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Volume I
TM/03929/V001/00/0/00

WSPACS AIRCRAFT INTEGRATION MODEL

MODEL DESCRIPTION

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-115

JUNE 1964

E. B. Berman, H. Glazer and T. J. Jannsen

Prepared for

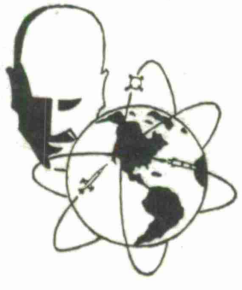
COMPTROLLER (PROGRAMS DIVISION)

ELECTRONIC SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

UNITED STATES AIR FORCE

L. G. Hanscom Field, Bedford, Massachusetts



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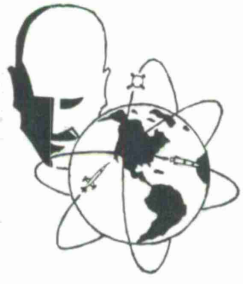

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FOREWORD

The authors would like to acknowledge the contribution of Miss Joan C. DesRoches who wrote the computer programs for the entire integration reprogramming and base-case models.

WSPACS AIRCRAFT INTEGRATION MODEL
VOLUME I (OF TWO VOLUMES) MODEL DESCRIPTION

ABSTRACT

This document contains a description of the aircraft integration model developed by MITRE for the WSPACS project. The model consists of (1) a reprogramming model used to simulate the impact on schedules and costs of possible reprogramming actions on an aircraft force structure, and (2) a base-case updating model, part of the base-case procedure used to update the contractor data for reprogramming runs. A brief description of the purpose of WSPACS and some historical background are also provided.

The technical descriptions of the models used to calculate reprogrammed schedules and costs for the subsystem (airframes, propulsion, airborne electronics, and other GFAE) have been documented elsewhere, and so are not presented.

Descriptions of the computer programs for the aircraft integration reprogramming model and base-case model are presented in Volume II, Computer Programs.

REVIEW AND APPROVAL

Publication of this technical documentary report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

FRANCIS J. HOERMANN
Colonel, USAF
Comptroller

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1.0 INTRODUCTION

WSPACS[1] is an Air Force Systems Command management system currently being developed by an Air Force-Industry-MITRE team to provide the Air Force with a broad planning device to be used in estimating the cost impact of reprogramming one or more of the Air Force systems being acquired. The information generated by WSPACS will be helpful to the Air Force in determining the allocation of funds among the various systems within the Air Force force structure.

WSPACS is meant to be a "decision-aiding," not a "decision-making" tool.[2] It is designed to handle planning data on a system basis from which estimates of the cost of reprogramming can be obtained and the results presented for evaluation and revision. It is not intended as a day-to-day control tool, but rather as a planning system. Thus, it should be available for consideration of reprogramming actions at any time so that approximate answers may be obtained rapidly. Current, updated data are an integral part of the WSPACS model.

WSPACS is based on the concept that the time to develop and produce Air Force systems, the quantity of systems acquired, and the cost of these systems are related in a meaningful way. Through WSPACS, the Air Force plans to determine the relationships between time, quantities, and cost within a system to determine the relationships among different systems, and to provide a man-machine planning system to be used in estimating total Air Force annual expenditures.

The WSPACS system as a whole is intended to provide estimates of the time-phased budget impact in terms of development, production, operating, and facilities costs, of reprogramming any or all of the aircraft, missile, space or electronic systems in the Air Force force structure.

This volume is concerned with one portion of the over-all WSPACS system; namely, the aircraft integration model, which integrates the airframe model with the propulsion, airborne electronics, and other

---

[1] The acronymn WSPACS originally stood for Weapon System Programming and Control System. However, WSPACS is a reprogramming rather than a programming system and has no control features but the acronym has become well known, and, hence, has not been changed. Reprogramming refers to changes to existing Air Force programs. WSPACS is designed to permit modifications (i.e., speed up or slippages) to three time parameters (time of go-ahead, time of delivery of first vehicle, time of delivery of last vehicle) and also to the number of vehicles delivered. Air Force cancellation of a system is also permitted. (See Section 1.2)

[2] Much of the material in this section and in 1.1 is presented in Reference [1].

government-furnished aircraft equipment (GFAE) models to produce (1) a reprogrammed delivery schedule, and (2) development and production costs for aircraft systems only. The role of the aircraft integration model in the total WSPACS system is illustrated in Fig. 1. It controls the operation of subsystem scheduling and costing models to produce a reprogrammed delivery schedule and estimates of the development and production cost portion of the budget impact of the reprogramming action. The delivery schedules and costs then enter a PROM[1] translation model in which the reprogrammed force structure is estimated in terms of squadrons and facilities costs are estimated. An input tape is then prepared for the RAND PROM force structure costing model, including the new force structure in squadrons, and the reprogrammed development, production, and facilities costs. PROM then estimates the reprogrammed operating costs to complete the estimate of the budget impact of the reprogramming action.

The WSPACS aircraft reprogramming model, combined with the PROM translation model and PROM, will enable the Air Force to obtain an estimate of the complete budget impact of reprogramming the aircraft portion of the force structure.

Models are now under development which will provide the capability of estimating the budget impact of reprogramming missile and electronic systems. The missile system model can be integrated with PROM as shown in Fig. 1, but it is presently proposed that the electronic system model will estimate the total range of development, production, facilities and operating costs within itself.

No space system model is shown in Fig.1, since none is yet under development.

1.1 Historical Background

The Air Force interest in developing WSPACS was motivated by the desire to achieve "more Air Force per dollar," and to improve its management planning techniques with respect to the development, production, and procurement of systems.

In 1959, Major General W. Austin Davis, then Director of Headquarters, Air Materiel Command Procurement and Production Headquarters Office, solicited the support of several aerospace industrial and consulting firms in developing WSPACS. The group met to define WSPACS objectives, to discuss the conceptual problems of such an effort, and to establish a preliminary work plan. On 24 February 1960, the Air Materiel Command presented the WSPACS concept and work plan to some twenty companies of the aerospace industry and invited their participation and support. A technical group was formed, tasks were defined, and various approaches to WSPACS problems were investigated. By August, 1960, an initial

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[1] PROM is an Air Force force structure cost model developed at RAND, with emphasis on estimating the operating cost implications of an Air Force program.

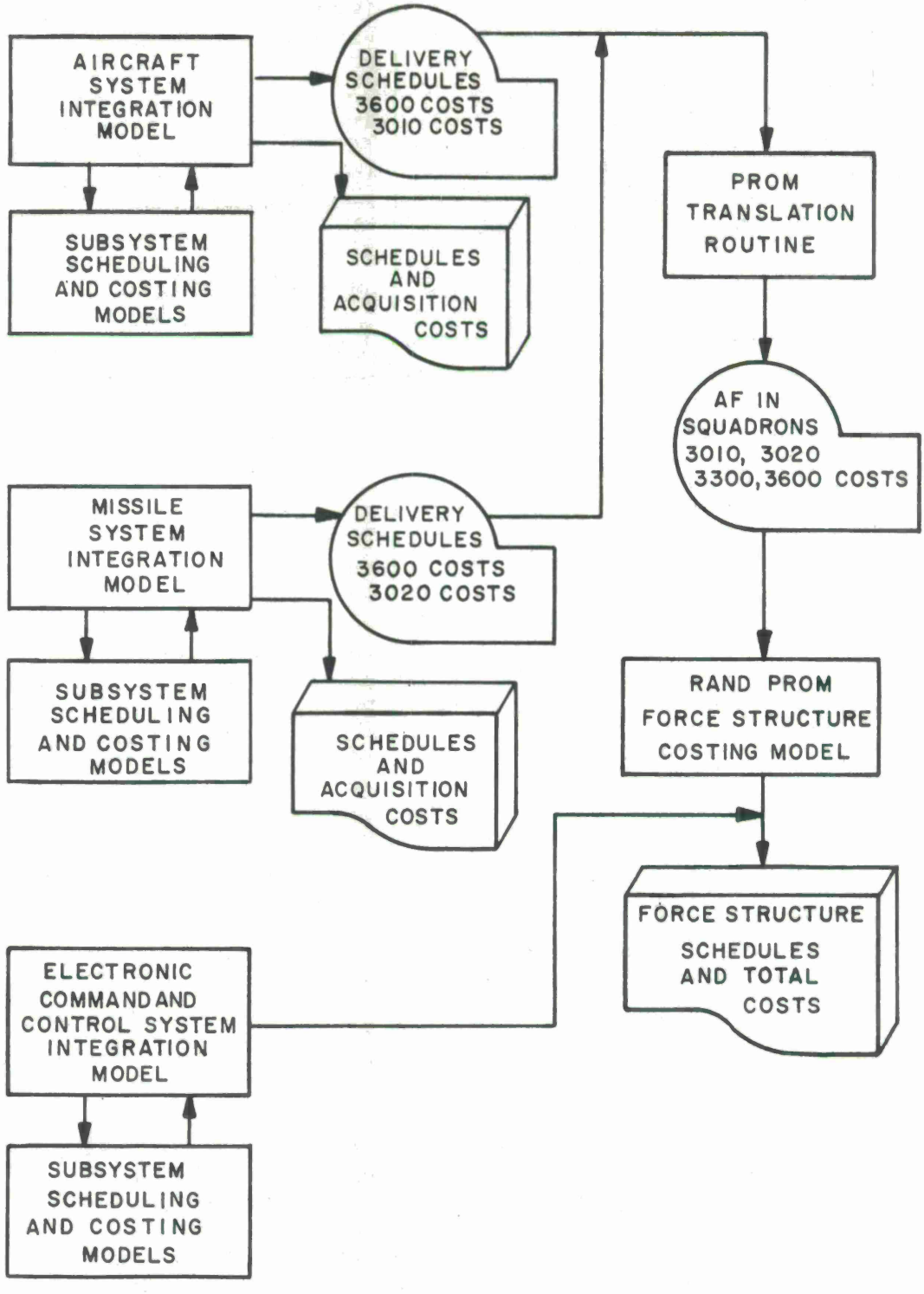

FIG. 1

INTERRELATIONSHIP OF THE WSPACS FORCE STRUCTURE REPROGRAMMING MODELS

IA-13,175

overall approach was agreed upon in which the WSPACS problem was to be formulated as a non-linear programming model. Contractors were to provide parameter values and upper and lower bounds in their equations relating to equipment and costs, while the Air Force was to provide ceilings on expenditures, estimates of non-system-connected costs, and offensive and defensive weapons requirements. The approach was to determine the parameters -- system go-ahead date, first delivery date, last delivery date, and total quantity -- for each system to meet Air Force requirements at minimal cost.

With the problem thus defined, it was decided to develop two models: a demonstration model (Mod Zero) that could be run on a desk-sized computer to illustrate that the objectives were properly oriented, and a detailed model for airframes to be processed on a large-scale computer. Models for other systems and subsystems were deferred until an adequate model was developed for the airframe.

Mod Zero was completed in November, 1960, with no cost minimization features, but with results that suggested that the WSPACS project could provide useful information. Mod I Airframe, the detailed airframe model, was presented to the Air Force at a meeting in August, 1961

Improvements to Mod I were suggested at the August meeting; Mod II Airframe, incorporating the improvements, was completed by January, 1962 [2]. Computer programming of Mod II was completed by June, 1962 [3]. A validation phase, in which several contractors performed reprogramming actions on assigned systems using both the Mod II Airframe model and their usual manual method, was successfully completed by February, 1963.

In February, 1962, technical groups were established to develop similar models for the airborne electronics, propulsion, and other GFAE subsystems, and an integration model for the aircraft system. In addition, development of base-case procedures, to be used to update data tapes used by the reprogramming model, was also begun. The final report on the airborne electronics model was released in February, 1963 [1], on the propulsion model, May, 1963 [4], and on the other GFAE model, November, 1963 [5]. Programming of these models and the integration model began in March, 1963.

The programming for the airframe subroutines was performed by Boeing, Pratt and Whitney and General Electric programmed the propulsion subroutines, while Aeronautical Systems Division programmed the airborne electronics and other GFAE subroutines and MITRE the integration model.

Programmer meetings were held periodically to combine the contractor subroutines of the subsystems with those of the integration reprogramming model. The complete reprogramming model, i.e., the integration model, all contractor subroutines, and the report generator, was successfully run in October, 1963.

---

[1] These subroutines are referred to as the contractor subroutines in this report.

The base case program was checked out and successfully run in February, 1964.

In February, 1962, an "L" system committee was formed to develop a model for assessing the cost impact of reprogramming large-scale, electronic command and control systems. A committee which had been established earlier to develop a missile system model proposed such a model in April, 1961, and completed Mod I in August, 1962 [6].

1.2 Air Force Reprogramming Parameters

In a typical reprogramming action, the Air Force changes parameters of certain systems selected from the aircraft force structure. The system parameters which may be modified are the following airframe schedule parameters:

T_G time of go-ahead

T_F delivery time of the first vehicle

T_L delivery time of the last vehicle

N the total number of vehicles

The changes to these airframe parameters are signified by primes; thus, T_G', T_F', T_L', and N' are the reprogrammed values. These values may be increased or decreased; in addition, a system may be cancelled. The effect of the reprogrammed parameters on the other subsystem (propulsion, airborne electronics, and other GFAE) parameters, schedules, and costs is controlled through the integration model.

The WSPACS model generates new schedules and costs for the reprogrammed systems. Presently, it is not possible to use the WSPACS model to explicitly reprogram the force structure on the basis of cost constraints. However, the use of an iterative technique is possible. A set of reprogramming parameters is hypothesized, and the WSPACS program is run. The reprogramming parameters are modified and the program rerun until a set of parameters is used that yields force structure costs consistent with the specified cost constraints.

2.0 DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

Important definitions, ground rules, and assumptions pertaining to the WSPACS models are discussed below. These are grouped into three broad categories: (1) those applicable to the integration reprogramming model, (2) additional definitions for the base-case procedure, and (3) those that are needed to permit a general understanding of the contractor models. The definitions applicable to the integration reprogramming model also apply to the base-case procedure unless otherwise specified.

