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HELICOPTER TRANSMISSION MODULARIZATION AND MAINTAINABILITY ANALYSIS

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United Aircraft Corporation

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13. ABSTRACT

The objective of the transmission modularization analysis was to develop a methodology to evaluate helicopter transmission modularization and to demonstrate the feasibility, methods, design criteria, and cost effectiveness of modularization.

A U.S. Army CH-54B helicopter was selected for the analysis and designs were completed for transmissions with seven, six, four and three modules. A mathematical model was derived that calculated the cost and performance characteristics of a helicopter with a modularized transmission. A computer program was written to implement the mathematical model.

It was found that transmission maintenance costs can be reduced by 10% to 60% by using a modularized transmission. Based on fleet effective cost, the four-module design was optimum. A savings of 2.2 million dollars is realized compared with the present CH54B. Transmission modularization is feasible and cost effective. Significant cost savings resulting from decreases in depot maintenance requirements can be realized for a helicopter with a modularized transmission.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
CH54-B HELICOPTER						
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MATHEMATICAL MODEL						

DEPARTMENT OF THE ARMY
U. S. ARMY AIR MOBILITY RESEARCH & DEVELOPMENT LABORATORY
EUSTIS DIRECTORATE
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This report was prepared by the Sikorsky Aircraft Division of United Aircraft Corporation under the terms of Contract DAAJ02-72-C-0106. The purpose of this research was to develop a methodology to evaluate helicopter transmission modularization and to demonstrate the feasibility, methods, design criteria, and cost effectiveness of modularization for a large helicopter transmission design.

The report presents design concepts for various degrees of modularization of the CH-54B main transmission and compares them with each other and with the present CH-54B main transmission in terms of reliability, maintainability, and cost parameters. All degrees of modularization significantly reduced the maintenance requirements and thus proved to be more cost effective than the current design, with the four-module configuration being the most cost effective.

This report has been reviewed by this Directorate and is considered to be technically sound.

The technical monitors for this contract were Messrs. Robert L. Campbell Sr., and Victor W. Welner of the Military Operations Technology Division.

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HELICOPTER TRANSMISSION MODULARIZATION AND MAINTAINABILITY ANALYSIS

Final Report

Sikorsky Engineering Report SER-64373

By

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FOREWORD

The program reported herein was conducted during a 9-month period from June 27, 1972, to March 27, 1973, for the Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory (USAAMRDL), Fort Eustis, Virginia, under Contract DAAJ02-72-C-0106, Task 1F162205A11902.

USAAMRDL technical direction was provided by Mr. R. L. Campbell, and Mr. V. W. Welner of the Eustis Directorate, Military Operations Technology Division.

The program was conducted at Sikorsky Aircraft, Stratford, Connecticut, under the technical supervision of Mr. Lester R. Burroughs, Supervisor, Transmission Design and Development Section. Principal investigators for the program were Mr. J. G. Kish, Mr. P. Menkes, and Mr. K. R. Cormier, assisted by Mr. S. Schuman and Mr. J. Giardino of the Transmission Design and Development Section and Mr. C. Holbert of the Reliability/Maintainability Section.

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INTRODUCTION

Current helicopter transmissions are not ideal from the point of view of maintainability and reliability.

With few exceptions, internal transmission failures necessitate removal and overhaul of the entire transmission. In addition, secondary damage to the transmission often occurs because of contamination of the lubrication system by metallic fragments resulting from the initial failure. Overhaul of the entire transmission requires removal of engines, blades, main rotor head, servos, accessories, hydraulic lines, and oil lines; disassembly and inspection of all transmission components; replacement of worn, fretted, or damaged parts; and thorough purging of the entire lubrication system. Moreover, if purging of the lubrication system is incomplete, the replacement may fail due to metal fragments remaining from the initial failure. These factors contribute substantially to high helicopter transmission maintenance costs.

As part of the effort to reduce helicopter costs, a new design concept was sought to eliminate the above cost factors from helicopter transmissions. The design would first provide a method for pinpointing the region of failure in the transmission and prevent spread of contamination from that region. It would also provide easy accessibility to any region in the transmission where failure occurred and permit rapid replacement of the damaged component, thus decreasing downtime of the helicopter.

These requirements are satisfied by transmission modularization, which is the division of the main transmission into compartmentalized units, each with its own chip isolation and detection devices.

In the analysis program covered by this report, helicopter transmission modularization was explored with special attention to feasibility, methods, design criteria, technical effectiveness, and cost effectiveness. The program required modularization of the U. S. Army CH-54B main transmission into seven separate modules, with each module designed to meet the following requirements:

(1) Replaceable at the organizational maintenance level using present Army skill levels and without requirements for meticulous shimming, adjustments, or special tools.

(2) Capable of being handled with a hand-powered hoist as a maximum lifting device requirement.

(3) Capable of being fault isolated unambiguously by integral sensors or inspection aids.

(4) Lubricated and sealed to preclude other module or system contamination from any single failure within the module.

Alternative approaches to the design of the modules were also developed so that optimum modular design practices could be determined. In addition to the seven-module CH-54B transmission, configurations of six, four, and three modules were also developed to permit evaluation of the effectiveness of various degrees of modularization compared with the standard production CH-54B transmission.

Evaluation of technical and cost effectiveness factors for the various modularized versions and the baseline production version was accomplished with a mathematical model developed as part of this program. The model employs various cost and reliability/maintainability data to determine such technical and cost effectiveness factors as total transmission maintenance costs, aircraft mission availability, aircraft mission reliability, aircraft mission capability, aircraft mission effectiveness, and aircraft fleet effective cost. These factors provide the quantitative data needed for accurate evaluation and comparison of modularized transmissions. A computer program of the mathematical model has been designed for use with the IBM 360 system.

APPROACH

The technical/cost effectiveness of helicopter transmission modularization has been determined in this program by choosing a study vehicle, designing various modularized transmissions for the study vehicle, writing a mathematical model capable of evaluating effectiveness of transmission modularization, and using this model to evaluate the designs and study the results. The vehicle chosen for study was the U. S. Army CH-54B Helicopter. This helicopter was chosen for study because:

(1) The CH-54B components are large. A large helicopter transmission is assumed to have greater cost payoffs for modularization.

(2) The CH-54B is in current production.

(3) Ninety helicopters have been built.

(4) An extensive data base is available from which transmission cost and reliability/maintainability data can be obtained readily.

The baseline CH-54 data required is obtained from Operations Reliability/Maintainability Engineering (ORME) data, from Sikorsky overhaul records, Sikorsky accounting records, purchasing records, and test reports. The majority of the data available is for the CH-54A aircraft because it has been in service longer than the CH-54B. Since the differences between aircraft and main transmission designs between the CH-54A and CH-54B are of a minor nature, it is assumed throughout this report that the data for the CH-54A is the same as for the CH-54B. A large part of the transmission data, for example, is derived from ORME records which represent a 33-month study of the CH-54A during which 47,993 flight hours were accumulated (Reference 1).

Baseline data such as mission abort rates, aircraft and transmission down-hours per flight-hour, transmission efficiency, aircraft reliability, and transmission weight are not significantly different in the CH-54A and CH-54B. Moreover, it is only the changes in these data that are used to calculate the factors used to evaluate the modular designs.

After selection of the CH-54B as the study vehicle, all degrees of modularization were examined. The maximum number of practical modules for the main transmission was found to be seven. Other lesser degrees of modularization were found by combining modules of the seven-module version. The first layouts were drawn of this version. The division of the CH-54B main transmission into seven modules was as follows:

(1) Left-Hand Input Bevel Gear Module

(2) Left-Hand Freewheel Unit Module

(3) Right-Hand Input Bevel Gear Module

(4) Right-Hand Freewheel Unit Module

(5) Tail-Takeoff and Accessory Drive Module

(6) Main Bevel Gear Module

(7) Planetary and Main Rotor Shaft Module

Concurrently with layout of the modularized transmission, the mathematical model was derived. A mission simulation was developed for the CH-54B, and 1000 missions were flown in a probabilistic environment. From the mission simulation, rates of change were defined for fuel flow and mission capability with respect to changes in weight and transmission efficiency. After completion of the mathematical model, a computer program was written for use with the IBM 360 computer. Baseline CH-54B cost and reliability/maintainability data were established, and the computer program was debugged using the special case of number of modules equal to one (baseline CH-54B). The test case was also calculated by hand to verify the computer results.

During development of the mathematical model and computer program, the layout design of the modularized transmission was continuing. Several approaches were considered and completed, and layouts were made of each design. Trade-off studies were completed for chip isolation, lubrication interface, and torsional interface designs. Finally, four candidate modularized CH-54B main transmissions were selected.

(1) Seven-module version

(2) Six-module version

(3) Four-module version

(4) Three-module version

After completion of the candidate layouts, all input data were compiled to run the computer program of the mathematical model. These data were collected, calculated, assumed, or derived from the following sources:

(1) Layouts of modular designs

(2) Test results

(3) Overhaul records

(4) Discrepancy/corrective action reports

(5) Operations reliability/maintainability engineering data

(6) Purchasing records

(7) Accounting records

(8) U. S. Army records

After running the computer program, the designs were evaluated using the computer output data.

A flowchart showing the basic steps taken to complete the modularized transmission program is shown in Figure 1.

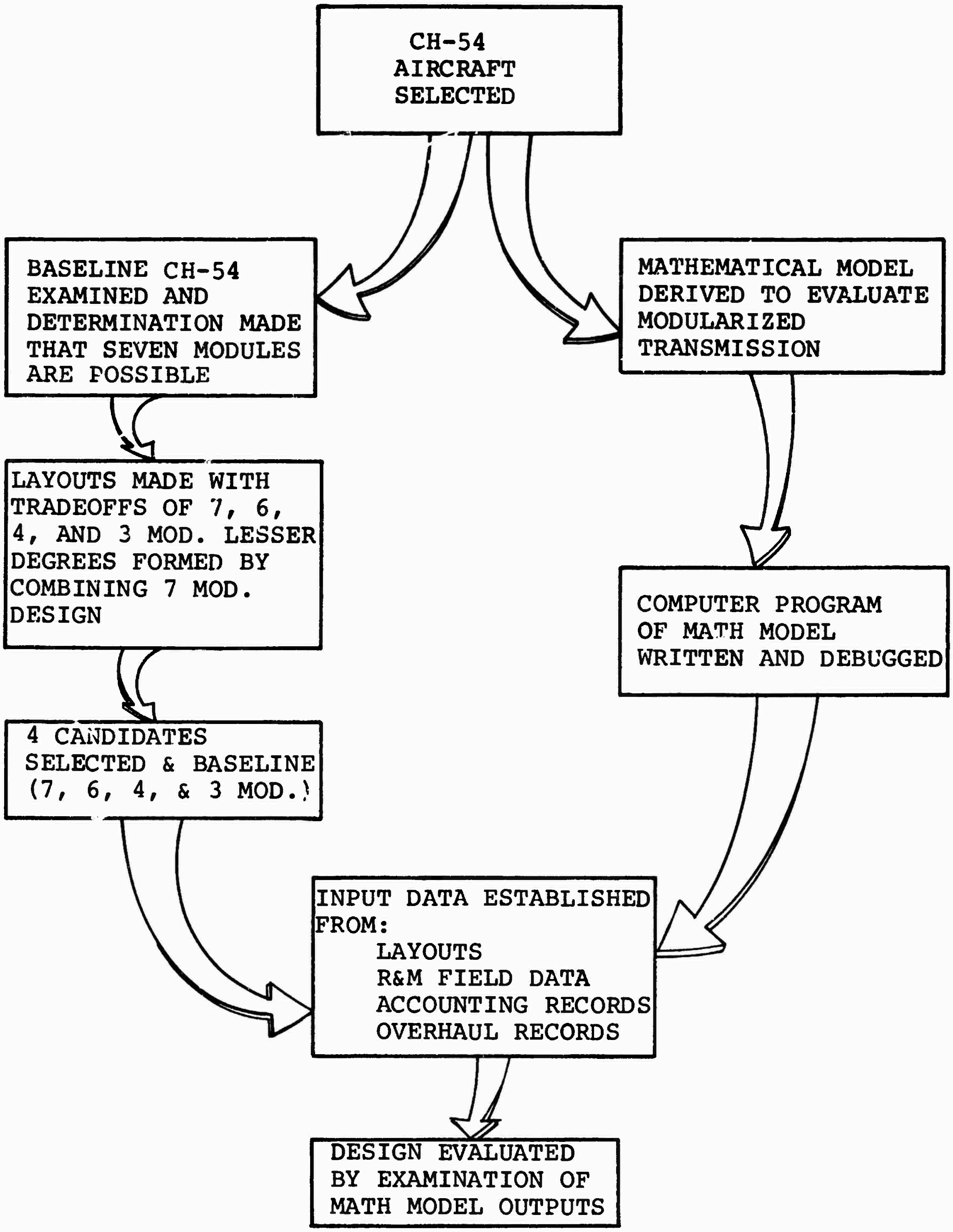


Figure 1. Flowchart Showing Development of Helicopter Transmission Modularization and Maintainability Analysis Program.

