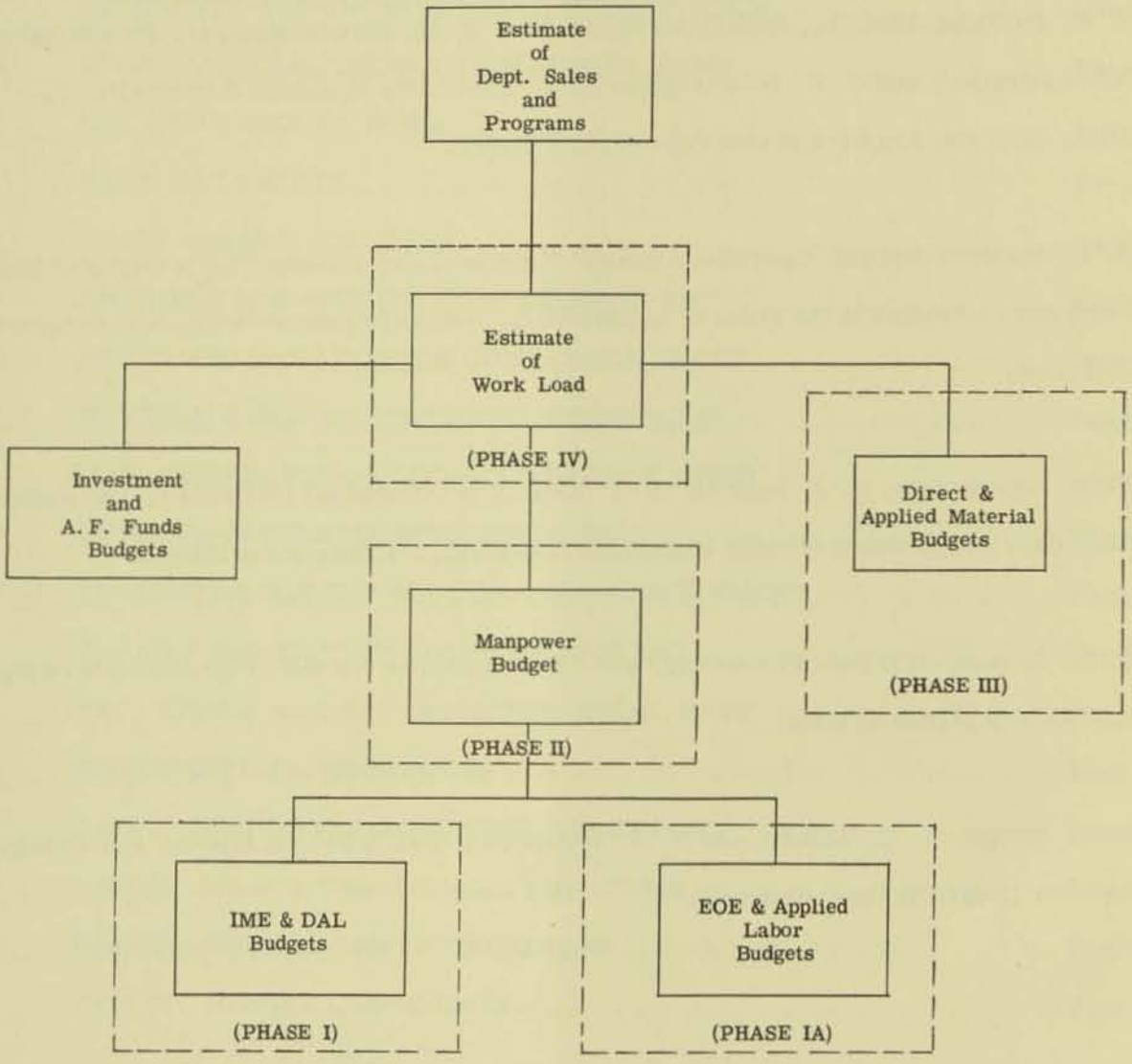
This project has been considered as Phase I of the complete mechanization of the Manufacturing Section's budgets. Figure 6 provides the recommended sequence of future research projects. Phase IA, Engineering Operating Expense & Applied Labor Budgets, can be instituted as soon as more historical data becomes available. Work already completed on the Manager Performance Measurement System Project makes Mechanized Manpower budgets, Phase II, and Direct and Applied Material Budgets, Phase III, practicable. Phase IV, Estimate of Workload, derived from the Department Sales and Engine Program estimates can also be mechanized. Investment and Air Force Funds Budgets are included here to complete the scope of Manufacturing Section budgeting but are doubtful areas for future budget mechanization due to their randomness from year to year.

In conclusion, this project has provided the bases for collecting and maintaining data, a method for predicting IME and DAL dollars, and a mechanical means of producing budgets. These methods have reduced the time for preparing IME and DAL budgets from an operation that has taken days to a system that takes hours. It has added a flexibility previously unknown to the Manufacturing Section budgeting; IME and DAL budget revisions can be completed in eight hours, variable budgets can be made operational, and forecasts can be made more realistically.