2.1 Integration Reprogramming Model

2.1.1 Types of Subsystems

The integration reprogramming model assumes that the same propulsion or airborne electronics subsystem may be used on a maximum of three aircraft systems. Subsystems used on more than one system are called common, while those used on a single system are called peculiar. Common subsystems are classed as Type A common or Type B common, depending on how costs are calculated. The costs for Type A common subsystems are obtained from the cumulative schedule of all appropriate systems. The costs are then allocated to the appropriate systems by cost allocation factors. These factors are calculated for each month in which there is a positive total subsystem delivery rate as the quotient of the subsystem/system delivery rate divided by the total subsystem delivery rate. The Type B common subsystem is scheduled for all aircraft together, but is costed as if it were several peculiar subsystems. The different dash numbers for a single aircraft engine model number might represent an example of a Type B common subsystem.

When reprogramming action is taken on more than one system, a subsystem that is used on only one reprogrammed system is called schedule-peculiar, even though this subsystem may also be used on systems that are not being reprogrammed. Subsystems that are used on more than one reprogrammed system are called schedule-common. Thus, the terms schedule-peculiar and schedule-common refer only to those subsystems that are identified with systems being reprogrammed.

Since aircraft systems are characterized and identified by their airframes, and the airframe delivery schedules are used as the system delivery schedules, the present integration model assumes all airframe and other GFAE subsystems are peculiar.

2.1.2 Subsystem Identification and Quantities of Subsystems

Subsystems are identified by a three-digit code, the first digit identifying the subsystem class and the next two the particular subsystem in the class. The maximum quantity of subsystems in any class is 50.

The following digits have been established for the various classes:

1XX	Airframe
2XX	Propulsion
3XX	Airborne Electronics
4XX	Other GFAE

(XX represents the numbers 01 to 50; numbers larger than 50 cannot be used.)

Restrictions on the quantities of subsystems are as follows:

(1) Each airframe may have one propulsion and one other GFAE subsystem only.

(2) Each airframe may have a maximum of nine subsystems. Since an airframe may have only one propulsion subsystem and one other GFAE subsystem, this leaves seven airborne electronics subsystems available to an airframe.

(3) The last two digits of an other GFAE subsystem must be the same as the last two digits of the airframe associated with the other GFAE subsystem. Propulsion and airborne electronics subsystems may take any number from 01 to 50. For example, airframe 133 would be associated with other GFAE subsystem 433 but could also have propulsion subsystem 249 and airborne electronics subsystems 301, 310, and 340.

(4) Although the current airborne electronics scheduling and costing models assume that no airborne electronics subsystems are common, the computer programs of the integration model are capable of handling common airborne electronics subsystems. This capability will be added to the airborne electronics model as soon as possible.

(5) The propulsion and airborne electronics subsystem classes are each allowed a total of 70 subsystem/system combinations, while the highest number of a subsystem in a class is 50. The extra 20 combinations permit the inclusion of up to 20 common subsystems without reducing the total number of possible subsystems below 50. For example, in the propulsion class there could be 10 common subsystems with three systems each, plus 40 peculiar subsystems, or, 20 common subsystems with two systems each, along with 30 peculiar subsystems. In general, any combination of peculiar and common subsystems is possible so long as:

(a) total quantity of different subsystems in a class does not exceed 50,

(b) total quantity of common subsystems in a class does not exceed 20, and

(c) total quantity of subsystem/system combinations in a class does not exceed 70.

(6) The maximum allowable number of schedule-common subsystems, propulsion and airborne electronics combined, is 30.

2.1.3 Relative and Absolute Times

Schedules are presented for a maximum of eleven years, or 132 months. In order to maintain a consistent time reference, while also conserving computer storage space, two time scales, relative and absolute, have been established, both using months as the unit of measure. The absolute time variable, denoted by t, is established with July 1963 equal to 1. All time parameters, such as T_G, T_F, and T_L (the times for system go-ahead, delivery of first vehicle, and delivery of last vehicle), are input in absolute time units, as are T_I, time of last updating, and T_D, the date of a reprogramming calculation. In addition, the WSPACS reprogramming time parameters, T_G', T_F', T_L', are also in absolute scale. The schedules are stored in the computer in relative time units, k being the time variable. The frame of reference for this variable is the beginning of the fiscal year in which T_I, the time of updating, occurs. Thus, if the updating occurs in December, 1964, k = 1 for July, 1964, so k = 6 and T_I = 18 for December, 1964.

A computer program exists for converting all time parameters from the absolute time scale t to the relative time scale k.

2.1.4 Time Parameters and Variables

The timing parameters listed below are major parameters used by the integration model. The first two parameters are independent of system, the next seven are associated with a particular system (airframe). Next is a system variable, and last is a variable related to either a propulsion or an airborne electronics subsystem.[1] All parameters, i.e., the first nine below, are input in absolute time and are converted to relative time by the computer conversion program.

General

T_D Present time (date of WSPACS reprogramming run)

T_I Time of last updating

---

[1] The airframe subsystem also has a T_1'; however, it is not used by the integration routine.

System

T_G Time of go-ahead for system

T_F Delivery time of the first vehicle

T_L Delivery time of the last vehicle

T_G' Reprogrammed time of go-ahead

T_F' Reprogrammed delivery time of the first vehicle

T_L' Reprogrammed delivery time of the last vehicle

$T_L max$ Latest time to which the last delivery can be delayed

T_D' Earliest time airframe management can react to a change in schedule at T_D.

Subsystem

T_1' Time after which subsystem acceleration can occur in reacting to a change in schedule at T_D. T_1' must not exceed 36.

2.1.5 Computation Limits

Since different systems will have different T_L's (and $T_L max$'s), and since the latest $T_L max$ may still be much earlier than period 132 (relative), a computation limit or maximum time has been established to decrease computer running time by obviating the need for unnecessary calculations all the way out to period 132. This limit, designated MT, must be a multiple of 12, must be between 48 and 132 inclusive, i.e. $48 \leq MT \leq 132$, and should be greater than or equal to the latest $T_L max$ (relative) for any system. Because $T_L max$ and other time parameters are defined in the absolute scale, MT is actually input as a quantity MTA in the absolute time scale and subsequently converted to MT, which is relative, by the computer program. The value of MTA input must be such that when converted to MT, it meets the restrictions on MT. Although MTA is input at each processing time, its value is established at T_I when the various input tapes are generated. Consequently, MTA may be changed only at T_I and then must remain constant for the ensuing three months.

2.1.6 Types of Schedules

With the exception of certain output reports, all the different schedules used in WSPACS are cumulative.

The following types of propulsion and airborne electronics schedules are calculated or are used in the integration reprogramming model:

Type of Schedule	Method of Calculation
Pre-reprogrammed Delivery	Schedules as of last updating.
Gross Maximum	Calculated by contractor maximum scheduling routine.
Net Maximum	Calculated as gross maximum minus pre-reprogrammed schedules of non-reprogrammed systems.
Requirements	Calculated by translating airframe schedule to subsystem basis using either preferred of minimum lead times and spares coefficients as appropriate.
Smoothed Delivery (Reprogrammed)	Total schedule only: calculated by contractor smoothing routine. The total smoothed schedule is allocated to the various systems by the integration routine; if peculiar, no allocation necessary.

2.1.7 Management Options For Schedule Infeasibilities

Three management options will be available to the decision maker[1] in the event that schedule infeasibility is observed for a schedule-common subsystem. The calculations associated with the options are performed after Step 8 of Chain 3 of the reprogramming model, Section 4.2.3. The options are:

Option (a): Recalculate schedules of systems associated with infeasible schedule-common subsystems under control of the system precedence table, using minimum spares and lead times. The system precedence table is a ranking of systems which is input in the form of a "precedence number" for each reprogrammed system in the REPS (Section 4.1.1.1).

Option (b): Same as option (a), except store data and stop computer after printing results, and examine data. It is possible to continue if the allocation has been satisfactory, or to modify reprogramming parameters and start at the beginning.

---

[1] Only Option (c) has been programmed in the current operating version of the model.

Option (c): Store data and stop program. Do not modify schedule. Print net maximum schedule for infeasible subsystems, the requirements for the subsystem per unit of each pertinent system, and reprogramming parameters before and after revisions, and stop. It is possible to change the option to (a) or (b) and continue at appropriate step, or to start at the beginning after the reprogramming parameters are modified.

2.1.8 Assumptions For Costing

System acquisition costs are accumulated in two major categories -- development and production -- which correspond to the Air Force budget categories 3600 and 3010, respectively.[1] In the subsystem costing models, however, costs are generated as non-recurring and recurring costs which correspond with but are not identical to the 3600 and 3010 categories. The integration reprogramming model converts the former categories into the latter by means of the following relationships:

$$3600(N) = 3600(0) + \text{Non-recurring}(N) - \text{Non-recurring}(0)$$

$$3010(N) = 3010(0) + \text{Recurring}(N) - \text{Recurring}(0)$$

where N denotes the reprogrammed (new) costs and 0 denotes the original (as of last T_I) costs before reprogramming.

Whereas the monthly schedules run from the beginning of the fiscal year in which T_I occurs to MT, costs are always generated for eleven years. Costs for the first three years are quarterly, starting with the year in which T_I occurs, and costs for the last eight years are annual, making a total of twenty entries for a cost schedule. The correspondence between the relative monthly time variable k and the twenty cost units is as follows: cost units 1 through 12 are quarterly, with k equal to 3, 6, 9, ..., 36; the cost units 13 through 20 are annual, and correspond to k equal to 48, 60, 72, ..., 132. Cumulative costs are always shown unless otherwise specified.

The Air Force desires to have available in the WSPACS model cumulative costs for current and future fiscal years only. When T_I is June, T_D will always occur in the following fiscal year so that no costs are needed for the year in which T_I occurs. The following cost data rules, therefore, apply:

(1) If T_I is September (k=3), cost schedules consist of the complete 20 costs;

(2) If T_I is December or March (k=6 or 9), cumulative costs are not maintained for quarters prior to December or March, respectively;

---

[1] Formerly designated P600 and P100, respectively.

(3) If T_I is June (k=12), no costs are maintained for the first four quarters (costs are available for only ten complete years).

In the case of a common propulsion or airborne electronics subsystem, the assumption is made that all development costs are assigned to one system only. Consequently, the system receiving the non-recurring and resulting 3600 costs is identified in the data tables ISST1J (propulsion) or ISST1Z (airborne electronics)[1].

2.2 Integration Base-Case Updating

The definitions, ground rules and assumptions that apply to the integration reprogramming model as described in Section 2.1 above also apply, in general, to the base-case updating procedure, with the exceptions discussed below. Some additional concepts are also required for the base case.

2.2.1 Types of Subsystems

In the base-case processing, all subsystems are examined in order to get all schedules on the same relative time scale. Therefore, there is no equivalent to the non-reprogrammed system of the integration reprogramming model, nor are the concepts of schedule-peculiar and schedule-common subsystems applicable.

2.2.2 Time

The time period for which updated contractor data are input is designated T_I. This should be either September, December, March or June, which, in terms of the relative time variable k, corresponds to k = 3, 6, 9 or 12.

The concept of a limit to the number of time periods for which schedules are calculated as defined in Section 2.1.5 is also relevant to the base-case procedure. However, the maximum time, MT, may be changed at any T_I as long as $48 \leq MT \leq 132$ (all times relative) and MT is a multiple of 12. If such a change is made, two MT's must be input at base-case processing time, viz., a new MTA to be used for the ensuing three months and the old MTA established at the last quarterly updating, designated MTO. The MTO is required for reading pre-reprogrammed data tapes from the previous T_I; these tapes are used in the computation of new 3600 and 3010 costs. The new MT controls the reading of updated schedules and the writing of new pre-reprogrammed data tapes.

2.2.3 Types of Schedules Input

New monthly cumulative delivery schedules, called base schedules, are input at processing time for the propulsion and airborne electronics subsystems. These schedules run from the beginning of the year of T_I

[1] See Section 4.1.1.3 for complete description of these tables.

to the new MT, with the months prior to T_I shown as zero. They may be input in one of the following modes:

Mode A: Schedules input for each subsystem/system combination and for the subsystem total.

Mode B: A total subsystem schedule input for common subsystems, with the allocation to individual systems to be accomplished in the base-case procedure.

2.2.4 Costs

The updated delivery schedules are costed in the base-case procedure using contractor costing subroutines. The only costs required from the contractors and to be input in September, December, and March are the historical cumulative costs (non-recurring and recurring) from the beginning of the fiscal year in which T_I occurs, up to T_I. No historical costs are input when T_I (relative) = 12, i.e. June. Historical costs are required where T_I (relative) is less than 12, in order to provide an annual cost for the fiscal year.

2.3 Selected Subsystem Definitions

Each subsystem model is subdivided into a series of cost components for computation purposes. Within the models, schedules are computed and then, on the basis of these schedules, costs are computed and aggregated.

2.3.1 Cost Components

Airframe, propulsion, and airborne electronics subsystem cost components are aggregated into two categories, non-recurring and recurring. The other GFAE subsystem has recurring cost components only.

Non-recurring cost components are independent of quantity of production; examples are R&D costs such as basic engineering, engineering acceptance testing, production planning, non-recurring subcontracting, and flight testing. Recurring cost components are related to quantity; examples are production labor, production materials, recurring subcontracting, and sustaining engineering. Within the recurring cost category are two classes, A and B. Class A cost components are directly associated with delivery units, e.g., production labor. Class B cost components are not directly associated with delivery units, e.g., sustaining engineering.

Both non-recurring and recurring costs are obtained as the sum of appropriate cost components as listed above; a variable number of cost components may be summed to obtain the cost category.

2.3.2 Schedules

The types of schedules input to and output from the various subsystem models are defined in Section 2.1.6.

2.3.3 Costs

Costs of non-recurring cost components are estimated in the subroutines in the following fashion. The total cost for a component is computed by a modified hyperbolic function of the total time required to complete the component. The total cost is then allocated to time periods by a PEPTS (percent expenditures to percent time) curve which defines the expenditure rate over time.

The costs of recurring components are calculated according to a number of formulae representing the various components and subsystems.

3.0 MAJOR SUBSYSTEM MODELS

In this section, descriptions of the subsystem models as they relate to the integration reprogramming model are given. The base-case updating procedure also uses several of these models with only minor modifications. All costing subroutines are used by the base-case procedure to obtain updated costs. In addition, the base-case updating routine uses propulsion and airborne electronics maximum scheduling subroutines, modified to return to the integration routine both updated and gross maximum schedules.