MATHEMATICAL MODEL

An important aspect of the Helicopter Transmission Modularization and Maintainability Analysis Program was the development of a mathematical model to evaluate the impact of transmission modularization on aircraft costs. The model consists of a set of equations (see Appendix II) that uses transmission and aircraft cost and reliability/maintainability data to calculate cost and technical effectiveness factors necessary for evaluation of modularized transmission configurations. The mathematical model can be used to evaluate and study the effects of modularization for any helicopter transmission. A simplified flowchart of the mathematical model is presented in Figure 2.

The flowchart of Figure 2 shows the flow of information in the mathematical model from the input factors through the calculated cost factors to the output. To facilitate use of the mathematical model, a computer program for use with the IBM 360 system was written. A listing of the program, definitions of the symbols used in the program, instructions for data setup, and sample runs are included in Appendix III of this report.

The input data used in the mathematical model are of five major types:

(1) Aircraft cost

(2) Aircraft reliability/maintainability

(3) Aircraft mission

(4) Transmission cost

(5) Transmission reliability/maintainability

The input points are shown (by number) in Figure 2. Items (4) and (5) are the input data used to evaluate transmission modularization. The transmission portion of the mathematical model is specified in detail and includes the following factors:

(1) Weight of transmission

(2) Efficiency of transmission (HP loss, etc.)

(3) Shipping costs between maintenance levels

(4) Cost to prepare to ship between maintenance levels

(5) Cost of shipping containers

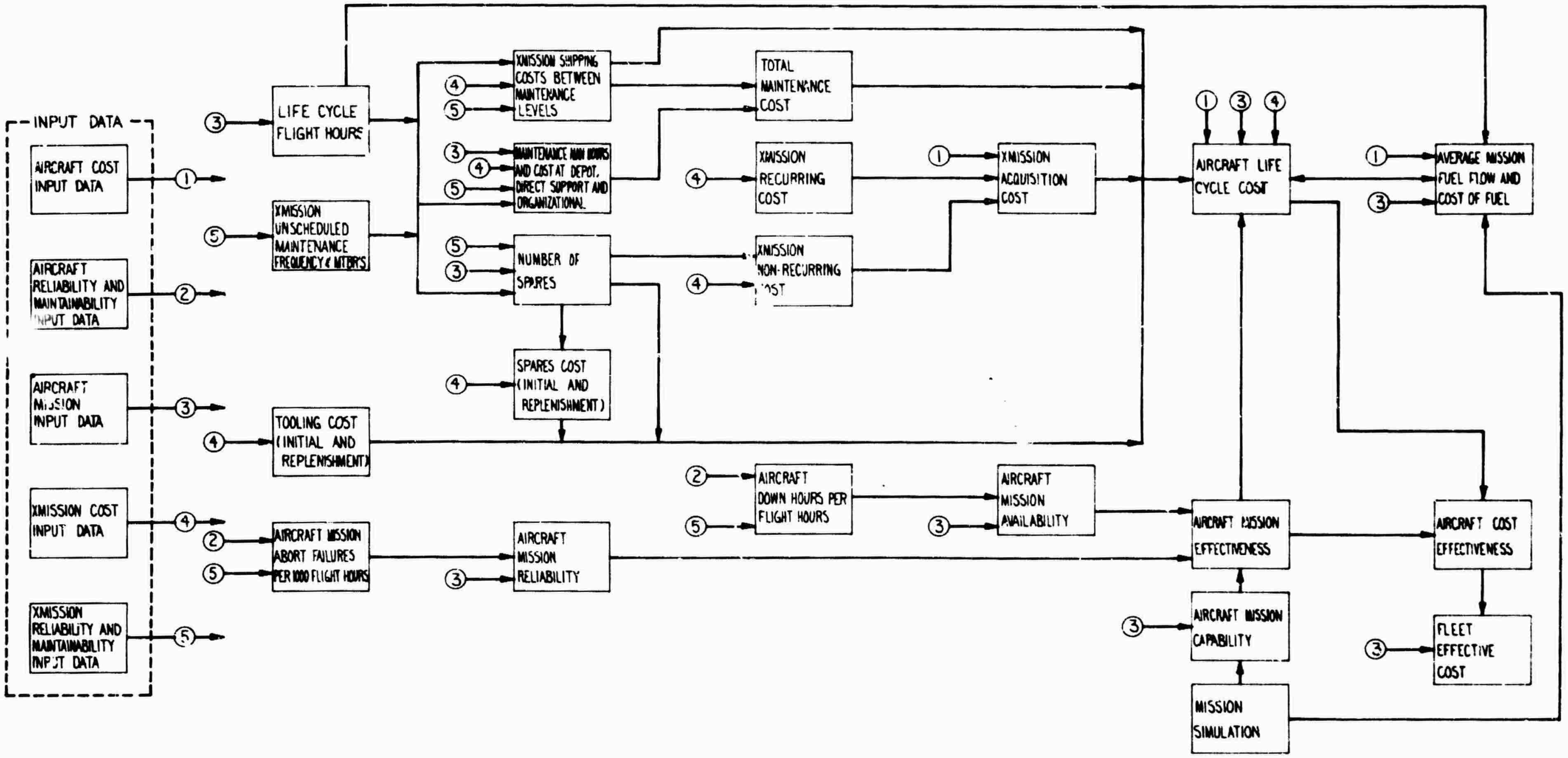


Figure 2. Flowchart of Mathematical Model.

(6) Cost of initial and replenishment tooling

(7) Cost of initial and replenishment spares

(8) Material repair costs on aircraft and at various maintenance levels

(9) Total recurring and nonrecurring cost

(10) Cost of acquisition of transmission

(11) Labor rates for military and civilian personnel

(12) Attrition rates of transmission

(13) Mean elapsed time to repair transmission

(14) Mean time between unscheduled transmission removals

(15) Maintenance hours to inspect transmission on aircraft and at various maintenance levels for scheduled and unscheduled inspections

(16) Maintenance hours to repair transmission on aircraft and at various maintenance levels

(17) Maintenance hours to scrap transmission on aircraft and at various maintenance levels

(18) Maintenance hours to remove and install modules

(19) Maintenance disposition (percentage shipped, repaired, and scrapped at each level)

(20) Time between overhauls

(21) Mission abort rates due to transmission

(22) Unscheduled maintenance frequency

The nature, derivation, and relation to the mathematical model of these and all other input data are discussed in detail in the Input Data section of this report.

Several of the input factors listed above refer to various Army maintenance levels: organizational, direct support, and depot. The organizational level is staffed by personnel who operate and maintain the helicopter in the field, for example, pilots and crew chiefs. These personnel perform scheduled inspections and minor maintenance. They are not allowed to disassemble a transmission or perform major repairs. The next higher level of maintenance is the direct support level.

These personnel perform more difficult repairs that the organizational level is not equipped to handle. They may also be equipped to overhaul minor components of the helicopter. The depot maintenance level has the skills, tools, fixtures, and equipment required to assemble and disassemble the helicopter. It is at this level that the transmission is disassembled and overhauled.

The values of the input factors used in the mathematical model were obtained from reliability and maintainability field records, accounting records, overhaul records, purchasing records, test results, and layout analysis. Weight changes due to modularization were calculated directly from layouts using a volume-density relationship.

Rates of change of fuel flow and mission capability with respect to weight and efficiency were obtained from mission simulations.

DESCRIPTION OF DESIGNS

BASELINE DESIGN

Description of Aircraft

The U. S. Army CH-54B helicopter chosen for this study is a heavy-duty vertical-lift aircraft. It has the ability to pick up, transport, and place heavy external loads with precision.

The CH-54B has twin engines rated at 4800 horsepower each and has the capability of transmitting 7900 horsepower to the main rotor. The six main rotor blades form a true diameter of 72.236 feet. Overall length is 88 feet 6 inches. The CH-54B is able to lift payloads exceeding 12 tons.

A cabin section, which is normally used for passengers or cargo with conventional helicopters, does not exist in the CH-54B. The fuselage is replaced by a skeletal framework which contains the pilot's compartment and interconnects all mechanical and electrical subsystems. The landing gear is arranged to straddle loads and to hold the framework off the ground such that external cargo can be drawn up to the frame. With this design, the CH-54B has a high payload to weight empty ratio.

Photographs of the CH-54B are shown in Figure 3. A three-view drawing of the aircraft is shown in Figure 4. Detailed physical dimensions and performance data are presented in Appendix I.

Description of Main Transmission

The main transmission of the CH-54B is rated at 7900 input horsepower and is powered by twin engines, each rated at 4800 hp. Power is transmitted by each engine directly into the four-stage main transmission which reduces the 9000-rpm engine speed to 185 rpm at the main rotor, a 48.54-to-1 reduction. Power is also transmitted from the tail/accessory drive section of the main transmission through the tail drive shaft at 3016 rpm and into the intermediate and tail gearboxes, which reduce speed to 850 rpm at the tail rotor. Figure 5 shows the dynamic components of the CH-54B.

Figure 3. U. S. Army CH-54B Aircraft.

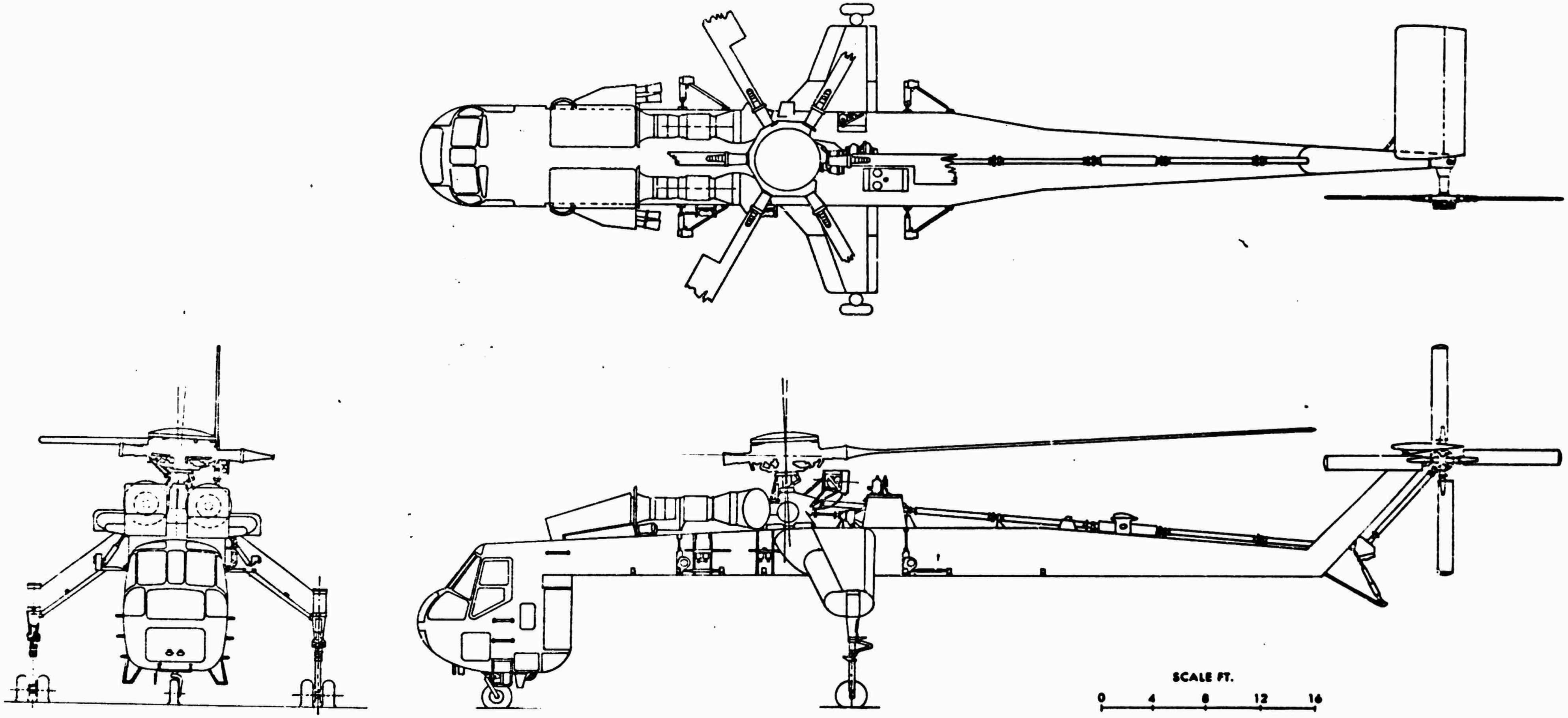


Figure 4. U.S. Army CH-54B Aircraft, Three-View Drawing.