Figure 6

RECOMMENDED EXPANSION

OF MECHANIZED BUDGETS & ESTIMATES



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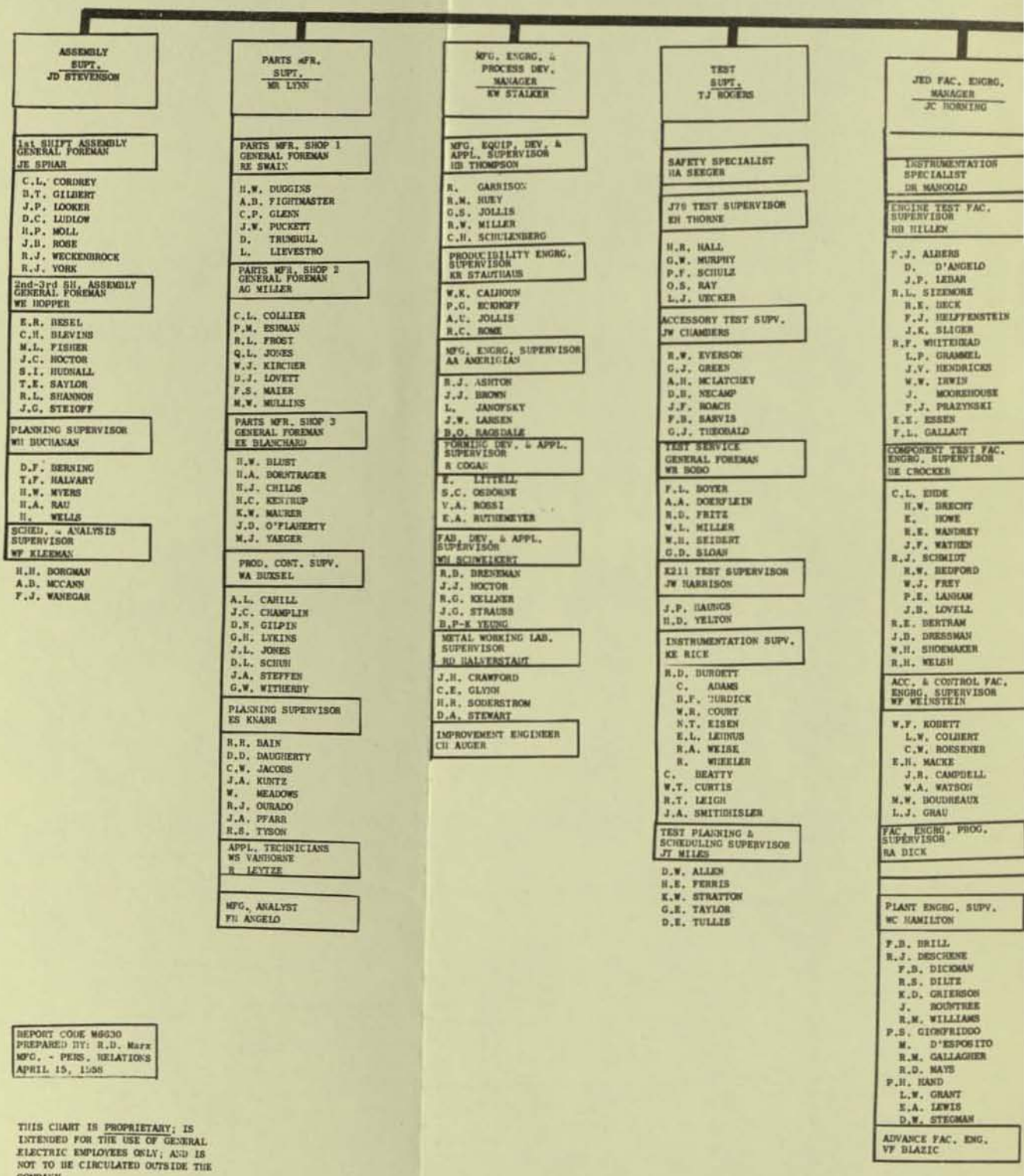
E. H. Martin, G. E. Walker, and N. L. Nordeen for their editorial efforts, and Marilyn Groh for preparing the manuscript.

VII APPENDICES

APPENDIX A



REPORT CODE M6G30
PREPARED BY: R.D. Marx
MFG. - PERS. RELATIONS
APRIL 15, 1958

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APPENDIX B1

SCHEDULE A
EXHIBIT 1

JET ENGINE DEPARTMENT
MANUFACTURING SECTION
MANPOWER AND GROSS PAYROLL
1958 BUDGET

DATE _____

CLASSIFICATION	TYPE FUNDS	NUMBER OF EMPLOYEES AT END OF MO.												AV. NO. EMP. 12 pts. (2)	AV. NIGHT SHIFT EMP. (3)
		D'57 (1)	J	F	M	A	M	J	J	A	S	O	N	D	
EXEMPT SALARIED															
APPLIED															
1. TECHNICAL ENG.	E.C.E.														
2. OTHER APPLIED	E.C.E.														
UNAPPLIED															
3. TECHNICAL ENG.	E.C.E.														
4. TECHNICAL ENG.	I.M.E.														
5. OTHER UNAPPLIED	E.C.E.														
6. OTHER UNAPPLIED	I.M.E.														
TOTAL															
NON-EXEMPT SALARIED															
APPLIED															
7. ENGINEERING ASSIST.	E.C.E.														
8. OTHER APPLIED	E.C.E.														
9. DIRECT & APPLIED	D.A.L.														
10. UNAPPLIED	E.C.E.														
11. UNAPPLIED	I.M.E.														
TOTAL															
HOURLY															
12. DIRECT & APPLIED	D.A.L.														
13. INDIRECT	I.M.E.														
TOTAL															
14. TOTAL E.C.E.	E.C.E.														
15. TOTAL I.M.E.	I.M.E.														
16. TOTAL D.A.L.	D.A.L.														
GRAND TOTAL															