The subsystem models have been programmed as nine major subroutines. The data required by these subroutines are organized on tapes in files, each file containing data for a particular subsystem.[1] For example, if there are ten airframe subsystems and twenty airborne electronics subsystems, there will be ten files with airframe contractor data and twenty files with airborne electronics subsystem data. The appropriate contractor tapes will have been positioned at the correct file and checked by the integration model before the contractor subroutines are entered.

The data required by each subroutine from the integration model and returned to the integration model are listed below.

3.1 Airframe Scheduling Subroutine

The airframe scheduling subroutine calculates a feasible reprogrammed airframe schedule under constraints of the reprogramming parameters, consistent with propulsion and airborne electronics subsystem capabilities. The airframe scheduling routine may be called by the integration routine in one of three modes. The calculations performed differ with the mode as follows:

(1) Mode 1 is the initial entry into the airframe scheduling routine using a preferred envelope (the result of translating the maximum schedules of each subsystem by preferred spares quantities, preferred lead times, and units per installation into airframes supportable schedules, and taking the minimum by time period of the schedules).

(2) Mode 2 is entered only if the preferred envelope cannot support the required airframe schedule calculated from the initial set of reprogramming parameters. A minimum envelope will have been calculated by means of integration from minimum spares quantities, minimum lead times, and units per installation. A feasible airframe schedule is calculated,

---

[1] A file is repositioned to its beginning regardless of whether a subsystem scheduling or costing subroutine is to be entered.

even if it is necessary to modify reprogramming parameters by delaying T_L' until $T_L max$ (the latest delay of T_L' possible) and then, if necessary, reducing N'.

(3) Mode 3 is entered only after a schedule has been calculated that is feasible based on schedule-peculiar subsystems, but subsequently has proved to be infeasible in terms of schedule-common subsystems.

The input and output data of the airframe scheduling routine are the following:

Data input to airframe scheduling subroutine

Mode signal

Contractor data tape unit name

T_I

T_D

MT

System number

T_G', T_F', T_L', N'

$T_L max$

Envelope

Data output from airframe scheduling subroutine

Reprogrammed airframe schedule

Feasibility signal (if schedule generated in Mode 1)

Modified reprogramming parameters (if applicable)

3.2 Airframe Costing Subroutine

The airframe costing subroutine has a simple interface with the integration routine. The data input to and output from this subroutine are the following.

Data input to airframe costing subroutine

Contractor data tape unit name

MT

System number

Reprogrammed schedule

Data output from airframe costing subroutine

Reprogrammed non-recurring costs for 20 periods (updated costs in the base case)

Reprogrammed recurring costs for 20 periods (updated costs in the base case)

3.3 Propulsion and Airborne Electronics Maximum Scheduling Subroutines

Although the model formulation for the calculation of maximum schedules differs between the propulsion and airborne electronics subsystems, the data input to these subroutines and output from them are the same, as follows:

Data input to maximum scheduling subroutines

Contractor data tape unit name

T_I

T_D

MT

Subsystem number

Data output from maximum scheduling subroutines

Gross maximum schedule

Updated schedules (for base case only)

T_1'

3.4 Propulsion and Airborne Electronics Smoothing Subroutines

These subroutines receive three schedules from the integration model, one of which is the total requirement. The requirements schedule is then smoothed so that for no time period is the cumulative delivery in the smoothed schedule less than the cumulative requirement. The data input to and output from these subroutines are as follows:

Data input to smoothing subroutines

Contractor tape unit name

T_I

T_D

MT

Subsystem number

Gross maximum schedule

Pre-reprogrammed total schedule

Total requirements schedule

Data output from smoothing subroutines

Total smoothed delivery schedule

3.5 Propulsion and Airborne Electronics Costing Subroutines

The costing subroutines for propulsion and airborne electronics subsystems may be entered in one of two modes. In one mode, costs are computed for a single system only, regardless of whether the subsystem is common. If the subsystem is Type B common, the costing subroutine is entered in this mode for each system. The second mode is used for Type A common subsystems. A total subsystem schedule and cost allocation factors are input. Costs for all systems used in the subsystem are calculated and allocated, and returned separately for each system. The data input to these subroutines, and output from them are as follows:

Data input to costing subroutines

Mode signal

Contractor data tape unit name

T_I

MT

Subsystem number

System number (all system numbers if Type A common)

System number of recipient of non-recurring costs

Smoothed subsystem schedule (single system if peculiar or Type B common; total schedule if Type A common)

Cost allocation factors (if Type A common)

Data output from propulsion and airborne electronics costing subroutines

Reprogrammed non-recurring and recurring costs for 20 periods (updated costs in base case)

3.6 Other GFAE Costing Subroutine

The other GFAE costing subroutine is the only subroutine for the other GFAE subsystem. The data input to and output from this subroutine are as follows:

Data input to other GFAE costing subroutine

Contractor data tape unit name

T_I
MT

Reprogrammed airframe schedule

Data output from other GFAE costing subroutine

Reprogrammed recurring costs for 20 periods (updated costs in base case)

4.0 AIRCRAFT INTEGRATION REPROGRAMMING MODEL

The aircraft integration reprogramming model coordinates the effect of reprogramming the various systems and their airframe propulsion, airborne electronics, and other GFAE subsystems.

Briefly, a set of possible reprogramming actions on an aircraft force structure is hypothesized. The scheduling portion of the integration model first identifies all subsystems associated with the reprogrammed systems, and then uses the propulsion and airborne electronics maximum scheduling subroutines to provide maximum schedules from which the requirements of non-reprogrammed systems are subtracted. Airframe schedules are then developed, restricted by the net maximum schedules of the appropriate subsystems translated into equivalent airframes supportable. Subsystem schedules are then calculated, based on these airframe schedules, and are smoothed by the contractor smoothing subroutines.

The costing section generates non-recurring and recurring costs using the schedules developed in the scheduling section. Such costs are then translated into the 3600 (formerly P600) and 3010 (formerly P100) Air Force budget categories. The costs for subsystems are accumulated with the appropriate airframe costs to obtain system costs. A report generator organizes the costs and schedules into reports designed for management review. In addition, data are prepared for input to the PROM translation routine.

Figure 2 shows the above data flow and the relationships among the integration reprogramming model and the subsystem scheduling and costing models.

The integration reprogramming model is described below. The input data requirements are presented in Section 4.1, which describes the data input on both magnetic tape and punched cards. Section 4.2 describes the scheduling procedure of the integration model. The costing procedure of the integration reprogramming model is presented in Section 4.3, and the report generator is described in Section 4.4.

4.1 Input Data Requirements

The data required by the integration model are (1) system reprogramming parameters, (2) pre-reprogrammed subsystem schedules and costs, and (3) other data such as subsystem/system inter-relationships. Some data are input on cards and are organized as tables in core memory; other data are maintained as records and files on magnetic tape. Section 4.1.1 describes the data organized on cards and stored in memory, while Section 4.1.2 describes the data maintained on magnetic tape.

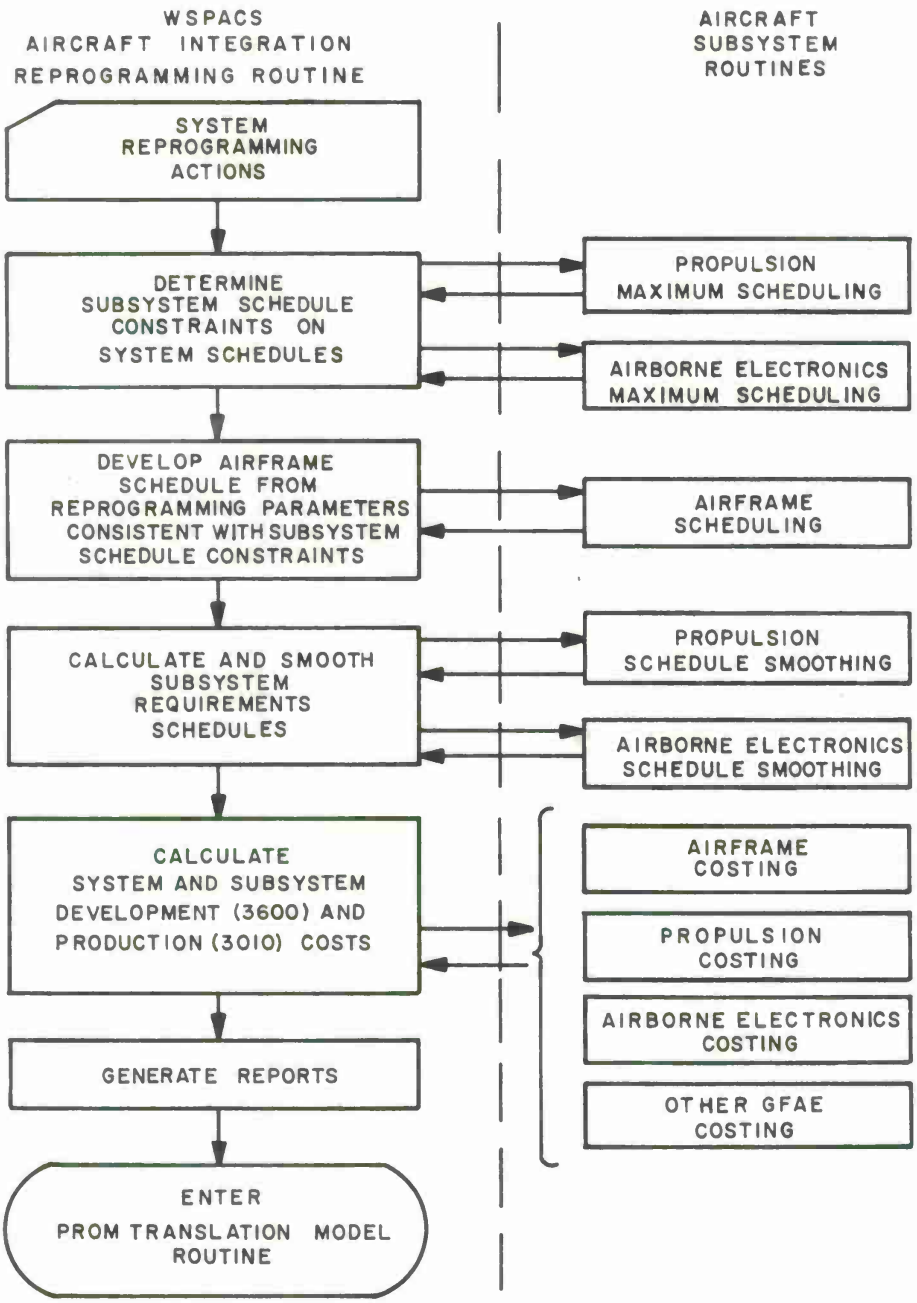

FIG. 2

WSPACS AIRCRAFT SYSTEM INTEGRATION REPROGRAMMING MODEL, SHOWING SUBSYSTEM SCHEDULING AND COSTING MODELS

4.1.1 Data Stored In Memory

Six data tables are read into core memory from cards -- REPS, ISYST, ISST1J, ISST1Z, SST2J, and SST2Z. With the exception of the REPS table, which identifies the reprogramming actions, the tables show the relationships between systems and subsystems, and usually remain constant unless systems are added to or deleted from the force structure.

4.1.1.1 REPS. REPS identifies those systems that are to be reprogrammed. This table contains the following information only for each system being reprogrammed:

(1) Reprogrammed system number

(2) T_G'

(3) T_F'

(4) T_L'

(5) N'

(6) $T_L max$

(7) P_i - fraction of flow time of airframe that must have been completed by T_D' to permit total completion in case of curtailment of quantity.

(8) Precedence number

4.1.1.2 ISYST. ISYST is organized by systems, i.e. airframes, and identifies for each system the propulsion and airborne electronics subsystems used on it. This table contains the following information for each system, whether reprogrammed or not:

(1) System number

(2) Number of (a) peculiar propulsion subsystems, (b) common propulsion subsystems, (c) peculiar airborne electronics subsystems, and (d) common airborne electronics subsystems used on this system.

(3-10) Subsystem numbers for subsystems referred to in (2).

4.1.1.3 ISST1J (Propulsion) and ISST1Z (Airborne Electronics). ISST1J and ISST1Z are subsystem tables which contain information similar to that in ISYST, but arranged in subsystem order. Thus, these tables identify for each subsystem all the systems associated with it. In addition, the tables contain a code for identifying Type A common subsystems and a non-recurring cost assignment code. The data are arranged as follows:

(1) Subsystem number and code for Type A common.

(2) Number of systems on which subsystem is used.

(3-5) System numbers and an identification of the system to which the non-recurring costs are assigned.

4.1.1.4 SST2J (Propulsion) and SST2Z (Airborne Electronics). SST2J and SST2Z contain subsystem data used to convert subsystem schedules to an equivalent airframe basis, and airframe schedules to an equivalent subsystem basis. Thus, there exists for each subsystem/system combination an entry as follows:

(1) Subsystem number.

(2) System number.

(3) Units per system installed.

(4) Parameters for calculating preferred lead time for installed and spare units, and preferred coefficients for the calculation of the spares requirements.

(5) Parameters for calculating minimum lead times for installed and spare units, and minimum coefficients for the calculation of spares requirements.

4.1.2 Data Stored On Tapes

The integration model reads data from six input data tapes. Three tapes contain the data used by the contractor subroutines for calculating schedules and costs. The other three contain pre-reprogrammed schedules and costs of the airframe, propulsion, airborne electronics, and other GFAE subsystems. The data for the other GFAE subsystems appear on the same tapes as the data for the airborne electronics subsystems. The data on all tapes are organized by files.

In addition to one file for each subsystem, dummy files are stored to facilitate tape manipulation. For example, if there are ten airframes, numbers 101, 110, 115, 123, etc., there will be dummy files for 102 through 109, 111 through 114, etc., so that the file for airframe number 110 is the tenth file on the tape. All six tapes are arranged in this fashion. The first file for the other GFAE subsystem is the fifty-first file on the tape shared with the airborne electronics subsystems.

The data appearing on the integration tapes and relevant data on the contractor tapes are listed below. These tapes will have been prepared during the base-case updating procedure.