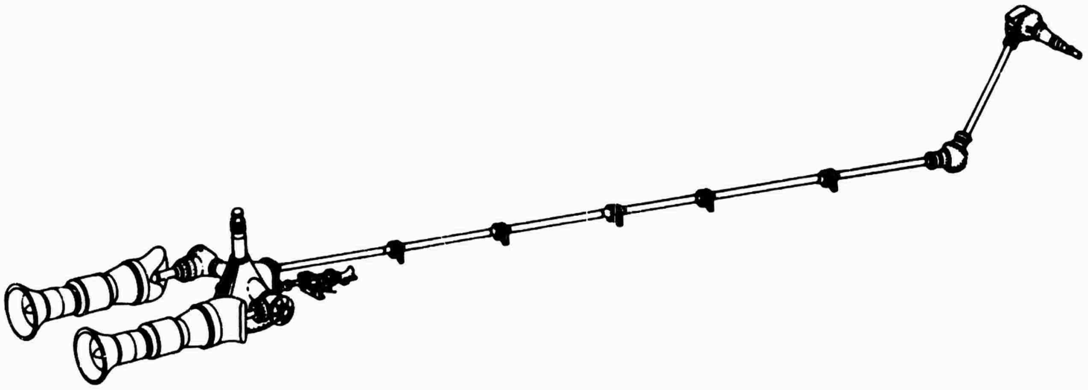


Figure 5. Isometric of Drive Train Components of the CH-54B Aircraft.

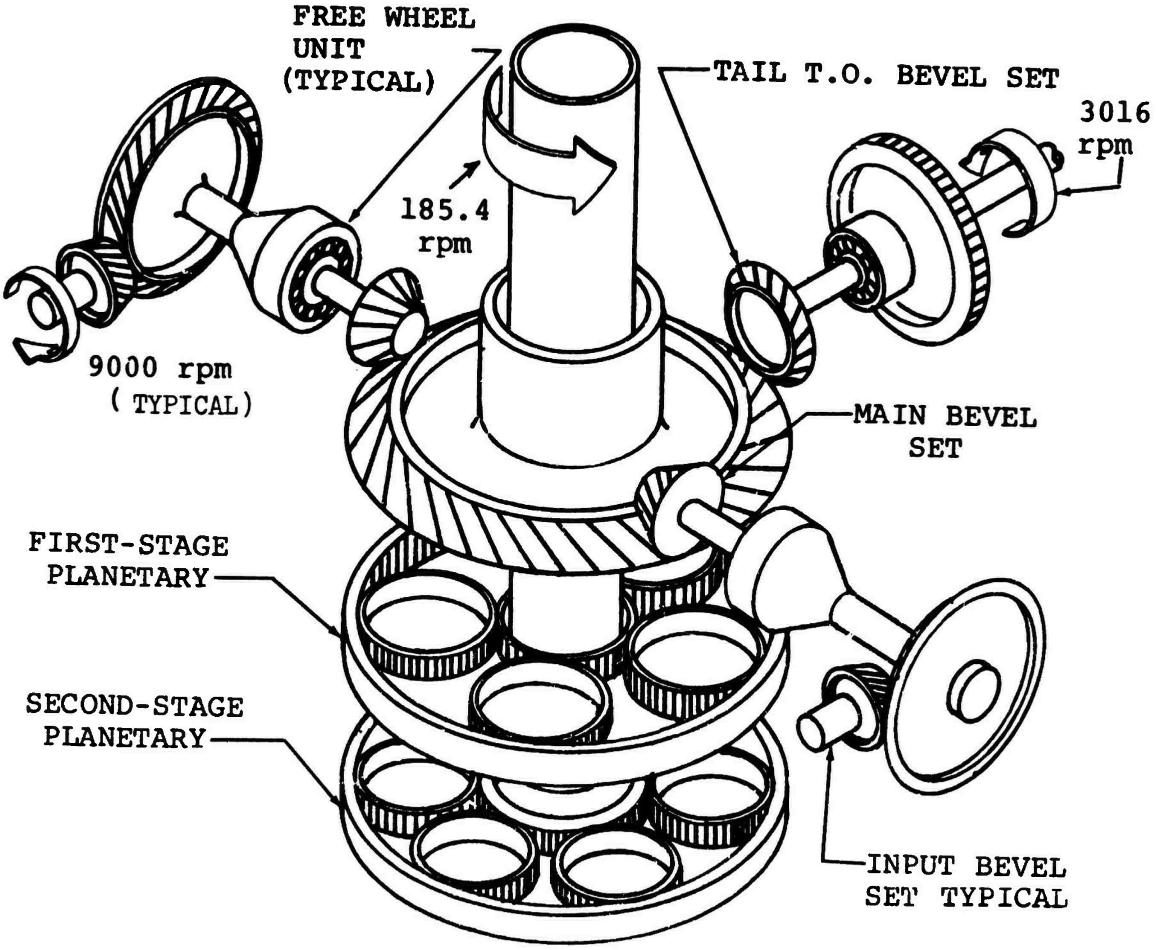
A schematic arrangement of the CH-54B main transmission is presented in Figure 6. This figure also contains numbers of teeth, reduction ratios, and speeds of the main transmission major reduction stages. CH-54B accessories are mounted on the rear cover of the main transmission and on the right-hand input bevel. The rear cover is shown in Figure 7.

Figure 8 shows the cross section of the transmission that was used in all modularized transmission layouts. This cross section cuts through all major basic dynamic components and permits all components to be viewed simultaneously on one drawing sheet. The orientations of all components are correct with one exception, the input pinion, which is rotated up 90°. This pinion is shown, however, in correct relationship to its mating gear.

A baseline layout of the CH-54B main transmission, sectioned as previously described, is shown in Figure 9.

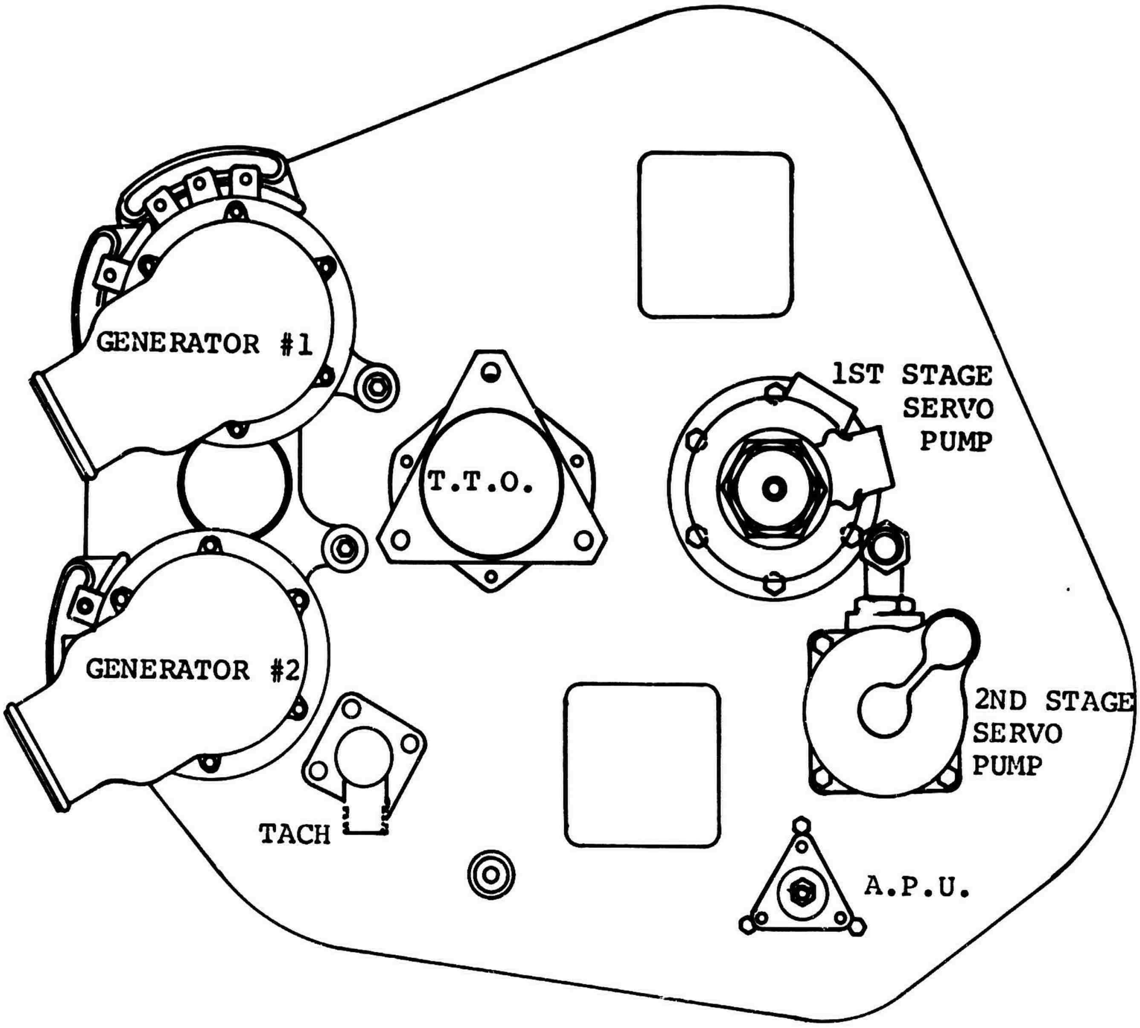
Power is transmitted from the engines to the first-stage spiral bevel mesh of 27-to-53 reduction. The gears of this stage are designed to transmit 4800 hp continuously at a 9000-rpm engine input speed. The 2.875-inch face width spiral bevel gears use a spiral angle of 25° and are of 3.313 diametral pitch. The left- and right-hand first-stage spiral bevel gears are identical in design and are interchangeable.

A ramp roller overrunning clutch (freewheel unit) is located between the first-stage output gear and the second-stage spiral bevel input pinion. This clutch is arranged with a driving outer housing and an overrunning cam (freewheel unit), which



GEAR MESH	REDUCTION	INPUT (rpm)	OUTPUT (rpm)
INPUT BEVEL SET	27/53	9000	4585.9
MAIN BEVEL SET	25/76	4584.9	1508.2
1ST STAGE PLANETARY	78/55/188	1508.2	442.3
2ND STAGE PLANETARY	166/32/230	442.3	185.4
TAIL T.O. BEVEL SET	76/38	1508.2	3016.4

Figure 6. Schematic of CH-54B Main Transmission.



PAD	MAXIMUM POWER (DESIGN)(HP)	SPEED (RPM)
GENERATOR #1	49.2	8025.7
GENERATOR #2	49.2	8025.7
TACH GENERATOR	1.0	4200
UTILITY PUMP *	53.0	4321
WINCH PUMP *	100.0	3796
2ND-STAGE SERVO PUMP	24.0	4585
1ST-STAGE SERVO PUMP	19.0	4321
TAIL-TAKEOFF	1220.0	3016

*NOT SHOWN - LOCATED ON RIGHT-HAND INPUT

Figure 7. Rear Cover and Accessories of CH-54B Main Transmission.