SUB-SECTION _____ BY _____

UNIT _____ APPROVED _____

(AMOUNTS IN DOLLARS)												
AV. YRLY. RATE (4)	TOT. BASE PAY (5)	N.S.B. ON BASE PAY (6)	BASE OVERTIME			N.S.B. IN BASE O.T.			TOTAL O.T. PREM. (13)	N.S.B. ON O.T. PREM. (14)	GROSS PAY-ROLL (15)
			TIME PLUS 1/2 (7)	DOUBLE TIME (8)	TOTAL (9)	TIME PLUS 1/2 (10)	DOUBLE TIME (11)	TOTAL (12)			
/											
/											
/											
/											
/											
/											
/											

APPENDIX B2

SCHEDULE A
EXHIBIT II

JET ENGINE DEPARTMENT
MANUFACTURING SECTION
GROSS PAYROLL DISTRIBUTION
1958 BUDGET

DATE _____

(AMOU

CLASSIFICATION	TYPE FUNDS	GROSS PAY-ROLL (16)	I.M.E. AND E				
			TOTAL O.T. 211 & 213 PREMIUM (17)	OTHER P.R.P. 270		NON-PROD. LABOR 230 (20)	TRAINING 240 (21)
				TOT. N.S. BONUS (18)	SHOP VA. & O.P.A. (19)		
EXEMPT SALARIED							
APPLIED							
1. TECHNICAL ENG.	E.C.E.						
2. OTHER APPLIED	E.C.E.						
UNAPPLIED							
3. TECHNICAL ENG.	E.C.E.						
4. TECHNICAL ENG.	I.M.E.						
5. OTHER UNAPPLIED	E.C.E.						
6. OTHER UNAPPLIED	I.M.E.						
TOTAL							
NON-EXEMPT SALARIED							
APPLIED							
7. ENGINEERING ASSIST.	E.C.E.						
8. OTHER APPLIED	E.C.E.						
9. DIRECT & APPLIED	D.A.L.						
10. UNAPPLIED	E.C.E.						
11. UNAPPLIED	I.M.E.						
TOTAL							
HOURLY							
12. DIRECT & APPLIED	D.A.L.						
13. INDIRECT	I.M.E.						
TOTAL							
14. TOTAL E.C.E.	E.C.E.						
15. TOTAL I.M.E.	I.M.E.						
16. TOTAL D.A.L.	D.A.L.						
GRAND TOTAL							

SUB-SECTION ______________________ BY ______________________

UNIT ______________________ APPROVED ______________________

NTS IN DOLLARS)

O.E.			D.A.L.	E.C.E. APPLIED LABOR				
CHARGED TO MIXED ACCOUNTS (22)	OVERHEAD SALARIES ACCT. 199 (23)	TOTAL OVERHEAD LABOR (24)	(25)	D. A. (26)	C.P.F.F. (27)	I.M.E. (28)	INVESTMENT (29)	A. F. FUNDS (30)

SCHEDULE B
EXHIBIT I OR II
UNIT OR SUB-SECT. NO._____
DATE _____

APPENDIX B3

JET ENGINE
MANUFACTUR
TYPE OF FUNDS: _
1958

ACCT NO.	ACCOUNT TITLE	(AMONTS IN DO						
		JAN	FEB	MAR	APR	MAY	JUNE	
199	OVERHEAD SALARIES							
211	O.T. PREM.-DAL							
213	O.T. PREM.-OTHER							
230	NON-PRODUCTIVE LABOR							
240	TRAINING							
270	OTHER PREMIUMS							
399	EMPLOYEE BENIFITS							
421	TOOLS & SHOP SUPPLIES							
422	OFFICE SUPPLIES							
445	MAINTENANCE							
449	APPROPRIATED EXP.							
459	UTILITIES							
464	ADVERTISING & PUBLIC.							
468	DATA PROCESSING							
472	EMPL. EDUCATION							
473	REARRANGEMENTS							
478	TELEPHONE & TEL.							
481	TRAVEL & LIVING							
482	EMPLOYEE TRANSFERS							
499	OTHER MISL. CONT. EXP.							
	TOTAL CONTROL EXP.							
519	RENT							
529	TAXES & INSURANCE							
549	DEPRECIATION & AMORT.							
710	GEN. CO. ASSESSMENTS							
720	A.S.D. ASSESSMENTS							
731	A.G.T.D. ASSESSMENTS							
749	OTHER ASSESSMENTS							
	GROSS EXPENSE							
799	EXPENSE CREDITS							
	NET EXPENSE							
	E.C.E. APPLIED LABOR							
	DIRECT & APPLIED LABOR							
	OVERHEAD RATE							

: DEPARTMENT
RING SECTION

SUB SECTION _____ BY _____

UNIT _____ APPROVED _____

BUDGET

(LLARS BY MONTHS)

JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL	BASIS FOR CALCULATING EXPENSE
							SCHEDULE A, EXHIBIT II COLUMN 23, LINE 14 OR 15
							SCHEDULE A, EXHIBIT II, COLUMN 17, LINE 16
							SCHEDULE A, EXHIBIT II, COLUMN 17, LINE 14 OR 15
							SCHEDULE A, EXHIBIT II, COLUMN 20, LINE 16
							SCHEDULE A, EXHIBIT II, COLUMN 21, LINE 16
							SCHEDULE A, EXHIBIT II, COLUMN 18, + COLUMN 19, LINE 15 + LINE 16 OR COL.18 LINE M
							10% OF SCHEDULE A, EXHIBIT II COLUMN 16 LINE 14 OR 15 + 16
							SCHEDULE B, EXHIBIT a
							SCHEDULE B, EXHIBIT b
							SCHEDULE B, EXHIBIT c
							SCHEDULE F, EXHIBIT II
							SCHEDULE B, EXHIBIT d
							SCHEDULE B, EXHIBIT e
							SCHEDULE B, EXHIBIT f
							SCHEDULE B, EXHIBIT g
							SCHEDULE B, EXHIBIT h
							SCHEDULE B, EXHIBIT j
							SCHEDULE B, EXHIBIT k
							SCHEDULE B, EXHIBIT m
							SCHEDULE B, EXHIBIT n
							SCHEDULE B, EXHIBIT o
							SCHEDULE B, EXHIBIT p
							SCHEDULE B, EXHIBIT q
							SCHEDULE B, EXHIBIT r
							SCHEDULE B, EXHIBIT s
							SCHEDULE B, EXHIBIT t
							SCHEDULE B, EXHIBIT u
							SCHEDULE B, EXHIBIT IV
							SCHEDULE B, EXHIBIT III

APPENDIX C

J.E.D. MANUFACTURING
BASIC DATA SHEET

PAGE ____ OF ____

CODE: _____ DATE: _____

SUB-SECTION: _____ UNIT: _____

MAJOR CATEGORY: _____ ACCOUNT: _____

YEAR	PERIOD	MONTHLY EXPENDITURE X_1	WEEKLY AVERAGE X_2	13 PERIOD YEAR X_3	QUARTERLY TOTAL X_4
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
Total					
Average					
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
Total					
Average					

APPENDIX - D

Least Squares Solution

A linear form will "best" fit observed data in the "Least Squares" sense when the sum of the squares of the deviations of actual from theoretical values is a minimum. The application of this principal was used to derive the normal equations as follows:

(1) Let $b_t = \sum_j a_j x_{tj}$ be the theoretical hyperplane to be fit to the sets of observations.

(2) From the p observations of the form $(b_t, x_{t1} x_{t2} \cdot \cdot \cdot x_{tr})$, find the difference between the theoretical and actual value:

$$d_1 = b_1 - (a_1x_{12} + a_2x_{12} + \cdot \cdot \cdot a_rx_{1r})$$

$$d_2 = b_2 - (a_1x_{21} + a_2x_{22} + \cdot \cdot \cdot a_rx_{2r})$$

. . .

. . .

. . .

$$d_p = b_p - (a_1x_{p1} + a_2x_{p2} + \cdot \cdot \cdot a_rx_{pr})$$

(3) Require that the sum of squares of these differences be a minimum:

$$\sum_{t=1}^{p} d_t^2 = \sum_{t=1}^{p} \left[b_t - (a_1x_{t1} + \cdot \cdot \cdot a_rx_{tr}) \right]^2$$

(4) It can be shown that this condition is satisfied when the partial derivatives with respect to the parameters are simultaneously zero:

$$\frac{\partial\left(\sum_{t=1}^{p} d_t^2\right)}{\partial a_1} = 2\sum_t \left[b_t - a_1 x_{t1} + \ldots a_r x_{tr}\right](x_{t1})$$

$$\frac{\partial\left(\sum_{t=1}^{p} d_t^2\right)}{\partial a_2} = 2\sum_t \left[\ldots\ldots\ldots\ldots\right](x_{t2})$$

$$\vdots \qquad\qquad \vdots$$

$$\frac{\partial\left(\sum_{t=1}^{p} d_t^2\right)}{\partial a_r} = 2\sum \left[\ldots\ldots\ldots\ldots\right](x_{tr})$$

(5) This yields a set of simultaneous linear equations, called "Normal Equations", in the parameters a_i the solution of which determines the best fitting hyperplane in the "Least Squares" sense:

$$\sum_t b_t x_{t1} - a_1 \sum_t 1\,(x_{t1})^2 - a_2 \sum_t x_{t2}x_{t1} - \ldots - a_r \sum_t x_{tr}x_{t1} = 0$$

$$\sum_t b_t x_t - a_1 \sum_t x_{t1}x_{t2} - a_2 \sum_t (x_{t2})^2 - \ldots - a_r \sum_t x_{tr}x_{t2} = 0$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$\sum_t b_t x_{tr} - a_1 \sum_t x_{t1}x_{tr} - a_2 \sum_t x_{t2}x_{tr} - \ldots - a_r \sum (x_{tr}) = 0$$