4.1.2.1 Pre-Reprogrammed Airframe Tape. The following data appear in each file of the airframe tape:

(1) Airframe number.

(2) Pre-reprogrammed schedule for MT months.

(3) Non-recurring costs for 20 time periods.

(4) Recurring costs for 20 time periods.

(5) 3600 costs for 20 time periods.

(6) 3010 costs for 20 time periods.

(7) The system nomenclature, represented by 12 alphanumeric characters.

(8) Pre-reprogrammed parameters T_G, T_F, T_L, and N, the total number of airframes scheduled to be produced.

If no data exist for a system, i.e., the system is non-existent, the file merely contains the airframe number with a "no data" flag.

4.1.2.2 Pre-Reprogrammed Propulsion and Airborne Electronics Tapes. The formats of the files of the two tapes for the pre-reprogrammed propulsion and airborne electronics subsystems are similar, differing only in the inclusion of the other GFAE files on the airborne electronics tape starting with file 51.

The following data appear in each file for propulsion and airborne electronics subsystems:

(1) Subsystem number.

(2) Number of schedules and costs following. A total schedule and total cost will always appear, even if the subsystem is peculiar.

(3) Total pre-reprogrammed schedule for MT months.

(4) System number and pre-reprogrammed schedule for MT months for each relevant system.

(5) Total non-recurring, recurring, 3600, and 3010 costs.

(6) System number and non-recurring, recurring, 3600, and 3010 costs for each relevant system.

If no data exist for a subsystem, the file contains merely the subsystem number with a "no data" flag.

The files for the other GFAE subsystem contain the following data:

(1) Other GFAE number.

(2) Pre-reprogrammed airframe schedule for MT months.

(3) 3010 costs.

If no data exist for a subsystem, the file contains merely the subsystem number with a "no data" flag.

4.1.2.3 Contractor Tapes. The first record in each contractor file is the subsystem number. This record is read by the integration program to check that the correct tape has been positioned at the proper file for use by the appropriate contractor subroutine. Following this record in each file are the parameters, schedules, and other data required by the subroutines.

4.2 Integration Scheduling Procedure

The computer programs for the scheduling procedure have been written in four large overlapping programs called chains. All calculations in one chain are completed before the instructions for the next chain are brought into core memory to overlap the instructions of the previous chain. The scheduling procedure is described in a series of steps with respect to each of these chains. Flow charts[1] are presented for Chains 3 and 4, to aid in understanding the program logic. It was necessary to chain the program because the contractor subroutines were too large for all to be stored in core memory at one time. However, the tables listed in Section 4.1.1 are in core memory for all chains.

4.2.1 Chain 1

All propulsion and airborne electronics subsystems used on reprogrammed systems are identified as either schedule-peculiar or schedule-common. Maximum schedules are then calculated for each of these subsystems. The steps of this chain are as follows:

1. Read from cards the six data tables (REPS, ISYST, ISST1J, ISST1Z, SST2J, SST2Z).

2. Identify all schedule-peculiar and schedule-common propulsion and airborne electronics subsystems using REPS and ISYST.

3. Compute gross maximum schedules for all schedule-peculiar and schedule-common propulsion systems using the propulsion maximum scheduling subroutine.[2]

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[1] All flow charts conform to MIL-STD-682A.

[2] All contractor subroutines will be underlined when mentioned.

4. Compute gross maximum schedules for all schedule-peculiar and schedule-common airborne electronics subsystems using the airborne electronics maximum scheduling subroutine.

5. Subtract from the propulsion gross maximum schedules the delivery requirements associated with non-reprogrammed systems, obtaining net maximum schedules.

6. Subtract from the airborne electronics gross maximum schedules the delivery requirements associated with non-reprogrammed systems, obtaining net maximum schedules.

7. Write all net maximum schedules on scratch tapes,[1] and go to Chain 2.

4.2.2 Chain 2

New airframe schedules are developed for each reprogrammed system, restricted by the net maximum schedules of the schedule-peculiar propulsion and airborne electronics subsystems up to MT, and also restricted by subsystem/system schedules of the schedule-common propulsion and airborne electronics subsystems to T_1', the time after which acceleration of the subsystem schedule can occur. The latter restriction represents a non-interchangeability of subsystem units among systems using the same subsystem during the early portion of the schedule following T_D.

The steps in this chain are performed serially for each reprogrammed system; i.e., all steps are performed for the first reprogrammed system, then all for the next reprogrammed system, etc. Steps 1 and 2 are performed serially for all subsystems associated with a reprogrammed system before proceeding to Step 3.

The steps are as follows:

1. Perform a quantity and lead-time translation on a net maximum schedule,[2] i.e., convert the subsystem schedule to airframes supportable, for a subsystem associated with the reprogrammed system, using preferred lead time and spare coefficients. If the subsystem is schedule-peculiar, the schedule conversion is from T_I to MT[3]; if the subsystem is schedule-common, the schedule conversion is from T_I to T_1' on the pre-reprogrammed subsystem/system schedule.

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[1] Scratch tapes are tapes that are used as an intermediate storage medium to retain from one chain to the next data that otherwise might be lost.

[2] It should be noted that all schedules are cumulative.

[3] Time units are relative in this case rather than absolute.

2. Calculate a preferred envelope from the monthly minima of the translated schedules. Repeat Steps 1 and 2 for all subsystems associated with a particular reprogrammed system.

3. Calculate the airframe delivery schedule using the airframe scheduling subroutine (Mode 1). An infeasibility signal is returned from the airframe scheduling routine if the envelope is less in any month than the schedule to be generated from the reprogramming parameters.

4. If the infeasibility signal is set, set a signal that minimum parameters are being used and go to Step 5. If it is not, go to Step 7.

5. Perform Steps 1 and 2 using the minimum lead time and spare coefficients. A minimum envelope is thus calculated.

6. Calculate a feasible airframe delivery schedule using the airframe scheduling subroutine (Mode 2). During this process, reprogramming parameters may be modified by the subroutine.

7. Store the airframe schedule, and go to Step 1 for the next reprogrammed system, or to Chain 3 if no reprogrammed systems remain to be processed.

4.2.3 Chain 3

The schedule-common subsystem schedules are checked to MT to determine whether their net maximum schedules are compatible with the airframe reprogrammed schedules developed in Chain 2. The checking of these schedule-common subsystems will thus complete the feasibility check of all subsystems. While the checking in Chain 2 proceeded by reprogrammed systems, Steps 1 through 5 in Chain 3 are performed serially for each schedule-common subsystem. The flow chart for Chain 3 is shown in Fig. 3. The numbers in each box in the figure correspond to the corresponding step of the narrative.

The steps in Chain 3 are as follows:

1. Calculate a preferred subsystem requirements schedule as the sum of appropriate airframe schedules, each translated by preferred lead times and preferred spares coefficients; i.e., the airframe schedules are converted to the same basis as the subsystem schedule.

2. Compare the preferred subsystem requirements schedule calculated in Step 1 with the net maximum schedule calculated in Chain 1. If the net maximum schedule is less than the preferred requirements schedule, the latter is infeasible; set a signal that minimum parameters are to be used and go to Step 3. If the net maximum schedule is greater, go to Step 5.

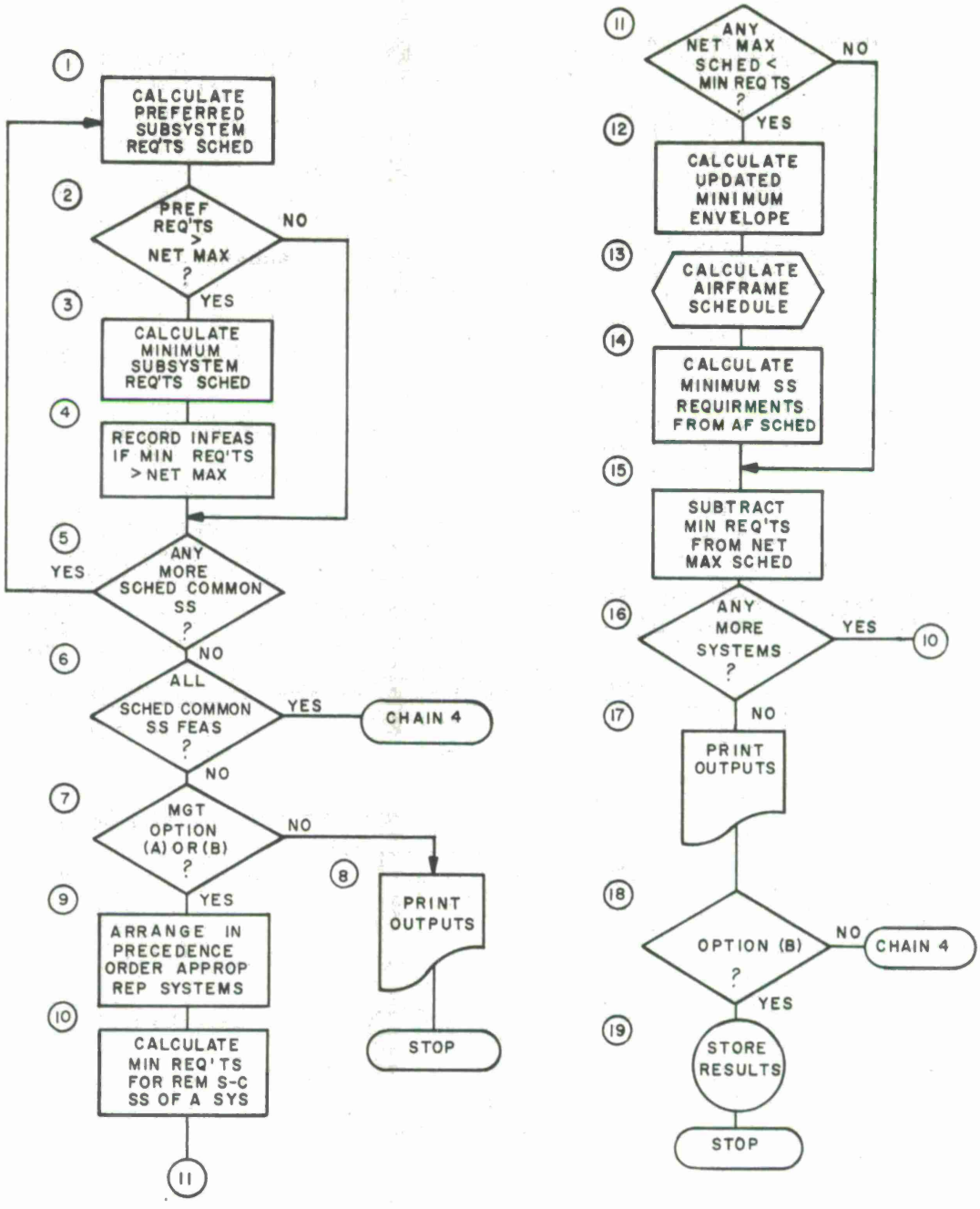

FIG. 3

FLOW CHART FOR CHAIN 3 — REPROGRAMMING MODEL

3. Calculate a minimum subsystem requirements schedule similar to Step 1, using minimum coefficients rather than preferred.

4. Record an infeasibility if the net maximum schedule is still less than the minimum subsystem requirements schedule calculated in Step 3.

5. Go to Step 1 for the next schedule-common subsystem or to Step 6 if all schedule-common subsystems have been checked.

6. If all schedule-common subsystems are feasible, go to Chain 4. If not, go to Step 7.

7. If either management option (a) or (b) is desired, go to Step 9; if neither, go to Step 8.

8. Option (c): Print net maximum schedule for the subsystem, the requirements for the subsystem per unit for each pertinent system, airframe delivery schedules for each pertinent system, system precedence, and time-phased excess requirements. Store results of computations through Step 5 and halt program. The problem may be reformulated, returning to Chain 1, or the option may be changed[1] to (a) or (b) and the program returned to Step 9 (a system precedence table must be made available in REPS if not previously provided).

Steps 9-19 are the steps in management options (a) and (b) (see Section 2.1.7). These have not yet been incorporated into the current operating version of the WSPACS computer program, so the computer program currently branches unconditionally to Step 8.

9. Arrange, according to the system precedence order,[2] all reprogrammed systems associated with all schedule-common subsystems that have infeasible minimum required schedules.

Steps 10 through 16 are performed serially, starting with the highest precedence (most important) system in the arrangement, and ending with the lowest precedence system associated with a reprogrammed schedule-common subsystem.

10. Calculate the minimum requirements for <u>all</u> schedule-common subsystems associated with the system. (Note that <u>all</u> now includes those schedule-common subsystems whose schedules are feasible as well as those whose schedules are infeasible).

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[1] Not possible with computer program as now written.

[2] See Section 2.1.7 for definition.

11. If any net maximum schedules are less than the minimum requirements for these subsystems, go to Step 12; otherwise, go to Step 15.

12. Consider all schedule-common subsystems as if they are schedule-peculiar. Calculate an updated minimum envelope for all subsystems based on modified net maximum subsystem schedules (the modified schedules are used because the net maximum schedules may have been reduced by requirements of higher precedence systems in Step 15 below).

13. Calculate an airframe schedule using airframe scheduling subroutine (Mode 3). Modify reprogramming parameters if necessary.

14. Calculate minimum requirements for each schedule-common subsystem, using the new schedule.

15. Subtract minimum requirements from net maximum schedule for each relevant subsystem.

16. If last system, go to Step 17; if not, go to Step 10 with next system.

17. Present the original net maximum schedule for each constrained common subsystem, the airframe delivery schedule for each pertinent system before and after revisions of this chain, and reprogramming parameters before and after revisions of this chain.

18. If option (a) is desired, go to Chain 4; if option (b), go to Step 19.

19. Store results, stop, and await management decision either to continue to Chain 4 or to modify reprogramming parameters and repeat all calculations with another WSPACS run starting at Chain 1.

4.2.4 Chain 4

In entering Chain 4, airframe schedules have been obtained which are consistent with all propulsion and airborne electronics net maximum subsystem schedules. In Chain 4, subsystem requirements schedules are calculated from the airframe schedules and are then smoothed by contractor smoothing subroutines. The total subsystem schedule is smoothed for a common subsystem. The integration routine allocates the smoothed subsystem schedules to the different reprogrammed systems, and establishes allocation factors for assigning costs to the appropriate systems for Type A common subsystems.