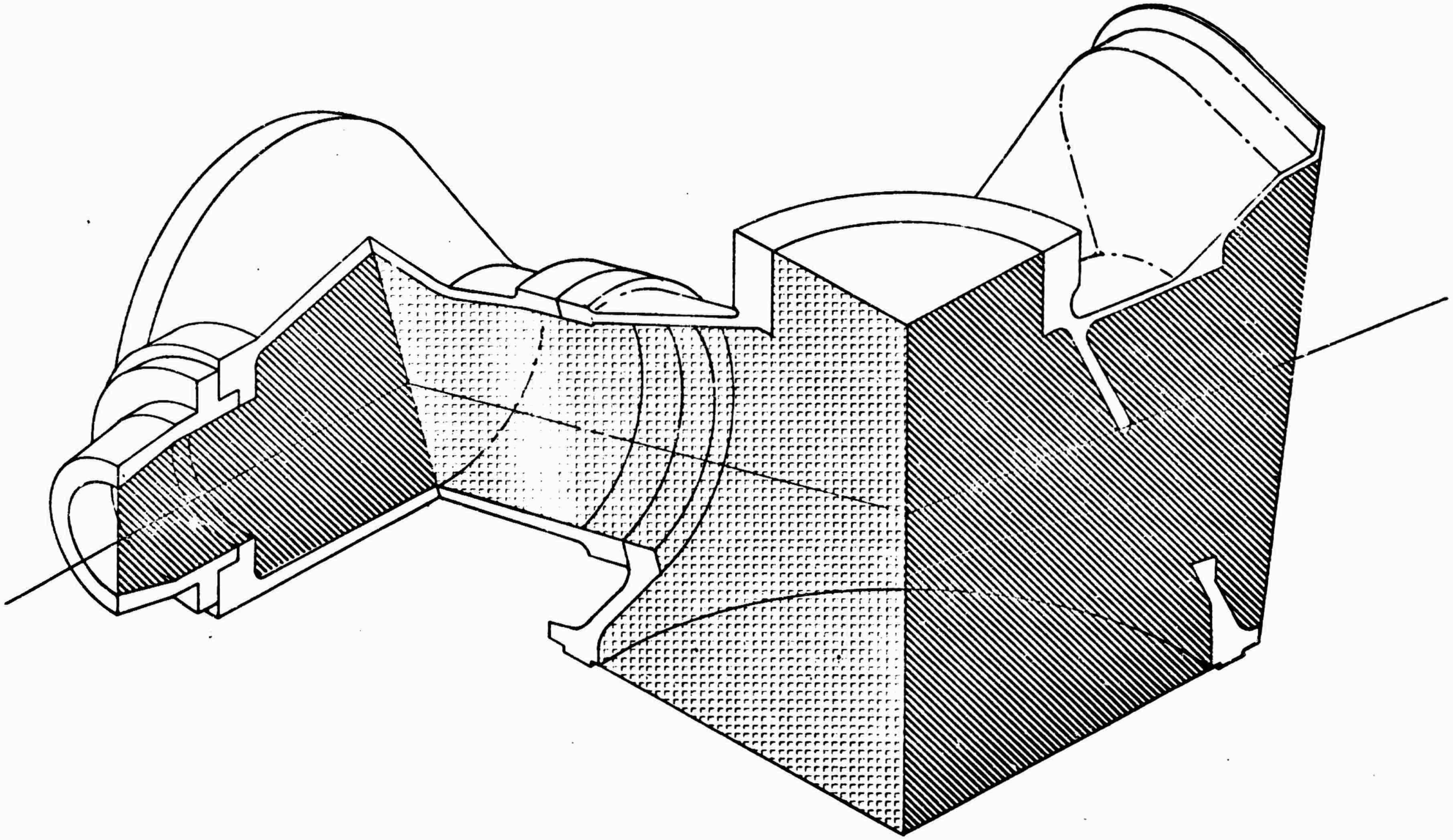


Figure 8. Isometric Drawing of CH-54B Main Transmission Showing Section Taken Through Transmission for All Layouts.

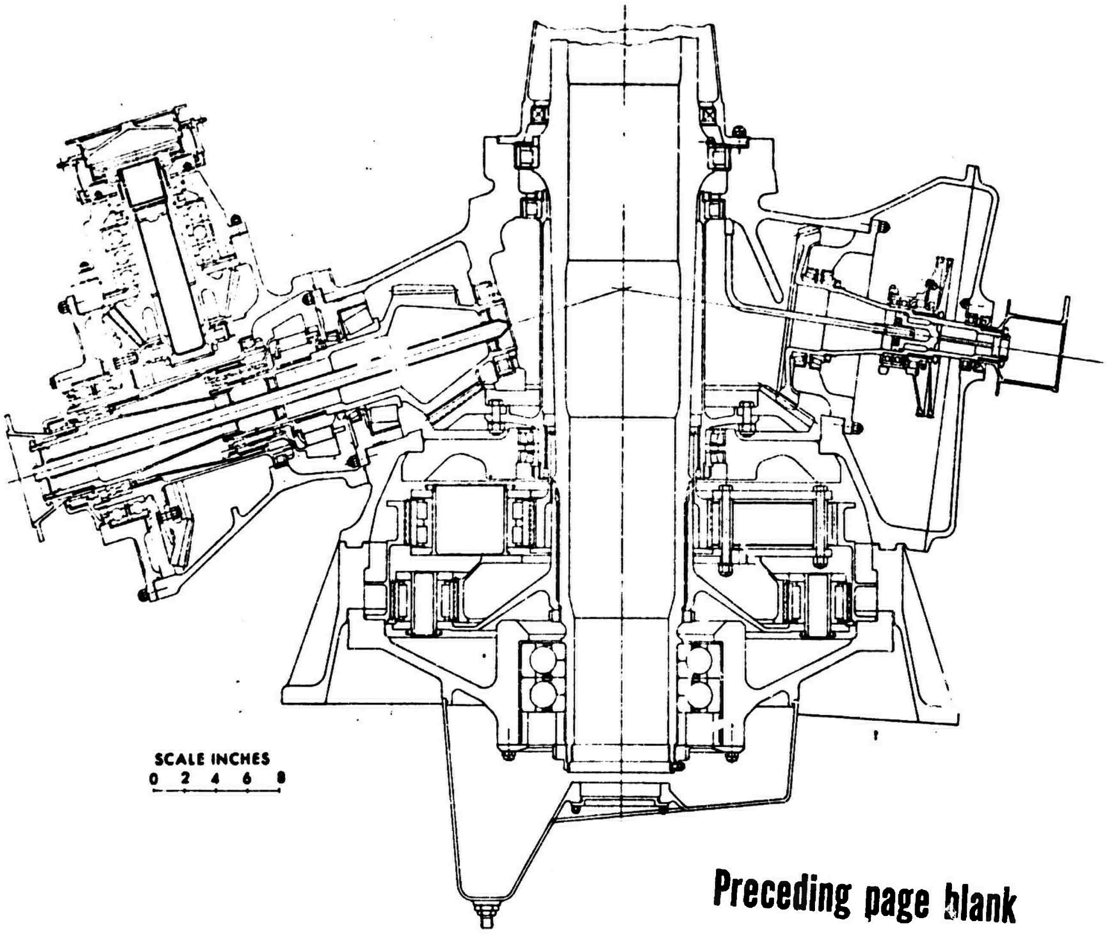


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Figure 9. Cross Section of Baseline CH-54B Transmission.

assures good lubrication to rollers, cage, cam, return springs, and outer housing. The relatively low speed of operation (4585 rpm) of this unit compared with other production freewheel units reduces centrifugal load of the rollers on the outer housing during overrunning. Wear has not been a problem with this design in service.

The cam output member of the ramp roller clutch drives the second-stage pinion of the 25-to-76 reduction spiral bevel mesh. The bevel gear of this stage is common to both second-stage input pinions, and combines power inputs from each engine. The spiral bevel mesh is designed with 25° mean spiral angle and 3.125 diametral pitch. Oil is fed centrifugally from an oil distribution tube inside the second-stage pinion to lubricate the freewheel unit and support bearings of the pinion.

A third spiral bevel pinion, driven by the second-stage spiral bevel gear provides power for accessories and tail rotor drives. Accessories mounted on the main transmission include generators, hydraulic pumps, and tachometer drive. A ramp roller-type freewheel unit is mounted between the tail-takeoff drive and accessory drive gear. This design allows ground operation of accessories from the auxiliary power unit (APU) with the main engines off. The tail-takeoff freewheel unit overruns during APU operation, so that the APU does not attempt to drive the main or tail rotors.

Attached to the output gear of the second stage bevel set is a quill shaft that transmits power to the lower part of the housing containing the planetary section of the main transmission. The overall reduction of 8.14-to-1 is accomplished with two stages of simple planetary meshes, a simple planetary being defined as sun gear driving, carrier output, and ring gear fixed. The first-stage planetary of 3.41-to-1 reduction ratio contains seven pinions. The first-stage planetary pinion is mounted on a two-row roller bearing connected to the straddle-mounted carrier plates through pinion shafts. The ring gear, which is rigidly bolted to the main transmission lower housing, contains both first- and second-stage internal gear members. Connected to the lower carrier plate of the first-stage planetary and driven through dowel pins is the sun gear of the second-stage planetary. The 2.39-to-1 reduction second-stage planetary is similar in design to the first-stage and contains eighteen planetary pinions. The lower carrier plate is splined to the main rotor shaft, which transmits torque to the main rotors.

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Design Criteria of Main Transmission

Design of the CH-54B main transmission follows modern helicopter transmission design practice. Bearings are designed for 3000 hours minimum B-10 life at a prorated horsepower, which is a weighted average power representing the expected operating spectrum. Steel liners provide a stress buffer interface between bearing outer races and the magnesium castings of the main transmission assembly. The bearing liners are designed to have a positive interference fit with the magnesium housing at 250°F, while maintaining low enough interference fits at -65°F to keep stresses in the magnesium housing below yield. Bearings are designed for maximum allowable slopes under the bearings at maximum torque operating conditions.

Gears and shafting are designed for infinite fatigue life at the maximum torque condition. Thus, the first-stage and second-stage bevel meshes, which may feel single-engine power, are designed for 4800 hp, while the planetary mesh is designed for the 6800-hp to the main rotor.

All threaded fasteners on the main transmission are provided with positive locking mechanisms to prevent loosening of nuts. Nuts and bolts, cotter pins, clevis pins, or Shurlocks are used to provide positive retention on larger nuts. On smaller threads using standard nuts, the deformed thread types are used. Nylon locking devices are not used in the CH-54B transmission due to softening of nylon at the high oil temperatures encountered.

Castings and housings of the main transmission are designed for crash conditions of 20 g vertical, 20 g forward, and 18 g lateral. The mass of the rotor head and blades acting on the main transmission during a crash condition represents the worst case of loading for structural design of the main housing.

The lubrication system for the CH-54B main transmission follows standard aircraft practice. Oil from the gearbox sump is pumped through a forced air/oil heat exchanger and then to a manifold on the main transmission. From the main transmission manifold, oil is fed to bearings, gear meshes, and oil distribution tubes throughout the transmission.

MODULAR DESIGNS

Design Criteria

All modularized versions of the CH-54B main transmission described in this report were designed according to standard helicopter transmission design practice. Speeds and reduction ratios of the modular designs are unchanged from the baseline CH-54B transmission. Structurally, the modular transmission design must be able to withstand the same loads and transmit the same powers with equal or lower levels of stress achieved by the baseline CH-54B main transmission.

A primary design objective of the modular transmission concept is to permit parts removal and replacement in the field by personnel at the U. S. Army organizational maintenance level. The tools required to remove modules are standard wrenches as found in the U. S. Army mechanic's tool kit. All shimming, for example, required for spiral bevel gear pattern setting, is to be accomplished internal to the module and done at the depot maintenance level, not in the field. A minimum of training and instruction is to be required to teach Army organizational level maintenance personnel procedures for module removal and installation.

Another primary design objective of the modularized transmission is to effect the isolation of each module and prevent the spread of contamination in the event of a malfunction of any internal module components. Shields or screens at module interfaces must effectively confine any debris or chips to the affected module.

The third primary design objective is to be able to pinpoint the particular module that is affected after a failure is detected, and chips and contamination are isolated. In the modularized designs presented herein, each module contains its own chip detector. Cockpit monitoring is by a single, warning light on the copilot's caution panel.