APPENDIX E1

ASSEMBLY

8610

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	475	438	- 8	477	0
O.T. PREM. - DAL	22	43	+95	24	+ 9
O.T. PREM. - OTHER	12	16	+33	11	- 8
NON-PRODUCTIVE LABOR	16	26	+62	26	+62
TRAINING	33	31	- 6	31	- 6
OTHER PREMIUMS	147	144	- 2	151	+ 3
EMPLOYEE BENEFITS	159	135	-15	149	- 6
*TOOLS & SHOP SUPPLIES	61	61	0	55	-10
*OFFICE SUPPLIES					
MAINTENANCE					
**APPROPRIATED EXPENSE	10			10	0
UTILITIES					
DATA PROCESSING	6	2	-67	7	+17
EMPLOYEE EDUCATION					
REARRANGEMENTS					
TELEPHONE & TELEGRAPH	4	4	0	4	0
TRAVEL & LIVING	2	2	0	2	0
**EMPLOYEE TRANSFERS					
OTHER MISL. CONT. EXP.	7	11	+57	8	+14
TOTAL CONTROL EXP.	954	913	- 4	955	+ 0
***RENT	1	157		1	0
***TAXES & INSURANCE					
***DEPRECIATION & AMORT.					
**OTHER ASSESSMENTS					
GROSS EXPENSE	955	1070	+12	956	0
EXPENSE CREDITS		3			
NET EXPENSE	955	1067	+12	956	0
DIRECT & APPLIED LABOR	883	885	0	885	0
TOTAL IME & DAL	1838	1952	+ 6	1841	0

* Reported as one account in 1957.

** New accounts for 1958.

*** Reported as "Fixed Expenses" in 1957.

APPENDIX E2

PARTS MFG.

8620

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	860	791	- 8	862	0
O.T. PREM. - DAL	22	93	+323	51	+132
O.T. PREM. - OTHER	8	47	+487	33	+312
NON-PRODUCTIVE LABOR	40	68	+ 70	68	+ 70
TRAINING	131	180	+ 37	180	+ 42
OTHER PREMIUMS	234	229	- 2	240	+ 3
EMPLOYEE BENEFITS	269	255	- 5	281	+ 4
*TOOLS & SHOP SUPPLIES	287	261	- 9	273	- 5
*OFFICE SUPPLIES					
MAINTENANCE					
**APPROPRIATED EXPENSE	10			10	0
UTILITIES					
DATA PROCESSING	33	13	- 61	35	+ 6
EMPLOYEE EDUCATION		3			
REARRANGEMENTS					
TELEPHONE & TELEGRAPH	6	6	0	6	0
TRAVEL & LIVING	6	7	+ 17	7	+ 17
**EMPLOYEE TRANSFERS					
OTHER MISL. CONT. EXP.		36		26	
TOTAL CONTROL EXP.	1906	1989	+ 4	2072	+ 9
***RENT	8	249		8	0
***TAXES & INSURANCE					
***DEPRECIATION & AMORT.					
**OTHER ASSESSMENTS					
GROSS EXPENSE	1914	2238	+ 17	2080	9
EXPENSE CREDITS		3			
NET EXPENSE	1914	2235	+ 17	2080	+ 9
DIRECT & APPLIED LABOR	1362	1378	+ 1	1378	+ 1
TOTAL IME & DAL	3276	3613	+ 10	3458	+ 6

* Reported as one account in 1957

** New accounts for 1958.

*** Reported as "Fixed Expenses" in 1957.

APPENDIX E3

MATERIALS

8630

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	1854	1712	- 8	1865	+ 1
O. T. PREM. - DAL					
O. T. PREM. - OTHER	24	23	- 4	16	-33
NON-PRODUCTIVE LABOR TRAINING					
OTHER PREMIUMS	28	27	- 4	29	+ 4
EMPLOYEE BENEFITS	191	166	- 13	182	- 5
*TOOLS & SHOP SUPPLIES	39			43	+10
*OFFICE SUPPLIES	5	79	+1580	5	0
MAINTENANCE					
**APPROPRIATED EXPENSE					
UTILITIES					
DATA PROCESSING	57				
EMPLOYEE EDUCATION					
REARRANGEMENTS					
TELEPHONE & TELEGRAPH	105	107	+ 2	107	+ 2
TRAVEL & LIVING	40	43	+ 8	43	0
**EMPLOYEE TRANSFERS					
OTHER MISL. CONT. EXP.	153	98	- 36	98	-36
TOTAL CONTROL EXP.	2496	2255	- 10	2388	- 4
***RENT	18	228		18	0
***TAXES & INSURANCE					
***DEPRECIATION & AMORT.					
**OTHER ASSESSMENTS					
GROSS EXPENSE	2514	2483	- 2	2406	- 4
EXPENSE CREDITS	18	23	+ 28	23	+28
NET EXPENSE	2496	2460	- 2	2383	- 5

* Reported as one account in 1957.

** New accounts for 1958.

***Reported as "Fixed Expenses" in 1957.

APPENDIX E4

MFG. ENGRG. & PROCESS DEV.

8640

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	237	206	- 13	224	- 5
O. T. PREM. - DAL					
O. T. PREM. - OTHER		1			
NON-PRODUCTIVE LABOR					
TRAINING					
OTHER PREMIUMS					
EMPLOYEE BENEFITS	24	18	- 25	20	-17
*TOOLS & SHOP SUPPLIES					
*OFFICE SUPPLIES		6			
MAINTENANCE					
**APPROPRIATED EXPENSE	12			12	0
UTILITIES					
DATA PROCESSING					
EMPLOYEE EDUCATION					
REARRANGEMENTS					
TELEPHONE & TELEGRAPH	4	3	- 25	3	-25
TRAVEL & LIVING	12	9	- 25	9	-25
**EMPLOYEE TRANSFERS					
OTHER MISL. CONT. EXP.	4	14	+285	6	+50
TOTAL CONTROL EXP.	293	257	- 13	274	- 6
***RENT					
***TAXES & INSURANCE					
***DEPRECIATION & AMORT.					
**OTHER ASSESSMENTS					
GROSS EXPENSE	293	276	- 7	274	- 6
EXPENSE CREDITS					
NET EXPENSE	293	276	- 7	274	- 6

* Reported as one account in 1957.