Calculations are performed serially over all steps, first for all reprogrammed propulsion subsystems and then for all reprogrammed airborne electronics subsystems.

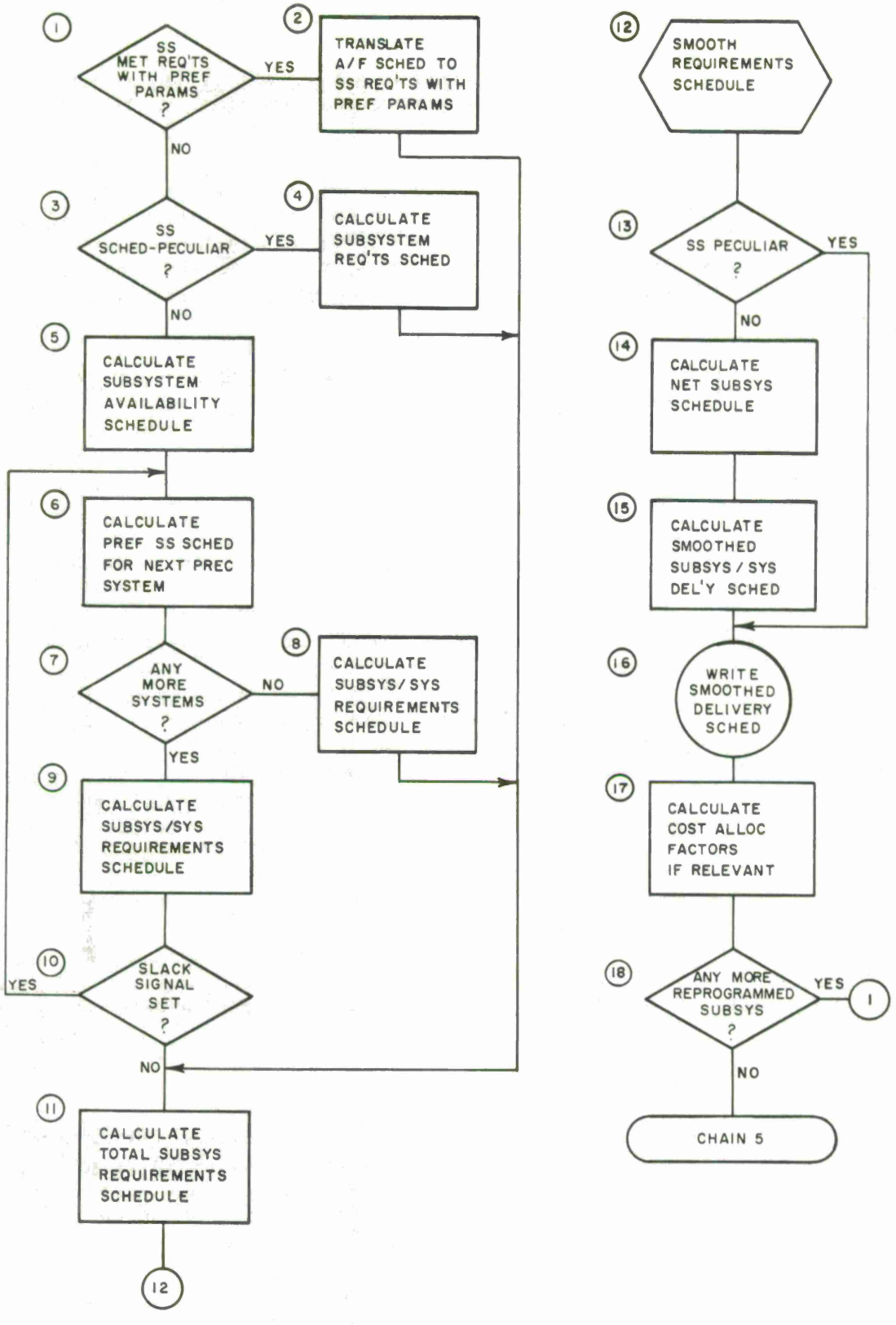

FIG. 4

FLOW CHART FOR CHAIN 4 - REPROGRAMMING MODEL

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The object of Steps 1 through 11 in Chain 4 is to calculate requirements schedules for propulsion and airborne electronics subsystems from final calculated reprogrammed airframe delivery schedules, using appropriate spares coefficients and lead times. These are totaled along with requirements for non-reprogrammed systems. The flow chart for Chain 4 is shown in Fig. 4. The numbers on each box in the figure correspond to the steps of the narrative. The steps in Chain 4 are as follows:

1. If the subsystem schedule satisfied requirements with preferred parameters for lead times and spare quantities, go to Step 2. If not, go to Step 3.

2. Translate each reprogrammed airframe schedule (only one, if schedule-peculiar) to subsystem requirements using preferred parameters. Go to Step 11.

3. If the subsystem is schedule-peculiar, go to Step 4; if not, go to Step 5.

4. Translate the appropriate airframe schedule to a subsystem basis using preferred parameters. The subsystem/system requirements schedule for each time period is the minimum of the calculated subsystem schedule and the net maximum subsystem schedule. Go to Step 11.

5. Calculate and store minimum subsystem schedules for systems other than the highest precedence system. Sum minimum schedules and subtract the sum from the subsystem net maximum schedule to obtain a subsystem availability schedule.

6. Calculate a preferred subsystem schedule for the (next) highest precedence system.

7. If another system remains, go to Step 9; if not, go to Step 8.

8. Calculate the requirements schedule for each period as the minimum of the preferred schedule and the availability schedule. Go to Step 11.

9. Calculate the requirements schedule for each time period as the minimum of the preferred schedule and the availability schedule. Set a slack signal if, for any time period, the preferred schedule has been selected. Add the difference to the minimum subsystem schedule for the next highest precedence system to obtain an availability schedule which can be allocated to the remaining reprogrammed systems for that subsystem.

10. If slack signal has not been set, go to Step 11, since the minimum subsystem schedules for the remaining systems are the requirements schedules; if it has, reset slack signal and go to Step 6.

11. Sum requirements schedules, and add requirements for non-reprogrammed systems to obtain the subsystem total requirements.

12. Calculate a smoothed reprogrammed delivery schedule using the propulsion (or airborne electronics) smoothing subroutine.

The purpose of Steps 13 to 15 is to allocate a smoothed total subsystem delivery schedule for common subsystems to the appropriate systems.

13. If subsystem is peculiar, go to Step 16; if not, go to Step 14.

14. Subtract the non-reprogrammed system requirements from the total subsystem smoothed schedule and from the total subsystem requirements schedule, obtaining a net smoothed schedule and a net total requirements schedule. Set the smoothed subsystem/system schedules equal to the pre-reprogrammed schedules for non-reprogrammed systems.

15. Proceed backwards from last time period, comparing the net total smoothed schedule with the net total requirements schedule. If the two are equal, set the subsystem/system smoothed schedules equal to the subsystem/system requirements schedules. If they are unequal (in which case the net smoothed schedules must be greater than the net requirements), allocate the difference to the subsystem/system requirements schedules to obtain subsystem/system smoothed, i.e., reprogrammed, schedules.

16. Write final delivery schedules for total and all subsystem/system schedules on tape.

17. Calculate cost allocation factors for Type A common subsystems for each month in which there is a positive subsystem delivery rate (see Section 2.1.1 for definition of Type A).

18. If another reprogrammed subsystem, go to Step 1; if not, go to Chain 5.

4.3 Integration Cost Procedure

The costs for airframes, propulsion, airborne electronics, and other GFAE subsystems are each obtained in separate chains, since the contractor costing subroutines are each quite large.

The contractor subroutines generate costs based on schedules calculated in Chain 4. The integration model aggregates these costs into total system costs, calculates changes from the pre-reprogrammed costs and revises the costs in the 3600 and 3010 budget categories for each system.

4.3.1 Chain 5 -- Airframe Costing

Steps 1 through 5 are performed serially for each reprogrammed airframe, as follows:

1. Obtain pre-reprogrammed airframe schedules and costs, and reprogrammed airframe schedules from appropriate tapes.

2. Calculate 20 non-recurring and recurring costs using the airframe costing subroutine.

3. Calculate new 3600 and 3010 costs from the new and the pre-reprogrammed costs, starting system total cost accumulations for the 20 periods.

4. Reduce the delivery schedules to 20 time periods for output and to 11 annuals for PROM; store appropriate schedule and cost information on tape.

5. Go to Step 1 for next reprogrammed system, or to Chain 6 if all airframes have been costed.

4.3.2 Chain 6 -- Propulsion Costing

Steps 1 through 6 are performed serially for each reprogrammed propulsion subsystem, as follows:

1. Obtain pre-reprogrammed subsystem schedules and costs, and reprogrammed subsystem schedules from appropriate tapes.

2. Calculate 20 non-recurring and recurring costs using the propulsion costing subroutine. If the subsystem is Type B common, enter the costing routine separately for each system.

3. Calculate new 3600 and 3010 costs from the new and pre-reprogrammed costs.

4. Update system total cost matrices.

5. Reduce the delivery schedules to 20 time periods for output and store the appropriate schedule and cost information on tape.

6. Go to Step 1 for next reprogrammed subsystem or to next chain if all subsystems have been costed.

4.3.3 Chain 7 -- Airborne Electronics

Steps 1 through 6 are performed serially for each reprogrammed airborne electronics subsystem, as follows:

1. Obtain pre-reprogrammed subsystem schedules and costs, and reprogrammed subsystem schedules from appropriate tapes.

2. Calculate 20 non-recurring and recurring costs, using the airborne electronics costing subroutine. If the subsystem is Type B common, enter the costing routine separately for each system.

3. Calculate new 3600 and 3010 costs from the new and pre-reprogrammed costs.

4. Update system total cost matrices.

5. Reduce the delivery schedules to 20 time periods for output and store the appropriate schedule and cost information on tape.

6. Go to Step 1 for next reprogrammed subsystem or to next chain if all subsystems have been costed.

4.3.4 Chain 8 -- Other GFAE

Steps 1 through 5 are performed serially for each reprogrammed airframe.

1. Obtain pre-reprogrammed airframe schedule and other GFAE costs, and reprogrammed airframe schedules from tape.

2. Calculate 20 3010 costs, using the other GFAE costing subroutine.

3. Update system total cost matrix.

4. Store appropriate other GFAE cost data on tape.

5. Go to Step 1 if more systems or to Step 6 if no more.

6. Write PROM tape with airframe schedules and 3600 and 3010 costs by system and by year for 11 years. Go to Chain 9 for output.

4.4 Chain 9 -- Report Generator

The reprogrammed schedules and costs obtained from a WSPACS run are organized in Chain 9 into a set of reports for analysis and decision making. These reports are in four sets at four different levels of detail from total force structure to subsystem, with the following titles:

WSPACS Summary

Aircraft Summary

Aircraft Detail

Common Subsystems

The Aircraft Detail is the only report currently operational -- the others have been deferred pending completion of programming of additional relevant portions of the model, in particular the WSPACS-PROM interface which is needed to obtain operating costs, and the portions of the contractor subroutines that deal with common subsystems.

All reports will have identical columns; that is, costs and schedules are shown for three years quarterly and for the following eight years annually, making a total of 20 entries. The restriction of 132 characters to a line requires that the quarters be shown in one row and the years in the next. Each row is subdivided into three lines -- Base, Reprogrammed, and Difference -- to reflect not only the reprogramming action itself but also its incremental impact. Each set of reports is presented twice: first, with cumulative costs and schedules shown, and second, with rates shown.

4.4.1 WSPACS Summary Report

The WSPACS Summary Report, when programmed, will show total force structure costs subdivided into system and non-system costs. The former will be further subdivided into total costs for aircraft systems, missile systems, space systems, and electronic (or "L") systems. Within these four system categories total development, production, and operating costs will be shown.

4.4.2 Aircraft Summary Report

The Aircraft Summary Report, when programmed, will contain the following data for each aircraft system being reprogrammed:

(1) Reprogramming parameters before and after reprogramming, and as modified in Chains 2 and 3.

(2) Total aircraft system costs.

(3) Development, production, and operating costs.

(4) System delivery schedule.

4.4.3 Aircraft Detail Report

The Aircraft Detail Report is currently operational in Chain 9 of the reprogramming model and, with the modifications described in Section 5.2.6, is also operational in Chain 6 of the base-case model. The report for each reprogrammed aircraft system, (see sample, Appendix C) presents reprogramming parameters, total system costs, other GFAE costs, and airframe, propulsion, and airborne electronics costs and schedules. Three sets of reprogramming parameters are shown in the report:

(1) The base-case parameters as of the latest T_I.

(2) The reprogramming parameters input at the beginning of the WSPACS run.

(3) Final reprogramming parameters, which, because of possible changes in T_F' or T_L' or reductions in N' by the airframe scheduling subroutine in Modes 2 and 3, may be different from those input.

Costs, except those of the other GFAE subsystem, are subdivided into development and production costs (Air Force budget codes 3600 and 3010, respectively). The 3600 and 3010 budget categories are related, but not necessarily identical, to the categories of non-recurring and recurring costs, as described in Section 2.1.8. There are no development costs for the other GFAE subsystem, nor is there an independent schedule.

In the event that there is more than one airborne electronics subsystem associated with the reprogrammed system, a total airborne electronics cost -- development and production -- is shown, as well as costs and schedules for each individual subsystem.

5.0 BASE-CASE PROCEDURE

The WSPACS base-case procedure is designed for use every three months as part of the quarterly updating process by which the data in the WSPACS model are kept current.

The updating process itself consists of the following steps:

(1) Key punching and verification of data received from contractors and the Air Force.

(2) Generation of new contractor tapes after appropriate verification checks have been made.

(3) Generation of new integration tapes after appropriate consistency checks have been made. This is the base-case procedure described below.

The data referred to in (1) consist of:

(a) Cumulative costs from the beginning of the fiscal year in which T_I occurs to T_I unless T_I is June.

(b) Updated parameters from both the contractors and the Air Force.

(c) Revised monthly delivery schedules from T_I forward for the remainder of the fiscal year of T_I and additional months up to a specified limit (MT).