A secondary objective of modularized transmission design is to design the module in such a manner as to minimize the protrusions of components. When a module is removed from the transmission, splines or other components projecting beyond the module interface flange are subject to damage from mishandling and contamination with dirt or foreign objects. In all modularized interface designs, quill shafts, oil lines, or oil distribution tubes that would normally project beyond the module interface for more than a reasonable length, have been redesigned to reduce chances of damage or contamination.

Another secondary design objective of the modularized designs presented herein is to eliminate all external oil lines and to redesign using internally cored or drilled lines. Internal oil lines are inherently more reliable than external "plumbing" and are used in the latest production Sikorsky helicopters. Internal oil lines also simplify assembly and disassembly, since lines that cross module interfaces can be designed to seal automatically when the module is removed. This technique eliminates the need to remove external plumbing. Inspection time, installation and removal time, mean time between unscheduled removals, unscheduled maintenance frequency, and overall transmission reliability can be expected to improve as a direct result of the use of internal oil lines. These improvements, however, have not been reflected in this report, since internal oil lines can be added without modularization of the main transmission. Care has been taken that only improvements resulting directly from modularization should be included in this report in order to evaluate modularization accurately. In effect, then, while the modularized designs show internal oil lines, the data are taken as if the oil lines were external.

All speeds of the modularized main transmissions are identical with the CH-54B baseline design, as previously shown in Figure 6. The main transmission design horsepowers, crash design conditions, and bearing minimum life requirements are also identical with the CH-54B baseline design and are presented in Table I. Accessory design is identical with the CH-54B, as previously shown in Figure 7.

TABLE I. CH-54B MODULARIZED TRANSMISSION BASIC DESIGN LOADS

Component	Design Condition
First-Stage Spiral Bevel Gear and Shaft	4800 HP (Single Engine)
Freewheel Unit	4800 HP (Single Engine)
Second-Stage Spiral Bevel Gear and Shaft	4800 HP (Single Engine)
Tail-takeoff Bevel Gear	1220 HP
First-Stage Planetary	6800 HP
Second-Stage Planetary	6800 HP
Main Housing Mounting	20-20-18g crash
Input Bevel Module	20-20-18g crash
Tail-takeoff Module	20-20-18g crash
All Bearings	3000 Hr. B-10 Life

The basic design approach for modularization of the main transmission is to begin with the maximum degree of modularization (seven modules in this case) and to combine modules to obtain lower degrees. The seven-module design contains all of the modules for any required lower degree. Trade-off studies are conducted on the seven-module version so as to include all versions. The following paragraphs will discuss the design of the seven-, six-, four-, and three-module versions of the main transmission. The five-module design was not chosen because of its similarity to the three-module design.

Description of the Seven-Module Design

The baseline CH-54B main transmission was divided first into seven modules: identical left-hand and right-hand input bevel modules, identical left-hand and right-hand freewheel units, a tail-takeoff and accessory module, a main bevel module, and a planetary module. A simplified isometric drawing, an exploded cross-sectional layout, and an assembled cross-sectional layout of the seven-module configuration are shown in Figures 10, 11, and 12.

The input bevel module contains the first-stage spiral bevel mesh of 27-to-53 reduction. An existing bolt circle on the main transmission housing was used as the module interface for the input bevel module. The engine drive shaft input area, consisting of torque sensing unit, input couplings, spherical bushing, and engine torque tube, is identical with the baseline design. Left-hand and right-hand input bevel modules are interchangeable.

To simplify assembly and disassembly in the seven-module versions of the main transmission, the freewheel units were moved from their positions near the second-stage spiral bevel pinions and attached to the outside of the input bevel module housing. The rotor brake takeoff flanges were also moved from their positions on the input bevel pinions and attached to the freewheel unit modules. The rotor brake is mounted on the left-hand freewheel unit module and is driven by the rotor-brake takeoff of that module. The right-hand rotor-brake takeoff is used to drive the spur gears that power the winch and utility pumps.

Support of the freewheel unit module was the primary design consideration. Three configurations of this module were developed. The first, which is shown in the exploded and assembled seven-module layouts, was chosen as the optimum design because of the wide span between the support bearings. Two alternative designs are shown in Figure 13. In the upper design, the freewheel unit is supported by the continuous shaft of the rotor-brake flange. While support in this configuration is essentailly the same as in the optimum design, an additional bearing had to be included at the interface with the input bevel module to allow overrunning. The additional bearing of this configuration is more expensive, heavier, less reliable, and less efficient. For this reason, this design was rejected. The lower configuration of Figure 13 separates the rotor brake flange from the freewheel unit. This necessitated use of piloted splines for support of the unit. Because these splines are close together, they do not provide adequate support for the unit.

To eliminate projections from the freewheel unit module, the 30-inch oil distribution tube of the baseline has been shortened and divided at the interface of the freewheel unit module and input bevel module. A probe jet feeds oil into the smaller diameter tube of the input bevel module, where it is distributed to the second-stage pinion bearings through holes in the tube and gear shaft. The oil that is not fed through these holes spills into the larger diameter tube of the freewheel unit module, where it is distributed to freewheel unit bearings, rollers, cam, cage, return springs, outer housing, and all splines. This design eliminates projections when the input bevel module is removed from the main bevel module. Torsional paths between modules are provided by splines located as close as possible to the module interfaces.

The tail-takeoff module design makes use of a new rear casting that, in effect, seals gears, bearings, and other components in the rear cover. The tail-takeoff section of the baseline design contains an oil pump drive that passes through the main casting to the oil pump in the main housing sump. The oil pump drive for the seven-module version has been relocated to the lower plate of the second-stage planetary gear set, where external spur gears increase the 185-rpm cage speed to 2750 rpm at the oil pump. This design eliminates the existing quill shaft, which would pass over the tail-takeoff module interface and would not allow module removal at angles that do not coincide with the quill shaft centerline.

Figure 14 shows two alternative designs of the tail-takeoff module. Both use the existing bolt pattern of the rear cover as the module interface. In both cases, the tail-takeoff bevel gear has been designed with the tail drive section remaining with the rear cover, and the bevel gear section remaining with the main module. Both designs use spur gears and splines as torque interface components. The accessory drive spur gear and freewheel unit are relatively high replacement items and are not removed with the rear cover in the designs shown, which is a disadvantage. In the selected tail-takeoff module design, the freewheel unit is removed with the module. A further disadvantage of the alternative tail-takeoff designs is that, when the rear cover is removed, accessory drive gearing and bearings are exposed to damage by contamination or mishandling. Additionally, the support structure for the tail-takeoff gear is weakened even though loading is low in this area. For these reasons, the two alternative tail-takeoff designs were rejected, and the design shown in Figure 11 was chosen as the candidate.

The planetary/main bevel interface uses an existing bolt pattern as the breakpoint. This area was extensively redesigned, including the main bevel outer shaft, bearings, and bolt connection. The inside diameter of the outer shaft has been increased from 9.375 inches to 11.75 inches to permit removal of the main housing over the inner race of the main rotor shaft upper roller bearing. The inner race of the upper roller bearing is, thus, located in the main bevel module, and the outer race, cage, and rollers are in the planetary module. The main bevel module uses an outer shaft inertia-bonded to the

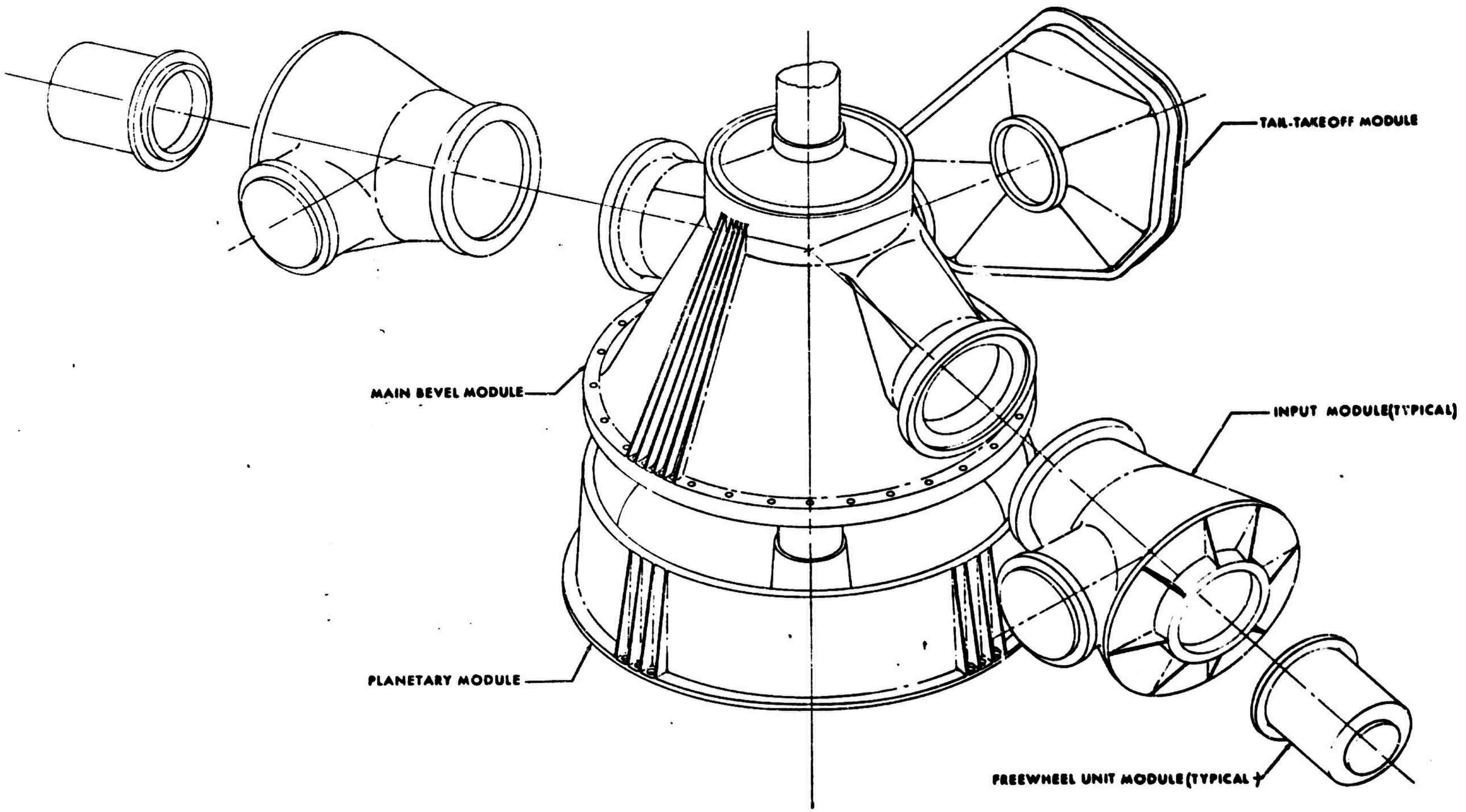

Figure 10. Exploded Isometric Drawing of CH-54B Main Transmission, Seven-Module Configuration.