** New accounts for 1958.

*** Reported as "Fixed Expenses" in 1957.

APPENDIX E5

TEST

8650

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	529	479	- 9	522	- 1
O. T. PREM. - DAL	22	75	+240	42	+ 91
O. T. PREM. - OTHER	5	12	+140	8	+ 60
NON-PRODUCTIVE LABOR	43	45	+ 5	45	+ 3
TRAINING	29	30	+ 3	30	+ 3
OTHER PREMIUMS	265	247	- 7	259	- 2
EMPLOYEE BENEFITS	242	215	- 11	237	- 2
*TOOLS & SHOP SUPPLIES	143	161	+ 13	145	+ 1
*OFFICE SUPPLIES MAINTENANCE	243	312	+ 28	282	+ 16
**APPROPRIATED EXPENSE	5			5	0
UTILITIES					
DATA PROCESSING	4	3	- 25	5	+ 25
EMPLOYEE EDUCATION					
REARRANGEMENTS	10	10	0	10	0
TELEPHONE & TELEGRAPH	7	6	- 14	6	- 14
TRAVEL & LIVING	4	3	- 25	3	- 25
**EMPLOYEE TRANSFERS					
OTHER MISL. CONT. EXP.	20	64	+156	32	+ 28
TOTAL CONTROL EXP.	1576	1662	+ 5	1631	+ 3
***RENT		429			
***TAXES & INSURANCE					
***DEPRECIATION & AMORT.					
**OTHER ASSESSMENTS					
GROSS EXPENSE	1576	2091	+ 33	1631	+ 3
EXPENSE CREDITS	4	8	+100	8	+100
NET EXPENSE	1572	2083	+ 32	1623	+ 3
DIRECT & APPLIED LABOR	1302	1244	- 4	1244	- 4
TOTAL IME & DAL	2874	3327	+ 16	2867	0

*Reported as one account in 1957.

**New accounts for 1958.

***Reported as "Fixed Expenses" in 1957.

APPENDIX E6

MFG. ADMINISTRATION

8660

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	221	198	- 11	215	- 3
O.T. PREM. - DAL					
O.T. PREM. - OTHER	3	3	0	2	-33
NON-PRODUCTIVE LABOR					
TRAINING					
OTHER PREMIUMS					
EMPLOYEE BENEFITS	22	17	- 23	19	-14
*TOOLS & SHOP SUPPLIES					
*OFFICE SUPPLIES	330	51	- 85	330	0
MAINTENANCE	16				
**APPROPRIATED EXPENSE	10			10	0
UTILITIES					
DATA PROCESSING	8	4	- 50	9	+13
EMPLOYEE EDUCATION	109	75	- 30	83	-24
REARRANGEMENTS					
TELEPHONE & TELEGRAPH	4	4	0	4	0
TRAVEL & LIVING	5	7	+ 40	7	+40
**EMPLOYEE TRANSFERS	1	3	+200		
OTHER MISCL. CONT. EXP.	41			45	+10
TOTAL CONTROL EXP.	770	362	- 53	724	- 6
***RENT	1	21		1	0
***TAXES & INSURANCE					
***DEPRECIATION & AMORT.					
**OTHER ASSESSMENTS					
GROSS EXPENSE	771	383	- 50	725	- 6
EXPENSE CREDITS					
NET EXPENSE	771	383	- 50	725	- 6

* Reported as one account in 1957.

** New accounts for 1958.

*** Reported as "Fixed Expenses" in 1957.

APPENDIX E7

QUALITY

8670

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	1052	1026	- 3	1118	+ 6
O.T. PREM. - DAL	12	31	+158	17	+ 42
O.T. PREM. - OTHER	10	21	+110	15	+ 50
NON-PRODUCTIVE LABOR	9	12	+ 33	12	+ 33
TRAINING	13	21	+ 62	21	+ 62
OTHER PREMIUMS	112	126	+ 10	133	+ 19
EMPLOYEE BENEFITS	189	168	- 11	185	- 2
*TOOLS & SHOP SUPPLIES	106	115	+ 8	103	- 3
*OFFICE SUPPLIES					
MAINTENANCE					
**APPROPRIATED EXPENSE					
UTILITIES					
DATA PROCESSING	3	6	+100	28	+833
EMPLOYEE EDUCATION		3			
REARRANGEMENTS					
TELEPHONE & TELEGRAPH	11	14	+ 27	14	+ 14
TRAVEL & LIVING	76	79	+ 4	79	+ 4
**EMPLOYEE TRANSFERS	2				
OTHER MISL. CONT. EXP.	14	48	+243	19	+ 35
TOTAL CONTROL EXP.	1609	1670	+ 3	1744	+ 8
***RENT	5	85		5	0
***TAXES & INSURANCE					
***DEPRECIATION & AMORT.					
**OTHER ASSESSMENTS					
GROSS EXPENSE	1614	1755	+ 9	1749	+ 8
EXPENSE CREDITS	30	61	+103	31	+ 3
NET EXPENSE	1584	1694	+ 7	1718	+ 8
DIRECT & APPLIED LABOR	683	678	- 1	678	- 1
TOTAL IME & DAL	2267	2372	+ 5	2396	+ 6

* Reported as one account in 1957.