The verification checks referred to in (2) above are specified by those responsible for the contractor subroutines.

The base-case procedure checks the consistency of the new propulsion and airborne electronics base-case schedules with their maximum schedules (internal consistency) and also with their relevant airframe schedules (external consistency). The entire schedule-consistency check procedure runs without stopping through all propulsion and airborne electronics subsystems. Certain types of inconsistencies are corrected and produce printed comments as they occur. If no schedule inconsistencies have occurred, the program continues on to a cost generation procedure; if there have been schedule inconsistencies, however, the program halts after completing the schedule consistency check procedure for all subsystems, in order to permit evaluation of the discrepancies and correction. After successful completion of the scheduling procedure, the program generates costs, creates new pre-reprogrammed data tapes, produces reports using the report generator routine, and produces a tape for input to the PROM base-case run. No special updating program is required for PROM as it contains its own built-in base-case procedure.

5.1 Input Data Requirements

The data required by the base-case procedure are input on both cards and tape as in the reprogramming model. The card input is essentially the same as in the reprogramming model, with the addition of the updated airframe schedules. Tape input includes the new contractor tapes and the pre-reprogrammed tapes from the previous updating.

The base-case procedure is the final step in the WSPACS quarterly updating process. A very thorough screening, checking, and testing of the numerous contractor and Air Force inputs should be made before operation is attempted.

5.1.1 Card Inputs

The same six tables that are used in the integration model are read from cards in the base-case procedure.[1] The tables ISYST, ISST1J, ISST1Z, SST2J, and SST2Z are identical to those of the reprogramming model. The REPS table, however, contains different information in the base-case procedure.

Since all systems are examined in the base case, there are no reprogrammed systems to be listed in REPS. The list of systems being processed is still required, however. Consequently, all systems are listed in REPS with the parameters T_G, T_F, T_L, and N entered in the REPS cards reflecting the base-case airframe schedules being processed. These parameters are written on the new pre-reprogrammed tapes so that they subsequently appear in the reprogramming model output as the values before reprogramming.

The other major card input is the set of new airframe schedules supplied by the contractors.

5.1.2 Tape Input

The base-case procedure reads input data from six tapes -- three contractor tapes and three pre-reprogrammed tapes -- as in the reprogramming model. The difference in this case is that the contractor tapes are the new tapes generated at T_I, while the pre-reprogrammed tapes used are those from the previous T_I.

5.1.2.1 Pre-Reprogrammed Tapes. The three pre-reprogrammed tapes used in the base-case procedure are identical to the reprogramming model tapes.[2] Physically, however, these three are copies of the actual tapes used during the previous three months, made just before the updating process started. The reason for using copies is that the old

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[1] See Section 4.1.1 for descriptions of these tables.

[2] See Sections 4.1.2.1 and 4.1.2.2.

pre-reprogrammed information is erased during the processing, and the new pre-reprogrammed data are written on the same tapes. Unless copies of the tapes are made, the old data would no longer be in existence for use in the event that the new data should prove incorrect.

5.1.2.2 Contractor Tapes. The three contractor tapes -- airframe, propulsion, and airborne electronics/other GFAE -- are the same tapes used by the reprogramming model, physically as well as in content. In the reprogramming model, the integration routine is concerned with only the first record of each file, i.e., the subsystem number for proper positioning of the tape. In the base-case procedure, the first record is still used for positioning the tape at a subsystem to be processed, but the updated contractor schedules are also required by the base-case integration routine. Consequently, the maximum scheduling sub-routines are modified to read the schedules into an area where they are accessible to the base-case integration program. If the subsystem is peculiar, a single schedule is input; if common, a total schedule is input plus, for Mode A[1] only, a schedule for each subsystem/system combination. These schedules[2] are all in months from the beginning of the year of T_I to MT, the periods before T_I being set to zero.

5.2 Base-Case Scheduling and Costing Procedures

The base-case procedure computer program has been organized into six large overlapping programs called chains. The first chain performs the external and internal consistency checks on each propulsion and airborne electronics subsystem. After any schedule inconsistencies have been resolved, the program proceeds to the cost generation routines. The flow chart for Chain 1 is shown in Fig. 5; the numbers on each box in the figure correspond to the steps of the narrative. As in the reprogramming model, the cost generation routines are in four separate chains; additional routines are included to produce new pre-reprogrammed tapes. The final chain is a report-generator chain similar to that of the reprogramming model.

5.2.1 Chain 1

The propulsion and airborne electronics base schedules are compared with their own maximum schedules and with relevant airframe schedules to insure consistency of data. This is accomplished by the following steps:

1. Read from cards six data tables (REPS, ISYST, ISST1J, ISST1Z, SST2J, SST2Z) and the updated airframe schedules. Write the airframe schedules on a base schedule tape for later use.

Steps 2 through 17 are performed first for all propulsion subsystems and then for all airborne electronics subsystems. Tables ISST1J and ISST1Z are used to indicate existence of a subsystem for processing purposes.

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[1] See Section 2.2.3 for the definition of Mode A.

[2] Referred to below as base schedules.

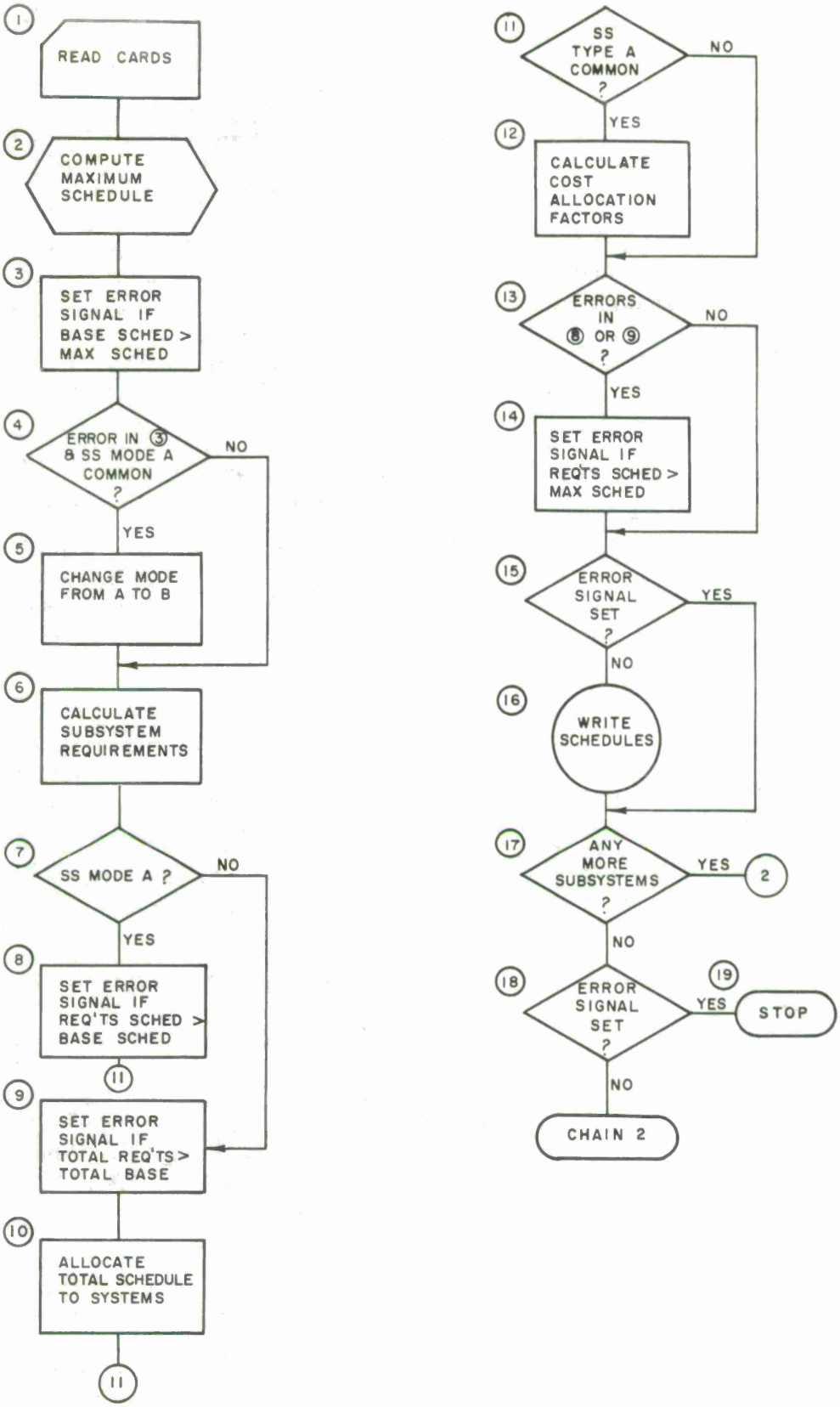

FIG. 5

FLOW CHART FOR CHAIN 1 - BASE-CASE MODEL

2. Compute a maximum schedule for the subsystem, using the subsystem maximum schedule subroutine. In addition, obtain the subsystem base schedule(s) from this subroutine.

3. Compare the total base schedule[1] against the maximum schedule. If the maximum schedule is less than the base schedule for any time period, set the base schedule equal to the maximum schedule for that period, print a comment to that effect, and set the master error signal.

4. Go to Step 5 if adjustments were made in Step 3, and if the subsystem is Mode A common, i.e. there are subsystem/system schedules as well as a total schedule; otherwise, go to Step 6.

5. Change the subsystem designation from Mode A to Mode B.

6. Calculate minimum subsystem requirements by translating the relevant airframe schedules by minimum lead times and spares quantities to obtain requirements schedules and, if the subsystem is common, total over systems to obtain a total subsystem requirements schedule.

7. Go to Step 8 if the subsystem is Mode A; otherwise, go to Step 9.

8. Compare the subsystem base schedule for a particular system with its associated requirements schedule. If the requirements schedule is greater than the base schedule in any time period, set the base schedule equal to the requirements schedule for that period and increase the total base schedule by the amount of the deficiency. Also print a comment and set the master error signal. Go to Step 11.

9. Compare the total base schedule with the total requirements schedule. If the total requirements schedule is greater than the total base schedule for any time period, set the total base schedule equal to the total requirements schedule for that period, print a comment, and set the master error signal.

10. Allocate the total base schedule to obtain individual subsystem/system base schedules for each relevant system. The allocation is performed in a manner similar to that of Step 15 of Chain 4 of the reprogramming model (see Section 4.2.4).

11. Go to Step 12 if the subsystem is Type A common, i.e., the costs for this subsystem are generated from a total schedule and then allocated to subsystem/system schedules; otherwise, go to Step 13.

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[1] For peculiar subsystems, the total and the subsystem/system schedule are, of course, identical.

12. Calculate cost allocation factors in a manner similar to Step 17 of Chain 4 in the reprogramming model (see Section 4.2.4).

13. Go to Step 14 if inconsistencies were discovered in Steps 8 or 9; otherwise, go to Step 15.

14. Compare the total requirements schedule with the maximum schedule. If the total requirements schedule is greater than the maximum schedule for any time period, print a comment to that effect and set the master error signal.

15. Go to Step 17 if the master error signal has been set; otherwise go to Step 16.

16. Write the base schedule(s) and, if relevant, the cost allocation factors on the scratch tape.

17. Go to Step 2 for the next subsystem or to Step 18 if no more propulsion or airborne electronics subsystems.

18. Go to Chain 2 if the master error signal has not been set in any step by any subsystem; otherwise, stop program.

5.2.2 Chain 2 -- Airframe Costing

The airframe costing chain generates costs from the base schedule input in Chain 1, starts total system cost aggregations, revises the 3600 and 3010 costs, and creates a new pre-reprogrammed airframe tape.

Steps 1 through 6 are performed serially for each airframe, as follows:

1. Obtain the old pre-reprogrammed airframe schedule and costs from old pre-reprogrammed airframe tape, and the new base schedule from the base schedule tape.

2. Enter airframe costing subroutine to obtain non-recurring and recurring costs -- three years by quarters and eight years annually.

3. Compute new 3600 and 3010 costs from the new base and old pre-reprogrammed costs.

4. Reduce the schedules to the 20 time periods for output and 11 annuals for PROM, start system total cost accumulations, and write the schedule and cost information on the output tape.

5. Write appropriate data on the new pre-reprogrammed airframe tape.

6. Go to Step 1 for next airframe or to Chain 3 if all airframes have been costed.

5.2.3 Chain 3 -- Propulsion Costing

Steps 1 through 7 are performed serially for each propulsion subsystem as follows:

1. Obtain the old pre-reprogrammed propulsion schedules and costs from the old pre-reprogrammed propulsion tape and the new base schedule from the base schedule tape.

2. Enter propulsion costing subroutine to obtain non-recurring and recurring costs. If the subsystem is Type B common, enter the subroutine separately for each system.

3. Calculate new 3600 and 3010 costs from the new base and the old pre-reprogrammed costs.

4. Update the system total cost matrix.

5. Reduce the schedules to 20 time periods for output and write the schedule and cost information on the output tape.

6. Write appropriate data on the new pre-reprogrammed propulsion tape.

7. Go to Step 1 for the next subsystem or to Chain 4 if all propulsion subsystems have been costed.

5.2.4 Chain 4 -- Airborne Electronics Costing

Steps 1 through 7 are performed serially for each airborne electronics subsystem, as follows:

1. Obtain the old pre-reprogrammed airborne electronics schedules and costs from the old pre-reprogrammed airborne electronics tape and the new base schedule from the base schedule tape.

2. Enter airborne electronics costing subroutine to obtain non-recurring and recurring costs. If the subsystem is Type B common, enter the subroutine separately for each system.

3. Calculate new 3600 and 3010 costs from the new base and the old pre-reprogrammed costs.

4. Update the system total cost matrix.

5. Reduce the schedules to 20 time periods for output and write the schedule and cost information on the output tape.

6. Write appropriate data on new pre-reprogrammed airborne electronics tape.

7. Go to Step 1 for next subsystem or to Chain 5 if all airborne electronics subsystems have been costed.

5.2.5 Chain 5 -- Other GFAE

Steps 1 through 6 are performed serially for each other GFAE subsystem, as follows:

1. Obtain the old pre-reprogrammed airframe schedule and other GFAE costs from the old pre-reprogrammed other GFAE tape (files 51 to 100 of the airborne electronics tape), and the new base airframe schedule from the base schedule tape.