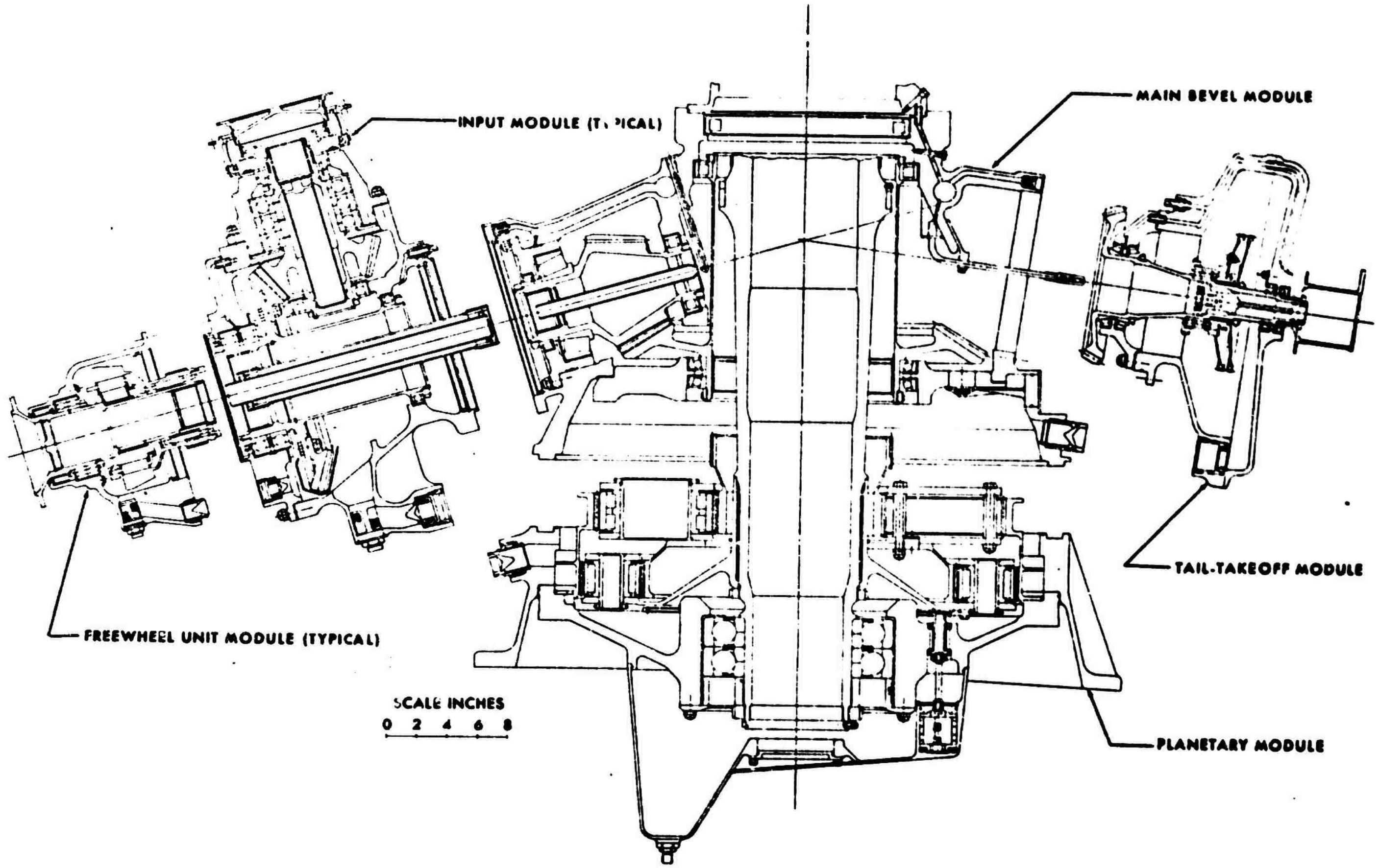

Figure 11. Exploded Cross Section of CH-54B Main Transmission, Seven-Module Configuration.

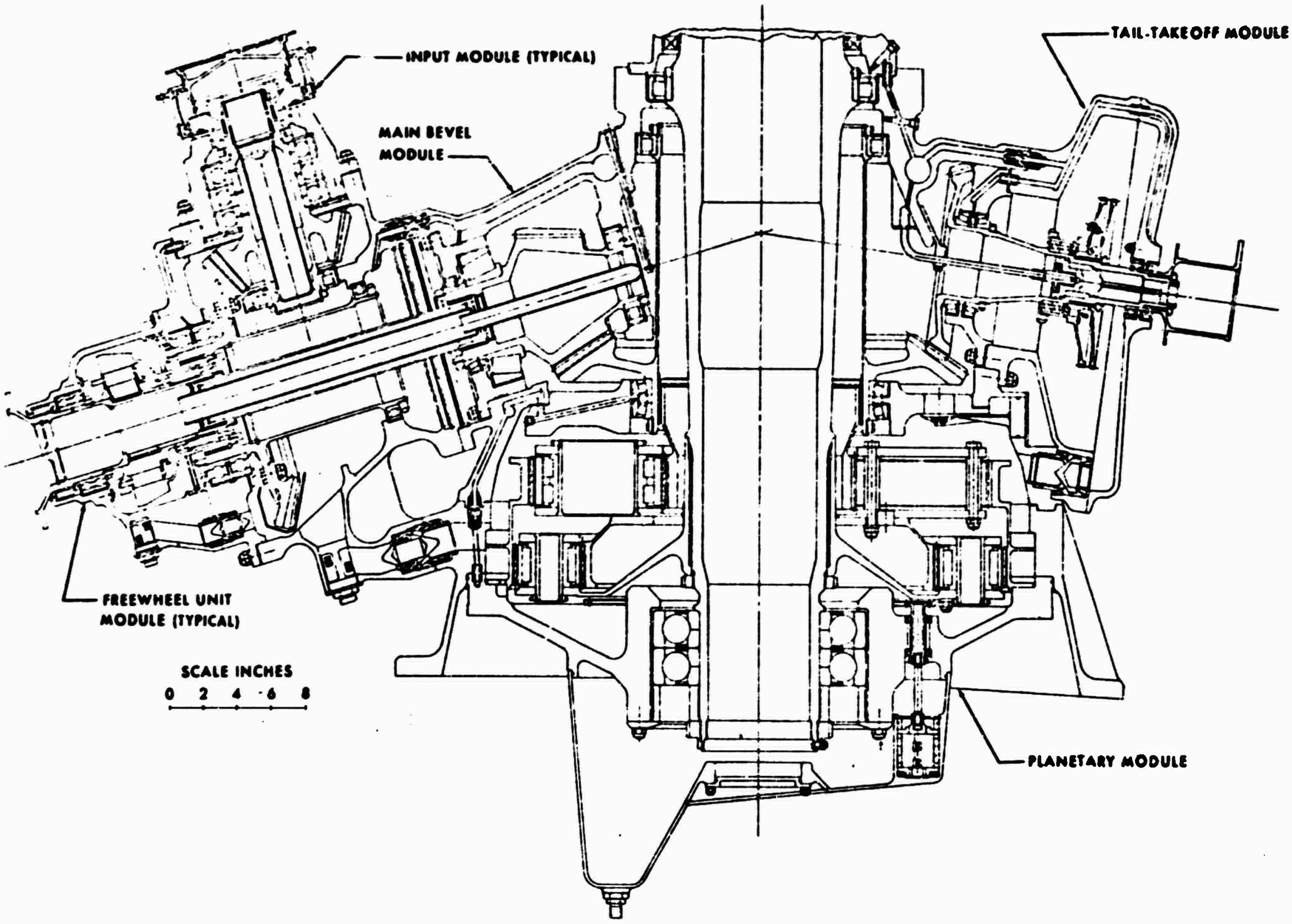

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Figure 12. Assembled Cross Section of CH-54B Main Transmission, Seven-Module Configuration.

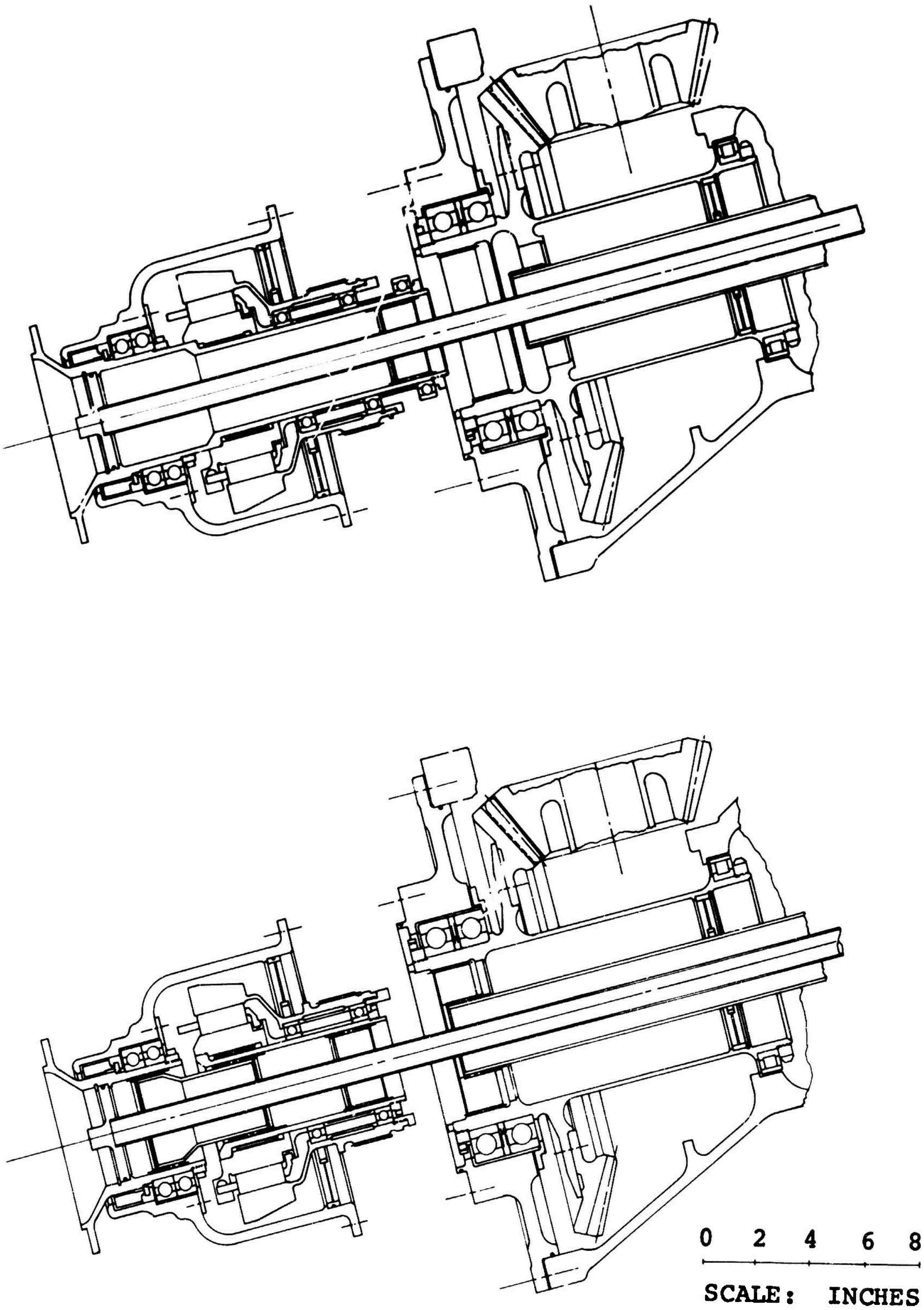


Figure 13. Alternate Freewheel Unit Module Designs.