** New accounts for 1958.

*** Reported as "Fixed Expenses" in 1957.

APPENDIX E8

FAC. ENGRG.

8690

ACCOUNT TITLE	1958 MANUAL BUDGET $ 000	UNADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET	ADJUSTED MECHANIZED BUDGET $ 000	V% FROM 1958 MANUAL BUDGET
OVERHEAD SALARIES	663	622	- 6	677	+ 2
O. T. PREM. - DAL	6	15	+150	8	+ 50
O. T. PREM. - OTHER	16	17	+ 6	12	- 25
NON-PRODUCTIVE LABOR	2	1	- 50	1	- 50
TRAINING	15	8	- 47	8	- 47
OTHER PREMIUMS	77	60	- 22	63	- 19
EMPLOYEE BENEFITS	113	86	- 24	94	- 17
*TOOLS & SHOP SUPPLIES	171	171	0	172	+ 1
*OFFICE SUPPLIES					
MAINTENANCE	378	475	+ 26	427	+ 13
**APPROPRIATED EXPENSE	875			875	0
UTILITIES	1000	931	- 7	931	- 7
DATA PROCESSING	5	2	- 60	5	0
EMPLOYEE EDUCATION					
REARRANGEMENTS	138	123	- 11	123	- 11
TELEPHONE & TELEGRAPH	4	5	+ 25	5	+ 25
TRAVEL & LIVING	2	2	0	2	0
**EMPLOYEE TRANSFERS					
OTHER MISL. CONT. EXP.	63	102	+ 61	61	- 3
TOTAL CONTROL EXP.	3528	2620	- 26	3464	- 2
***RENT	55	193	+251	54	- 2
***TAXES & INSURANCE	165			165	0
***DEPRECIATION & AMORT.	1333			1333	0
**OTHER ASSESSMENTS	200			200	0
GROSS EXPENSE	5281	2813	- 47	5216	- 1
EXPENSE CREDITS	1255	1311	+ 4	1311	+ 4
NET EXPENSE	4026	1502	- 63	3905	- 3
DIRECT & APPLIED LABOR	21	11	- 48	11	- 48
TOTAL IME & DAL	4047	1513	- 63	3916	- 3

* Reported as one account in 1957.

** New accounts for 1958.

*** Reported as "Fixed Expenses" in 1957.

APPENDIX F

Mathematical Techniques

It was decided, for reasons previously discussed, that programming would be done within the project with the aids of IBM Applied Science personnel and 650 Library Programs. The programs consisted of matrix operations and utility routines such as loading routines, translating routines, conversion routines, and tracing routines.

It was found that the "Least Squares" fitting problem could be easily solved by matrix algebra. Consider first the representation of the observed values in matrix form:

$$\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1r} \\ x_{21} & x_{22} & \cdots & x_{2r} \\ \vdots & \vdots & & \vdots \\ x_{t1} & x_{t2} & \cdots & x_{tr} \\ \vdots & \vdots & & \vdots \\ x_{t12,1} & x_{12,2} & \cdots & x_{12,r} \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ \vdots \\ a_r \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_t \\ \vdots \\ b_{12} \end{pmatrix}$$

Let the matrix (X_{tj}) be denoted X and the vectors (a_j) and (b_t) be denoted A and B respectively. Then the resulting form is given:

$$XA = B$$

It can be shown that the normal equations, derived from the partial derivitives of the residual function, can be simply obtained by the left multiplication of X^T. (the transpose of X):

$$X^T X A = X^T B$$

This yields a set of simultaneous equations with a square coefficient matrix of dimension r. This form has a unique solution when $X^T X$ is non-singular:

$$A = (X^T X)^{-1} X^T B$$

In these cases, the matrix $X^T X$ is non-singular with probability near zero, so the method can be employed with little difficulty.

A solution in exactly this manner requires finding the four elements $X^T X$, $X^T B$, $(X^T X)^{-1}$ and $(X^T X)^{-1} X^T B$. The mechanized process can be optimized by reducing the number of operations by two.

First form the matrices X^T and $(X \vdots B)$. Then multiply these matrices to get:

$$X^T (X \vdots B) = (X^T X \vdots X^T B)$$

By performing the left inversion transformations of $(X^T X)$ on both parts of the matrix the solution is obtained:

$$(X^T X)^{-1} \left[X^T X \vdots X^T B \right] = \left[I \vdots (X^T X)^{-1} X^T B \right]$$

In the actual programs the column order and output differ slightly, but the processes identical.

APPENDIX G

Pass I: Derivation of Normal Equations

A. Purpose: This program utilizes L. W. Ayres Matrix Multiplication to obtain normal equations for a multiple linear fit of historical data.

B. Input Data:

Each group of cards consists of twelve observations of five independent variables X_i, sets of twelve observations of the dependent variable b_t, and a control card following each set of dependent variable values.