2. Enter the other GFAE costing subroutine to obtain 20 3010 costs.

3. Update the system total cost matrix.

4. Write other GFAE cost data on the output tape.

5. Write appropriate data on new pre-reprogrammed other GFAE tape.

6. Go to Step 1 for next subsystem, or to Step 7 if all subsystems have been costed.

7. Write PROM tape with airframe schedules and 3600 and 3010 costs by system and by year for 11 years. Go to Chain 6 for output.

5.2.6 Chain 6 -- Output

Format output reports are prepared in Chain 6. These are in addition to the various comments and diagnostics printed in Chains 1 through 5. The output reports are similar in format to the Aircraft Detail reports of the reprogramming model. However, instead of showing the base-case and the reprogrammed schedules and costs, the reports show the new base and the previous base. Also, instead of base-case, reprogrammed and WSPACS modified reprogramming parameters, there are only parameters reflecting the new base and previous base schedules.

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Harold Glazer
H. Glazer

Thomas Jansen
T. J. Jansen

APPENDIX A

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APPENDIX B

GLOSSARY

Base-case model -- The model or procedure that performs final consistency checks on data input to the WSPACS system by contractors and the Air Force. The base-case model generates new pre-reprogrammed cost and schedule data tapes for use by the WSPACS reprogramming model.

Cancellation percentage -- Designated P_i, that fraction of the flow time of an airframe which must have been completed by T_D' to permit total completion if a reprogramming action calls for termination of production. Airframes less than P_i complete are terminated, while those P_i or greater complete are finished.

Cost allocation factors -- Factors used by Type A common subsystems to allocate total subsystem recurring costs to relevant systems. Factors are calculated for each month with a positive subsystem delivery rate as the quotient of the monthly subsystem/system delivery rate, divided by the total monthly subsystem delivery rate.

Cost component -- A subdivision of the subsystem costs which facilitates the definition and generation of costs; a cost element. Typical cost components include basic engineering, flight testing, and production labor.

Costs, Class A recurring -- Recurring costs generated from cost components that are directly related to the delivery schedule, such as production labor or production materials.

Costs, Class B recurring -- Recurring costs generated from cost components that are only indirectly related to the delivery schedule, such as sustaining engineering.

Costs, non-recurring -- Costs that are independent of the number of units to be delivered; primarily research and development. They also may include such one-time expenditures as initial tooling.

Costs, recurring -- Costs that are directly or indirectly related to the number of units to be delivered; primarily production costs but also may include such costs as sustaining engineering.

Costs, 3010 -- An Air Force budget category for aircraft procurement, related but not identical to recurring costs.

Costs, 3600 -- An Air Force budget category for research and development, related but not identical to non-recurring costs.

Envelope -- An airframe schedule constraint produced by the specific propulsion and airborne electronics subsystems associated with an airframe. It is derived by taking the minimum by time period of every relevant subsystem net maximum schedule translated to an airframes supportable basis, the translation being effected by considering installation and spare units required per airframe and their respective lead times.

Management options -- Alternative courses of action which will be available to the decision-maker if schedule infeasibilities occur in schedule-common subsystems. (Three options, (a), (b), and (c), are described in Section 2.1.7)

Minimum parameters -- Lowest values allowed for subsystem/system unit lead times and spares quantities.

Other GFAE (Government Furnished Aircraft Equipment) -- A subsystem which represents the aggregation of all items of hardware other than propulsion or airborne electronics which are furnished by the government to the aircraft contractor.

Precedence number -- A number assigned to each system and indicating the ranking in importance of the system. Used in allocating a smoothed total subsystem schedule to its associated systems, and in Management Option (a).

Preferred parameters -- Desired values for subsystem/system unit lead times and spares quantities.

PROM -- Cost model developed by the RAND Corporation to estimate total Air Force force structure costs, which calculates detailed operating costs. The acronym PROM is derived from Program Requirements Oriented to Management.

Reprogramming model -- The WSPACS model that provides the time-phased estimates of the cost and schedule impacts of reprogramming the Air Force force structure.

Reprogramming parameters -- Those quantities that may be varied by the Air Force in the WSPACS reprogramming model. Although a system is reprogrammed, the parameters are associated with the airframe schedule, viz.:

T_G time of go-ahead, i.e., date contract is let

T_F time of delivery of the first vehicle

T_L time of delivery of the last vehicle

N total number of vehicles to be delivered

Schedule, gross maximum -- A cumulative delivery schedule calculated by the propulsion or airborne electronics model representing the production capacity available to the Air Force.

Schedule, Mode A -- A cumulative propulsion or airborne electronics schedule (for peculiar subsystems) or a set of schedules (for common subsystems) input by a contractor at the quarterly updating time for use in the base-case model. The set of schedules for common subsystems is composed of a total subsystem schedule and a separate schedule for each subsystem/system combination.

Schedule, Mode B -- A cumulative total propulsion or airborne electronics schedule for a common subsystem submitted by a contractor at the quarterly updating time for use in the base-case model. No subsystem/system schedules are submitted.

Schedule, net maximum -- A cumulative propulsion or airborne electronics schedule calculated by subtracting from a gross maximum schedule the pre-reprogrammed subsystem/system schedules of systems not being reprogrammed.

Schedule, pre-reprogrammed delivery -- A cumulative airframe, propulsion or airborne electronics subsystem schedule that was processed by the base-case model at the last quarterly updating time.

Schedule, requirements -- A cumulative propulsion or airborne electronics schedule defining the deliveries required to support a given airframe schedule. Produced by translating the airframe schedule using appropriate lead times and installed and spare units factors.

Schedule, smoothed delivery (reprogrammed) -- A cumulative propulsion or airborne electronics schedule that satisfies both airframe requirements and subsystem constraints; the final schedule produced by the reprogramming model.

Subsystem -- One of the four major hardware elements of an aircraft system; viz., airframe, propulsion, airborne electronics, and other government-furnished aircraft equipment (GFAE).

Subsystem, common -- A subsystem used on more than one aircraft system. In the current model, only the propulsion and airborne electronics subsystems may be common.

Subsystem, non-reprogrammed -- A subsystem that is associated only with systems that are not being reprogrammed.

Subsystem, peculiar -- A subsystem used on a single system. In the current model, all airframes and other GFAE subsystems are peculiar; propulsion and airborne electronics subsystems may or may not be peculiar.

Subsystem, schedule-common -- A subsystem that is used on more than one system that is being reprogrammed.

Subsystem, schedule-peculiar -- A subsystem that is used on only one system that is being reprogrammed (however, the subsystem may also be common).

Subsystem, Type A common -- A common subsystem in which costs are generated from its total schedule and then allocated to the relevant subsystem/system schedules by cost allocation factors.

Subsystem, Type B common -- A common subsystem in which costs are generated separately from each subsystem/system schedule.

Time, absolute -- A time scale designated by the variable t, using a month as the unit of measure, with t=1 for July, 1963.

Time, relative -- A time scale designated by the variable k, using a month as the unit of measure, with the first month of the fiscal year in which T_I occurs as k=1.

Time variables and parameters --

- T_D Present time - month of WSPACS reprogramming run.
- T_D' Earliest time airframe management can react to a change to schedule at T_D.
- T_I Time of last updating.
- MT Computation limit - time beyond which schedules need not be computed.
- T_G Time of go-ahead for a particular airframe subsystem.
- T_L Time of delivery of the last vehicle for a particular airframe subsystem.
- $T_{L\max}$ Latest time to which the last airframe delivery can be delayed for a particular airframe subsystem.
- T_l' Earliest time after which a propulsion or airborne electronics subsystem schedule can be increased in reacting to a change in schedule at T_D.

APPENDIX C

AIRCRAFT DETAIL REPORT

The Aircraft Detail Report consists of the following pages:

Title	Cumulative or Rates	Report Page	Page
Total System	Cumulative	1	C-2
Airframe	Cumulative	2	C-3
Engines	Cumulative	3	C-4
Electronics	Cumulative	4	C-5
Total System	Rates	5	C-6
Airframe	Rates	6	C-7
Engines	Rates	7	C-8
Electronics	Rates	8	C-9

AIRCRAFT DETAIL - VER TEST

DATE 2MAR64
RUN TEST1

PARAMETERS	TG	TF	TL	N	P
AS OF SEP 63 (T1)	JUL 62	FEB 66	MAR 69	400	
REPROGRAMMED	JUL 62	SEP 65	OCT 68	510	0.500
WSPACS MODIFIED	JUL 62	FEB 66	NOV 68	510	

COSTS AND SCHEDULES-CUMULATIVE
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
TOTAL SYSTEM													
TOTAL COST													
QTRS	BASE	550.	34120.	82356.	153923.	243385.	338667.	421829.	480014.	513354.	539406.	597005.	721607.
	REPR	550.	34121.	82352.	154094.	244039.	337992.	421374.	479184.	512247.	539205.	591588.	715581.
	DIFF	0.	1.	-4.	171.	654.	-675.	-455.	-830.	-1107.	-201.	-5417.	-6026.
YRS	BASE	1097253.	1387644.	1513350.	1513350.	1513350.	1513350.	1513350.	1513350.				
	REPR	1209996.	1683354.	1778274.	1778274.	1778274.	1778274.	1778274.	1778274.				
	DIFF	112743.	295710.	264924.	264924.	264924.	264924.	264924.	264924.				
DEVELOPMENT													
QTRS	BASE	0.	33480.	81627.	153104.	241467.	333867.	413878.	467034.	490420.	495156.	502092.	550556.
	REPR	0.	33481.	81623.	153275.	242121.	335089.	415435.	468595.	491928.	496642.	503603.	552148.
	DIFF	0.	1.	-4.	171.	654.	1222.	1557.	1561.	1508.	1486.	1511.	1592.
YRS	BASE	605515.	605515.	605515.	605515.	605515.	605515.	605515.	605515.				
	REPR	607198.	607198.	607198.	607198.	607198.	607198.	607198.	607198.				
	DIFF	1683.	1683.	1683.	1683.	1683.	1683.	1683.	1683.				
PRODUCTION													
QTRS	BASE	550.	640.	729.	819.	1918.	4800.	7951.	12980.	22934.	44250.	94913.	171051.
	REPR	550.	640.	729.	819.	1918.	2903.	5939.	10589.	20318.	42563.	87985.	163432.
	DIFF	0.	0.	0.	0.	0.	-1897.	-2012.	-2391.	-2616.	-1687.	-6928.	-7619.
YRS	BASE	491738.	782129.	907835.	907835.	907835.	907835.	907835.	907835.				
	REPR	602798.	1076156.	1171077.	1171077.	1171077.	1171077.	1171077.	1171077.				
	DIFF	111060.	294027.	263242.	263242.	263242.	263242.	263242.	263242.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	15.
	REPR	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	15.
	DIFF	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
YRS	BASE	153.	297.	400.	400.	400.	400.	400.	400.				
	REPR	177.	411.	510.	510.	510.	510.	510.	510.				
	DIFF	24.	114.	110.	110.	110.	110.	110.	110.				

TM/03929/001/00/0/00

AIRCRAFT DETAIL - VER TEST DATE RUN 2MAR64 TEST1

COSTS AND SCHEDULES-CUMULATIVE
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
AIRFRAME 101													
TOTAL COSTS													
QTRS	BASE	0.	21384.	64855.	132584.	218761.	310293.	390364.	445335.	475069.	494724.	533473.	631608.
	REPR	0.	21384.	64855.	132584.	218761.	310293.	390364.	445334.	475069.	494724.	533504.	632311.
	DIFF	0.	0.	0.	0.	0.	0.	0.	-1.	0.	0.	31.	703.
YRS	BASE	904409.	1100779.	1191557.	1191557.	1191557.	1191557.	1191557.	1191557.				
	REPR	971386.	1275276.	1336169.	1336169.	1336169.	1336169.	1336169.	1336169.				
	DIFF	66977.	174497.	144612.	144612.	144612.	144612.	144612.	144612.				
DEVELOPMENT													
QTRS	BASE	0.	21384.	64855.	132584.	218761.	310293.	390096.	443127.	466319.	470819.	477528.	525850.
	REPR	0.	21384.	64855.	132584.	218761.	310293.	390096.	443127.	466319.	470819.	477528.	525850.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
YRS	BASE	580798.	580798.	580798.	580798.	580798.	580798.	580798.	580798.				
	REPR	580798.	580798.	580798.	580798.	580798.	580798.	580798.	580798.				
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.				
PRODUCTION													
QTRS	BASE	0.	0.	0.	0.	0.	0.	268.	2208.	8750.	23905.	55945.	105758.
	REPR	0.	0.	0.	0.	0.	0.	268.	2208.	8750.	23905.	55976.	106462.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	31.	704.
YRS	BASE	323611.	519981.	610759.	610759.	610759.	610759.	610759.	610759.				
	REPR	390588.	694477.	755371.	755371.	755371.	755371.	755371.	755371.				
	DIFF	66977.	174496.	144612.	144612.	144612.	144612.	144612.	144612.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	15.
	REPR	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	15.
	DIFF	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
YRS	BASE	153.	297.	400.	400.	400.	400.	400.	400.				
	REPR	177.	411.	510.	510.	510.	510.	510.	510.				
	DIFF	24.	114.	110.	110.	110.	110.	110.	110.				
GEAE 401													
PRODUCTION													
QTRS	BASE	550.	640.	729.	819.	819.	819.	819.	819.	819.	3222.	8207.	16369.
	REPR	550.	640.	729.	819.	819.	819.	819.	819.	819.	3222.	8207.	16369.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
YRS	BASE	48718.	80514.	92763.	92763.	92763.	92763.	92763.	92763.				
	REPR	58405.	106538.	110576.	110576.	110576.	110576.	110576.	110576.				
	DIFF	9687.	26024.	17813.	17813.	17813.	17813.	17813.	17813.				