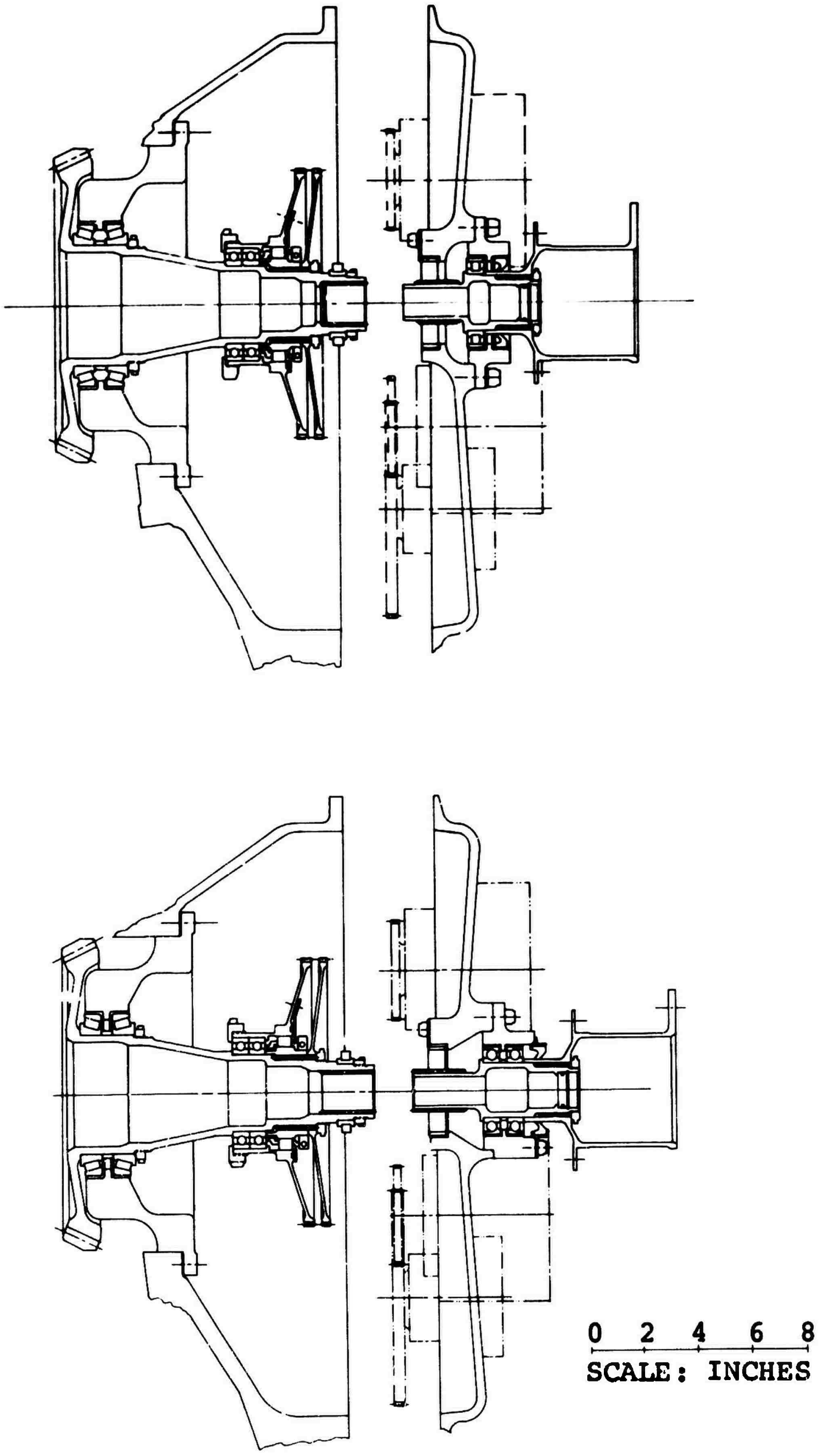


Figure 14. Alternate Tail-Takeoff Module Designs.

main bevel gear. Inertia-bonding saves axial space and permits the design to fit into the existing housings.

The two designs of Figure 15, one on each side of the centerline, present alternative methods of attachment of the main bevel gear to the outer shaft. In the design shown to the left of the centerline, which is the baseline main bevel module design. the bevel gear is inertia-bonded to the outer shaft. In the alternative design to the right of the centerline, the bevel gear is bolted to the outer shaft. To accommodate the increased bearing sizes in the bolted design, the overall length of the outer shaft, main rotor shaft, and main housing has been increased by .88 inch. On the basis of the increased weight of 17.8 pounds, of the bolted design, the inertia-bonded design was selected as the candidate module for the seven-module version. The inertia-bonding technique has proven successful with several production applications on turbine engine transmissions.

The candidate seven module design shown uses quick-disconnect couplings at all module oil drains and inlet interfaces. These couplings are designed for automatic opening when modules are assembled. In the event of malfunction of springs or other components of the quick-disconnect couplings, they will remain open and will not close upon disassembly. The advantages of quick-disconnect couplings are:

- Contamination by dirt or other foreign objects is eliminated.
- Oil spillage during assembly and disassembly is held to a minimum. Secondary damage caused by the effects of oil spillage is eliminated.
- Maintenance hours required to clean spillage are reduced.

Two other methods for oil inlet and drain line module interface connections are shown, along with quick-disconnect couplings, in Figure 16. The first alternative method shows transfer tubes consisting of a tube trapped in counterbored holes in each module. "O" rings on each end of the tube prevent oil leakage in the assembled position. While this design is inexpensive, simple, and reliable, the sealing advantages offered by quick-disconnect couplings are not realized with oil transfer tubes. A second alternative design is the "O" ring face seal shown in Figure 16. This design is also simple, reliable, and inexpensive. However, the sealing disadvantage of transfer tubes is also inherent in "O" ring face seals. As will be shown in the Transmission Cost Input Data section, the cost of self-sealing quick-disconnect couplings is negligible in life-cycle aircraft cost. They have, therefore, been included in

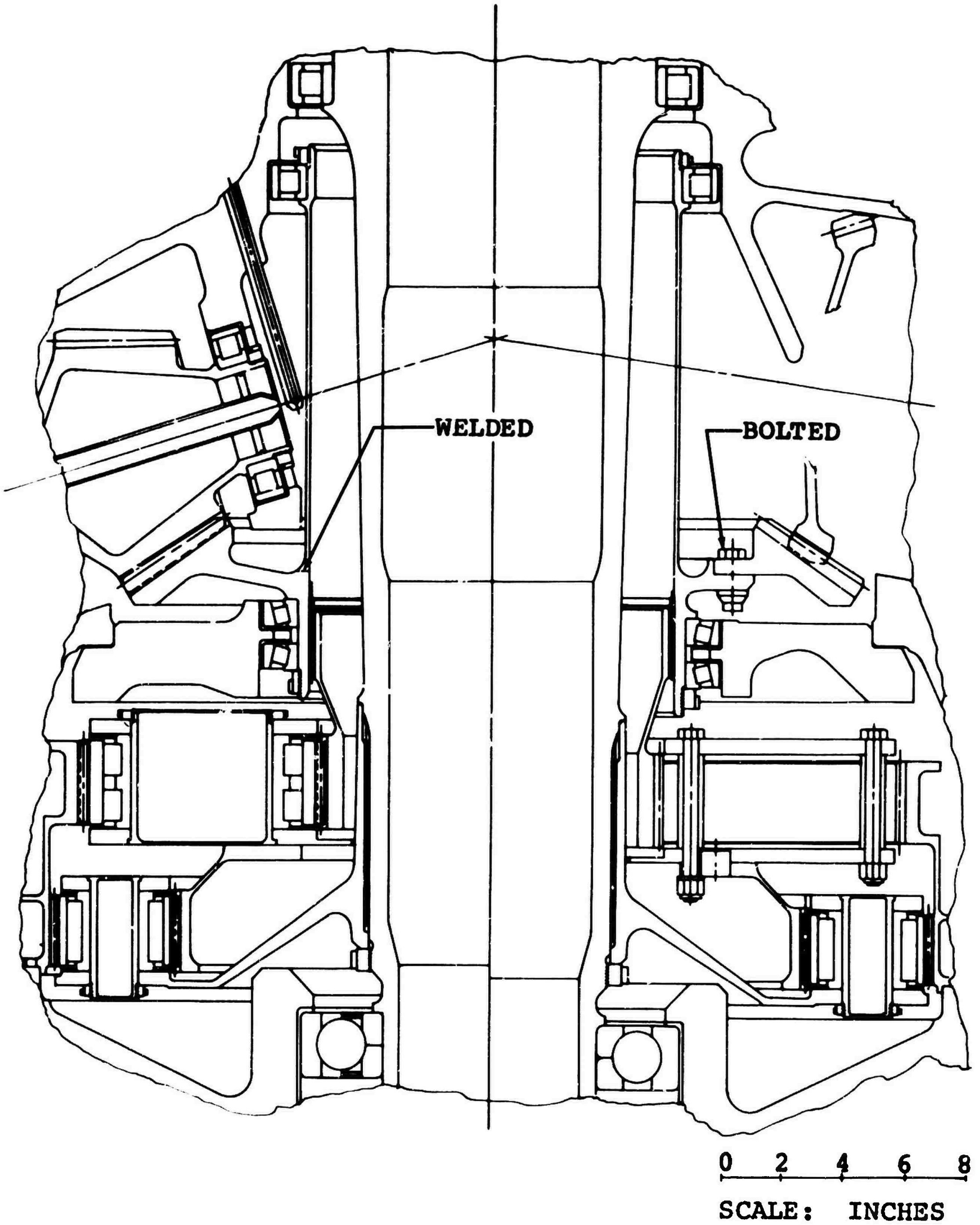
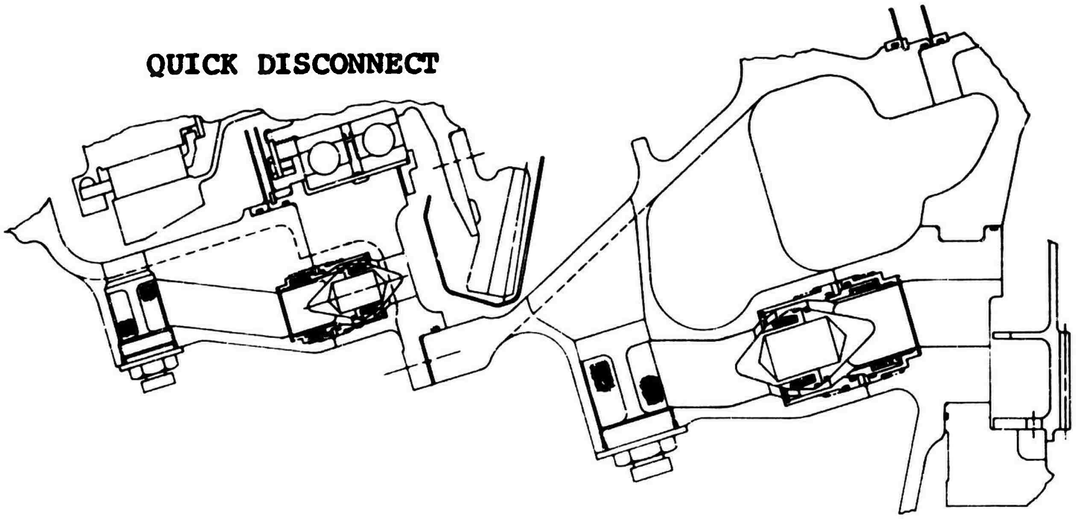
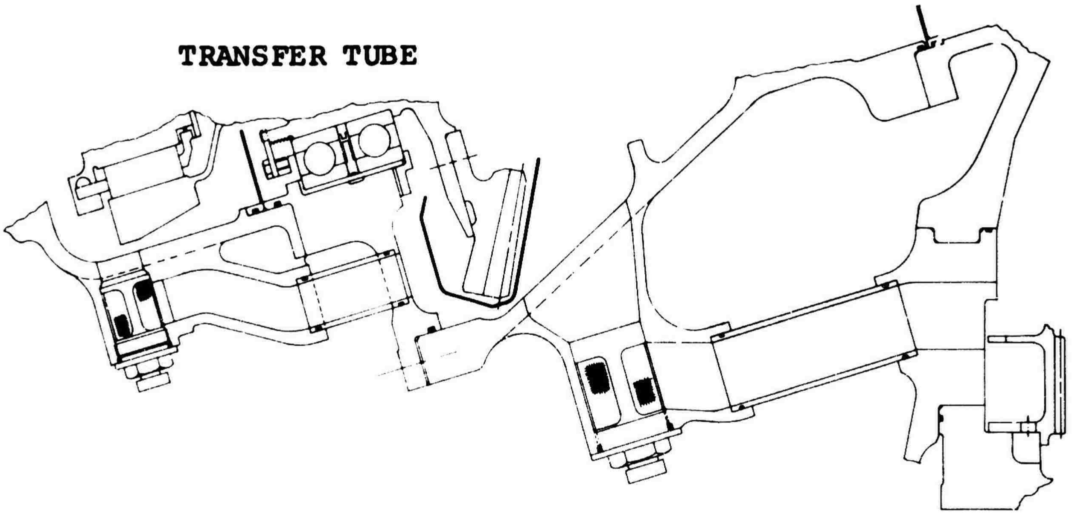


Figure 15. Alternate Methods of Attachment of the Main Bevel Gear to the Outer Shaft.