1) Variable Card Form

Column 38-41:	sub-section number:	word 1
42-44:	account number:	word 2
54-55:	month number:	word 3
65-67: 69-71:	variable value:	word 4
80:	eleven punch if negative	

2) Control Card Form

Column 1-4 :	0900 if X_1 is used:	word 5	zeros otherwise
5-8 :	0901 if X_2 is used:	word 6	
9-12:	0902 if X_3 is used:	word 7	
13-16:	0903 if X_4 is used:	word 8	
17-20:	0904 if X_5 is used:	word 9	
21-24:	0905 always:	word 10	
38-41:	sub-section number:	word 1	
42-44:	account number:	word 2	
54-55:	number of X_i's:	word 3	
79:	a twelve punch:	read control	

C. Output Data:

Each group of cards include the following:

1) Product Matrix: these cards are in "7 per card" load form to be read in the 0000 band and contain the results of multiplication which are the normal equation coefficients.
2) Inversion Control Card: this is a non-load card punched in "7 per card" form and contains the dimension of the matrix to be inverted in column two and this number plus one in column ten.
3) Identification Card: this is a non-load card punched in "7 per card" form containing the following identification:

word 1: sub-section number
word 2: account number
word 3: zeros
word 4: 0900 if X_1 was used
word 5: 0901 if X_2 was used
word 6: 0902 if X_3 was used
word 7: 0903 if X_4 was used
word 8: 0904 if X_5 was used

} zeros otherwise

D. Operation Instructions:

1) Set Console to: 70 1951 XXXX
2) Set Error Stop, overflow sense, and programmed stop
3) Load the Input in the following order
    a) Self loading "7 per card" program
    b) Independent Variable Data Deck
    c) Dependent variable Data Deck
    d) Control Card
    e) Repeat c, d until new independent variable data is required then repeat b.

E. Program Stops: Display Lights read as follows:

1) 01 0001 8000 : card just read contains wrong sub-section number. Correct the mistake and reload program, preceding independent variable data deck, and current dependent variable data deck.

2) 01 0002 8000 : card just read has wrong account number. Correct error and reload as above.

3) 01 0003 8000 : card just read has wrong monthly sequence. Correct error and reload as above.

4) 01 0004 8000 : card just should be for month one and is not. Correct error and reload as above.

5) 01 8034 XXXX : control card has wrong sub-section or account number. Correct error and reload as above.

APPENDIX H

Pass II: Solution of Normal Equations

A. Purpose: This program utilized D. W. Sweeney Matrix Inversion to solve the normal equations set up in Part I. This program has been modified in that it can be preserved for consecutive inversions.

B. Input Data:

The output of Part I

1) Matrix to be inverted
2) First control card
3) Identification card

C. Output Data:

Eight word ten digit non-load form punched as follows:

1) word 1: sub-section number
2) word 2: account number
3) word 3: number five
4) word 4: a_1 or zeros
5) word 5: a_2 or zeros
6) word 6: a_3 or zeros
7) word 7: a_4 or zeros
8) word 8: a_5 or zeros

D. Operating Instructions:

1) Set console to: 70 1951 XXXX
2) Set error stop card overflow stop
3) Load the input as follows

a) self loading "7 per card" program

b) output of Part I

E. Program Stops: none

APPENDIX I

Pass III: Evaluation of Estimator

A. Purpose: This program utilizes L. W. Ayres Matrix Multiplication to evaluate the budget estimators by vector-matrix multiplication. The vector is 1 X 5 and the matrix 5 X 12.

B. Input Data:

1) Matrix: Independent variable data as in Pass #1

2) Vector: The output of Pass #2

C. Output Data:

1) Inadjusted budget dollars: load cards in floating decimal "seven per card" form.

2) Identification Card: non-load

a) word 1: sub-section number

b) word 2: account number

c) word 3: zeros

d) word 4: a_1 or zeros

e) word 5: a_2 or zeros

. . . . .

f) word 8: a_5 or zeros

D. Operating Instructions

1) Set the console: 70 1951 XXXX

2) Set the error stop, overflow sense, and programmed stop.

3) Load the Input Deck as follows:

a) Self loading "seven per card" program

b) Independent variable data

c) Vector and identification card

d) Repeat c until new sub-section and then repeat b.

E. Programmed Stop: Console readings as indicated

1) 01 0001 8000: first X_i card is not month one. Correct the error reload the program, current X_i deck, and subsequent vector cards.

2) 01 0002 8000: sub-section number is wrong. Correct error and reload as above.

3) 01 0003 8000: account number is wrong. Correct and reload as above.

4) 01 0004 8000: monthly sequence is wrong. Correct and reload as above.

APPENDIX J

Pass IV: Budget Conversion

A. Purpose: This program adjust the simple four week monthly evaluation to the four-four-five week fiscal month schedule and converts the data to fixed decimal form. It also provides for the modification of results through intuitive factors.

B. Input Data:

Output of Part II

1) Inadjusted budget dollars in "7 per card" load form.
2) Load punched modification, if desired, in 4-4-5 week form.
3) Identification non-load card.

C. Output Data:

1) One set of twelve cards is reproduced for each account for all sub-sections.
2) The card form is as follows:

Column 0-17: blank
18-27: zeros
28-35: dollars
36-37: cents
} year to date budget
38-41: S.S. number
42-44: acct. number
45-49: zeros
50-56: dollars
57-58: cents
} current month budget
59-64: general ledger #050606
72-73: month number
74-79: zeros
80: code six

D. Operating Instructions

1) Set Console: 70 1951 XXXX

2) Set the error stop and overflow stop.

E. Programmed Stops: none