AIRCRAFT DETAIL - VER TEST

DATE RUN 2MAR64 TEST1

COSTS AND SCHEDULES-CUMULATIVE
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
ENGINES 201													
TOTAL COSTS													
QTRS	BASE	0.	0.	0.	0.	1099.	2084.	2955.	3712.	4355.	5184.	14716.	27773.
	REPR	0.	0.	0.	0.	1099.	2084.	2955.	3712.	4569.	6383.	11864.	24905.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	214.	1199.	-2852.	-2868.
YRS	BASE	74078.	117018.	132195.	132195.	132195.	132195.	132195.	132195.				
	REPR	85080.	138356.	160221.	160221.	160221.	160221.	160221.	160221.				
	DIFF	11002.	21338.	28026.	28026.	28026.	28026.	28026.	28026.				
DEVELOPMENT													
QTRS	BASE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	REPR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
YRS	BASE	0.	0.	0.	0.	0.	0.	0.	0.				
	REPR	0.	0.	0.	0.	0.	0.	0.	0.				
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.				
PRODUCTION													
QTRS	BASE	0.	0.	0.	0.	1099.	2084.	2955.	3712.	4355.	5184.	14716.	27773.
	REPR	0.	0.	0.	0.	1099.	2084.	2955.	3712.	4569.	6383.	11864.	24905.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	214.	1199.	-2852.	-2868.
YRS	BASE	74078.	117018.	132195.	132195.	132195.	132195.	132195.	132195.				
	REPR	85080.	138356.	160221.	160221.	160221.	160221.	160221.	160221.				
	DIFF	11002.	21338.	28026.	28026.	28026.	28026.	28026.	28026.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	44.	179.	395.
	REPR	0.	0.	0.	0.	0.	0.	0.	0.	20.	50.	120.	329.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	20.	6.	-59.	-66.
YRS	BASE	1300.	2206.	2520.	2520.	2520.	2520.	2520.	2520.				
	REPR	1529.	2729.	3229.	3229.	3229.	3229.	3229.	3229.				
	DIFF	229.	523.	709.	709.	709.	709.	709.	709.				

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AIRCRAFT DETAIL - VER TEST DATE RUN 2MAR64 TEST1

COSTS AND SCHEDULES-CUMULATIVE
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
ELECTRONICS 301													
TOTAL COSTS													
QTRS	BASE	0.	12096.	16772.	20520.	22706.	25471.	27691.	30148.	33111.	36276.	40609.	45857.
	REPR	0.	12096.	16768.	20692.	23360.	24796.	27237.	29319.	31789.	34877.	38013.	41995.
	DIFF	0.	0.	-4.	172.	654.	-675.	-454.	-829.	-1322.	-1399.	-2596.	-3862.
YRS	BASE	70048.	89333.	96835.	96835.	96835.	96835.	96835.	96835.				
	REPR	95125.	163183.	171308.	171308.	171308.	171308.	171308.	171308.				
	DIFF	25077.	73850.	74473.	74473.	74473.	74473.	74473.	74473.				
DEVELOPMENT													
QTRS	BASE	0.	12096.	16772.	20520.	22706.	23574.	23782.	23907.	24101.	24337.	24564.	24706.
	REPR	0.	12096.	16768.	20692.	23360.	24796.	25339.	25468.	25609.	25823.	26075.	26299.
	DIFF	0.	0.	-4.	172.	654.	1222.	1557.	1561.	1508.	1486.	1511.	1593.
YRS	BASE	24717.	24717.	24717.	24717.	24717.	24717.	24717.	24717.				
	REPR	26399.	26399.	26399.	26399.	26399.	26399.	26399.	26399.				
	DIFF	1682.	1682.	1682.	1682.	1682.	1682.	1682.	1682.				
PRODUCTION													
QTRS	BASE	0.	0.	0.	0.	0.	1897.	3909.	6241.	9010.	11939.	16045.	21151.
	REPR	0.	0.	0.	0.	0.	0.	1897.	3850.	6180.	9054.	11938.	15696.
	DIFF	0.	0.	0.	0.	0.	-1897.	-2012.	-2391.	-2830.	-2885.	-4107.	-5455.
YRS	BASE	45331.	64616.	72118.	72118.	72118.	72118.	72118.	72118.				
	REPR	68726.	136784.	144909.	144909.	144909.	144909.	144909.	144909.				
	DIFF	23395.	72168.	72791.	72791.	72791.	72791.	72791.	72791.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	4.	17.	47.
	REPR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	17.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-14.	-30.
YRS	BASE	228.	396.	480.	480.	480.	480.	480.	480.				
	REPR	213.	504.	638.	638.	638.	638.	638.	638.				
	DIFF	-15.	108.	158.	158.	158.	158.	158.	158.				

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AIRCRAFT DETAIL - VER TEST

DATE RUN 2MAR64 TEST1

PARAMETERS	TG	TF	TL	N	P
AS OF SEP 63 (TI)	JUL 62	FEB 66	MAR 69	400	
REPROGRAMMED	JUL 62	SEP 65	OCT 68	510	0.500
WSPACS MODIFIED	JUL 62	FEB 66	NOV 68	510	

COSTS AND SCHEDULES-RATES
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
TOTAL SYSTEM													
TOTAL COSTS													
QTRS	BASE	550.	33570.	48236.	71567.	89462.	95282.	83162.	58185.	33340.	26052.	57599.	124602.
	REPR	550.	33571.	48231.	71742.	89945.	93953.	83382.	57810.	33063.	26958.	52383.	123993.
	DIFF	0.	1.	-5.	175.	483.	-1329.	220.	-375.	-277.	906.	-5216.	-609.
YRS	BASE	375646.	290391.	125706.	0.	0.	0.	0.	0.				
	REPR	494415.	473358.	94920.	0.	0.	0.	0.	0.				
	DIFF	118769.	182967.	-30786.	0.	0.	0.	0.	0.				
DEVELOPMENT													
QTRS	BASE	0.	33480.	48147.	71477.	88363.	92400.	80011.	53156.	23386.	4736.	6936.	48464.
	REPR	0.	33481.	48142.	71652.	88846.	92968.	80346.	53160.	23333.	4714.	6961.	48545.
	DIFF	0.	1.	-5.	175.	483.	568.	335.	4.	-53.	-22.	25.	81.
YRS	BASE	54959.	0.	0.	0.	0.	0.	0.	0.				
	REPR	55050.	0.	0.	0.	0.	0.	0.	0.				
	DIFF	91.	0.	0.	0.	0.	0.	0.	0.				
PRODUCTION													
QTRS	BASE	550.	90.	89.	90.	1099.	2882.	3151.	5029.	9954.	21316.	50663.	76138.
	REPR	550.	90.	89.	90.	1099.	985.	3036.	4650.	9729.	22245.	45422.	75447.
	DIFF	0.	0.	0.	0.	0.	-1897.	-115.	-379.	-225.	929.	-5241.	-691.
YRS	BASE	320687.	290391.	125706.	0.	0.	0.	0.	0.				
	REPR	439366.	473358.	94921.	0.	0.	0.	0.	0.				
	DIFF	118679.	182967.	-30785.	0.	0.	0.	0.	0.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	12.
	REPR	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	12.
	DIFF	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
YRS	BASE	138.	144.	103.	0.	0.	0.	0.	0.				
	REPR	162.	234.	99.	0.	0.	0.	0.	0.				
	DIFF	24.	90.	-4.	0.	0.	0.	0.	0.				

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AIRCRAFT DETAIL - VER TEST DATE RUN 2MAR64 TEST1

COSTS AND SCHEDULES-RATES
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
AIRFRAME 101													
TOTAL COSTS													
QTRS	BASE	0.	21384.	43471.	67729.	86177.	91532.	80071.	54971.	29734.	19655.	38749.	98135.
	REPR	0.	21384.	43471.	67729.	86177.	91532.	80071.	54970.	29735.	19655.	38780.	98807.
	DIFF	0.	0.	0.	0.	0.	0.	0.	-1.	1.	0.	31.	672.
YRS	BASE	272801.	196370.	90778.	0.	0.	0.	0.	0.				
	REPR	339075.	303890.	60893.	0.	0.	0.	0.	0.				
	DIFF	66274.	107520.	-29885.	0.	0.	0.	0.	0.				
DEVELOPMENT													
QTRS	BASE	0.	21384.	43471.	67729.	86177.	91532.	79803.	53031.	23192.	4500.	6709.	48322.
	REPR	0.	21384.	43471.	67729.	86177.	91532.	79803.	53031.	23192.	4500.	6709.	48322.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
YRS	BASE	54948.	0.	0.	0.	0.	0.	0.	0.				
	REPR	54948.	0.	0.	0.	0.	0.	0.	0.				
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.				
PRODUCTION													
QTRS	BASE	0.	0.	0.	0.	0.	0.	268.	1940.	6542.	15155.	32040.	49813.
	REPR	0.	0.	0.	0.	0.	0.	268.	1940.	6542.	15155.	32071.	50486.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	31.	673.
YRS	BASE	217853.	196370.	90778.	0.	0.	0.	0.	0.				
	REPR	284126.	303889.	60894.	0.	0.	0.	0.	0.				
	DIFF	66273.	107519.	-29884.	0.	0.	0.	0.	0.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	12.
	REPR	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	3.	12.
	DIFF	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
YRS	BASE	138.	144.	103.	0.	0.	0.	0.	0.				
	REPR	162.	234.	99.	0.	0.	0.	0.	0.				
	DIFF	24.	90.	-4.	0.	0.	0.	0.	0.				
GEAR 401													
PRODUCTION													
QTRS	BASE	550.	90.	89.	90.	0.	0.	0.	0.	0.	2403.	4985.	8162.
	REPR	550.	90.	89.	90.	0.	0.	0.	0.	0.	2403.	4985.	8162.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
YRS	BASE	32349.	31796.	12249.	0.	0.	0.	0.	0.				
	REPR	42036.	48133.	4038.	0.	0.	0.	0.	0.				
	DIFF	9687.	16337.	-8211.	0.	0.	0.	0.	0.				

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AIRCRAFT DETAIL - VER TEST

COSTS AND SCHEDULES-RATES
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
ENGINES 201													
TOTAL COSTS													
QTRS	BASE	0.	0.	0.	0.	1099.	985.	871.	757.	643.	829.	9532.	13057.
	REPR	0.	0.	0.	0.	1099.	985.	871.	757.	857.	1814.	5481.	13041.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	214.	985.	-4051.	-16.
YRS	BASE	46305.	42940.	15177.	0.	0.	0.	0.	0.				
	REPR	60175.	53276.	21865.	0.	0.	0.	0.	0.				
	DIFF	13870.	10336.	6688.	0.	0.	0.	0.	0.				
DEVELOPMENT													
QTRS	BASE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	REPR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
YRS	BASE	0.	0.	0.	0.	0.	0.	0.	0.				
	REPR	0.	0.	0.	0.	0.	0.	0.	0.				
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.				
PRODUCTION													
QTRS	BASE	0.	0.	0.	0.	1099.	985.	871.	757.	643.	829.	9532.	13057.
	REPR	0.	0.	0.	0.	1099.	985.	871.	757.	857.	1814.	5481.	13041.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	214.	985.	-4051.	-16.
YRS	BASE	46305.	42940.	15177.	0.	0.	0.	0.	0.				
	REPR	60175.	53276.	21865.	0.	0.	0.	0.	0.				
	DIFF	13870.	10336.	6688.	0.	0.	0.	0.	0.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	44.	135.	216.
	REPR	0.	0.	0.	0.	0.	0.	0.	0.	20.	30.	70.	209.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	20.	-14.	-65.	-7.
YRS	BASE	905.	906.	314.	0.	0.	0.	0.	0.				
	REPR	1200.	1200.	500.	0.	0.	0.	0.	0.				
	DIFF	295.	294.	186.	0.	0.	0.	0.	0.				

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AIRCRAFT DETAIL - VER TEST DATE RUN 2MAR64 TEST1

COSTS AND SCHEDULES-RATES
(COSTS IN THOUSANDS OF DOLLARS)

FISCAL YR		1964				1965				1966			
QUARTER		1	2	3	4	1	2	3	4	1	2	3	4
FISCAL YR		1967	1968	1969	1970	1971	1972	1973	1974				
ELECTRONICS 301													
TOTAL COSTS													
QTRS	BASE	0.	12096.	4676.	3748.	2186.	2765.	2220.	2457.	2963.	3165.	4333.	5248.
	REPR	0.	12096.	4672.	3924.	2668.	1436.	2441.	2082.	2470.	3088.	3136.	3982.
	DIFF	0.	0.	-4.	176.	482.	-1329.	221.	-375.	-493.	-77.	-1197.	-1266.
YRS	BASE	24191.	19285.	7502.	0.	0.	0.	0.	0.				
	REPR	53130.	68058.	8125.	0.	0.	0.	0.	0.				
	DIFF	28939.	48773.	623.	0.	0.	0.	0.	0.				
DEVELOPMENT													
QTRS	BASE	0.	12096.	4676.	3748.	2186.	868.	208.	125.	194.	236.	227.	142.
	REPR	0.	12096.	4672.	3924.	2668.	1436.	543.	129.	141.	214.	252.	224.
	DIFF	0.	0.	-4.	176.	482.	568.	335.	4.	-53.	-22.	25.	82.
YRS	BASE	11.	0.	0.	0.	0.	0.	0.	0.				
	REPR	100.	0.	0.	0.	0.	0.	0.	0.				
	DIFF	89.	0.	0.	0.	0.	0.	0.	0.				
PRODUCTION													
QTRS	BASE	0.	0.	0.	0.	0.	1897.	2012.	2332.	2769.	2929.	4106.	5106.
	REPR	0.	0.	0.	0.	0.	0.	1897.	1953.	2330.	2874.	2684.	3758.
	DIFF	0.	0.	0.	0.	0.	-1897.	-115.	-379.	-439.	-55.	-1222.	-1348.
YRS	BASE	24180.	19285.	7502.	0.	0.	0.	0.	0.				
	REPR	53030.	68058.	8125.	0.	0.	0.	0.	0.				
	DIFF	28850.	48773.	623.	0.	0.	0.	0.	0.				
SCHEDULE													
QTRS	BASE	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	4.	13.	30.
	REPR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	14.
	DIFF	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-10.	-16.
YRS	BASE	181.	168.	84.	0.	0.	0.	0.	0.				
	REPR	196.	291.	134.	0.	0.	0.	0.	0.				
	DIFF	15.	123.	50.	0.	0.	0.	0.	0.				

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