QUICK DISCONNECT



TRANSFER TUBE



"O" RING

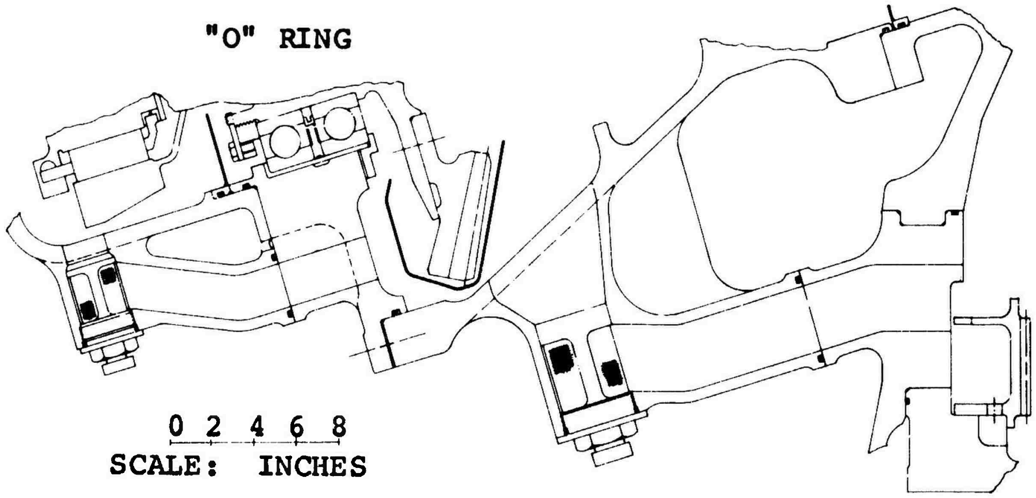


Figure 16. Alternate Oil Drain Interface Designs.

all the modular design evaluations because of the advantages of sealing modules upon disassembly.

An important aspect of the seven-module transmission design is the isolation of contamination. With normal design practice, chips from a failure often spread and damage other components. With modularization, chips or other particles from broken components are prevented from spreading to other sections of the transmission by the use of screens or shields at modular interfaces. Screens and shields considered for use in the modular designs are basically end caps that seal the module at the module interface. A concentric central hole in the shield or screen permits the torsional interface connector to pass through the shielded end. This hole locates the splined shaft in such a manner that, during assembly, the splines are located within .030 inch concentricity alignment but after assembly, retain a running clearance. From experience, number 30 screens of .015-inch-diameter wire with an opening of .018 inch have proven to be effective for free flow of oil, yet prevent passage of most chips. Screens at module interfaces, however, have several drawbacks. Since oil is capable of flowing through the screens, chips carried along with the oil may collect at the bottom of the screen and not reach the chip detectors in the drains of each module. Upon module removal, screens do not isolate dust and dirt.

A solid shield overcomes both deficiencies of screens. Oil cannot flow through the shield. It is forced to flow through the intended drain and chip detector. Contamination with chips is then quickly detected, and less damage is likely. Solid shields also prevent dust, dirt, and other foreign objects from entering the internal mechanisms of the module upon disassembly.

For these reasons, shields have been selected for use at the module interfaces. At the drains of each module of the seven-module design, one or more chip detectors will trap contamination. These chip detectors can detect magnetic and nonmagnetic chips and are usually set with a gap of approximately .25 inch. With this gap, sensitivity is reduced so that normal wear particles do not continually indicate false failures. The "exit" side of each chip detector contains a number 30 screen of .015-inch-diameter wire with an opening of .018 inch to prevent contamination of adjacent modules. Each module contains its own chip detector, and a cockpit monitoring light is provided. With shields at interfaces and chip detectors at drains, any failures are quickly detected and isolated to the module where they originate.

In the design of a modularized transmission, torque must be transmitted across the interface of each section. This can be accomplished with splines and couplings or with spur, helical, or bevel gears. In the seven-module designs, splines and bevel gears have been used.

The bevel gear has been used as the torsional interface for the candidate tail-takeoff module. Splines are used in all other modules of the seven-module design.

Gear interfaces offer one method of providing a module separation if the gear contact is used as the separation point. For spur gears or helical gears, it is difficult to provide shields around the contact points. A bevel gear provides a convenient breaking point if one of the gears is allowed to protrude from the module, as shown in the design of the candidate tail-takeoff module of Figures 12 and 13. The problem with this arrangement lies in the gear pattern development, since the module bolt circle face presents an additional tolerance normally not encountered in standard bevel gear shimming. For this arrangement to be practical, the distance from the pitch apex point of the bevel set in the main housing to the module mounting face must be closely held during manufacture, with a recommended ± .002 inch tolerance. The tail-takeoff gear in this case is then internally shimmed in the tail-takeoff module to align with the mounting face of the tail-takeoff module. This procedure is not recommended for highly loaded bevel gear sets or where shaft angle is shallow. In the case of the CH-54B tail-takeoff bevel gear set, the gear stresses are well below normal aircraft allowables at the maximum transmitted horsepower of 1220. In addition, this gear is not sensitive to axial alignment errors because of the high shaft angle of 82 degrees and 15 minutes.

In addition to geared torsional interface transmitters, coupling torsional transmitters can be employed. These include splines and face couplings. A special type of face coupling often used in aircraft design is the curvex coupling. It is a toothed-face coupling that can transmit high torques in a compact arrangement. Since the teeth of the curvex coupling are inclined, axial shaft loads are induced whenever torque is transmitted. Even with very low pressure angles, the axial load produced by the torque transmitted in the CH-54B main transmission is too high to allow use of these couplings as an interface torsional load carrier. The curvex coupling has not been used in any of the modular designs presented. The face coupling is similar to a curvex coupling and may be thought of as a curvex coupling with zero degree pressure angle, although the face coupling has straight sided teeth. The outside diameter of the face coupling provides a natural journal upon which the module interface shield can be fitted. A typical face-coupling module interface design is shown in Figure 17.

The disadvantage of face coupling is the concentricity alignment requirement. It would be difficult to assemble the module with the face coupling because of inherent concentricity

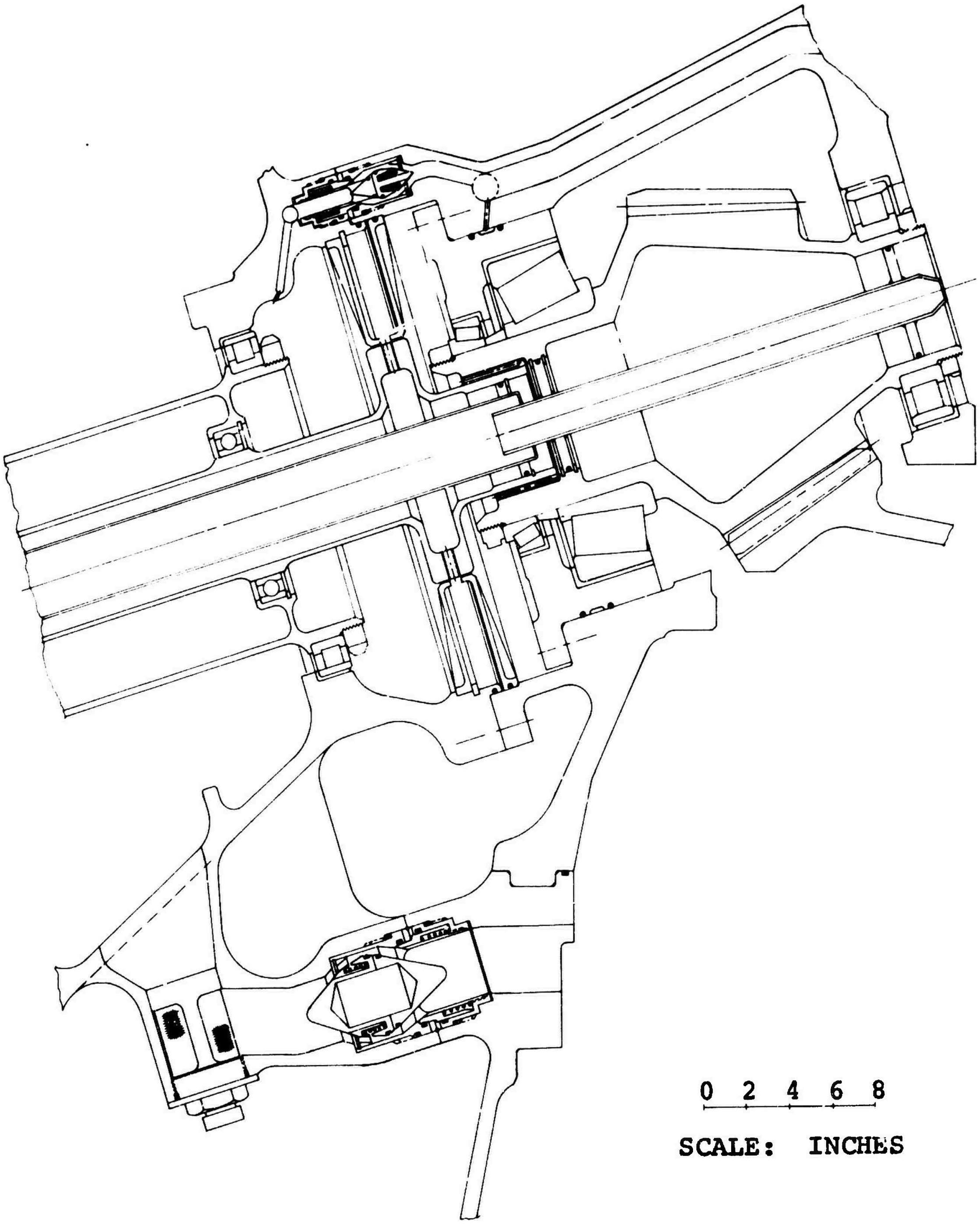


Figure 17. Typical Face Coupling Torsional Interface Design.

errors. For this reason, face couplings have not been used in the modular designs.

The most efficient torque carrier is the involute spline. It can be assembled loosely to provide a convenient module interface connector. Most of the seven-module designs use involute splines as the torsional interface element. The spline can be allowed to protrude from the module upon disassembly, since any dirt can easily be wiped clean prior to assembly. The involute spline is compact and offers a convenient method for shielding. Concentric alignment is the same as for any normal quill shaft, and assembly is easily accomplished. For these reasons, the involute spline is best as the modular transmission torsional interface connector.

In the seven-module design presented, no major drive gear tooth geometry has been changed. All bearings are identical with the baseline design except for the outer shaft roller and outer shaft double tapered roller, which have been increased in size and capacity. The dynamic components are structurally identical with the baseline CH-54B transmission and should have the same reliability. Additional components are required, however, and the total number of parts has increased. Additional splines, bolts, drain paths, chip detectors, shields, etc., have added to the complexity and have slightly reduced overall reliability, considering that more parts will generally have more failures. This is reflected in the input data to the mathematical model and will be discussed in the Input Data chapter.

A primary advantage of the seven-module design is the ease with which certain components can be repaired or replaced. For example, a chronic failure mode of the baseline transmission is wear on the outer housing of the tail-takeoff freewheel unit. This failure is often cause for removal of the entire transmission and shipment to the depot level for overhaul. Removal of the tail-takeoff baseline main transmission requires the following procedure:

(1) Disconnect all accessories.

(2) Remove rotor blades.

(3) Remove rotor head.

(4) Disconnect engines (right and left).

(5) Remove main rotor servos.

(6) Remove oil lines to cooler.

(7) Disconnect tail drive shaft.

(8) Unbolt main attachment to airframe.

Removal of the tail-takeoff in the modularized version will only require the following procedure:

(1) Disconnect all accessories on rear cover only.

(2) Disconnect tail drive shaft.

(3) Unbolt eight 1/2-inch bolts on module interface flange.

(4) Remove module.

The easiest module to remove is the freewheel unit module. It requires removal of the rotor brake or the winch and utility pumps, depending on what side is being removed, followed by removal of six bolts. Removal of the input bevel module requires dropping one engine and unbolting the module.

Although the planetary and main bevel units are two separate modules, no advantage is derived in combining them, since removal of either module entails the same procedure as removal of the entire baseline transmission.

All modules of the seven-module design are subject to contamination or damage from mishandling during removal or installation. To aid in preventing contamination or damage, a protective cover can be used, as shown in Figure 18. This cover can be plastic or fiberglass. It remains with the shipping container. When a damaged module is removed, the container for the replacement module is opened, the protective cover is taken off the new module and replaced on the damaged module, the new replacement module is then installed on the transmission, and the defective unit is replaced in the shipping container, along with the protective cover.

Description of the Six-Module Design

The six-module CH-54B main transmission consists of left- and right-hand input bevel gear modules, left- and right-hand freewheel unit modules, tail-takeoff module, and planetary/main bevel module. The left- and right-hand input bevel gear modules, left- and right-hand freewheel unit modules, and tail-takeoff module are identical in the six- and seven-module versions. The planetary and main bevel gear modules of the seven-module design have been combined into one unit to form the planetary/main bevel module in the six-module design. Figure 19 shows an isometric exploded view of the six-module design. An exploded layout of the six-module version is shown in Figure 20. The assembled cross-section layout of the six-module design is shown in Figure 21.

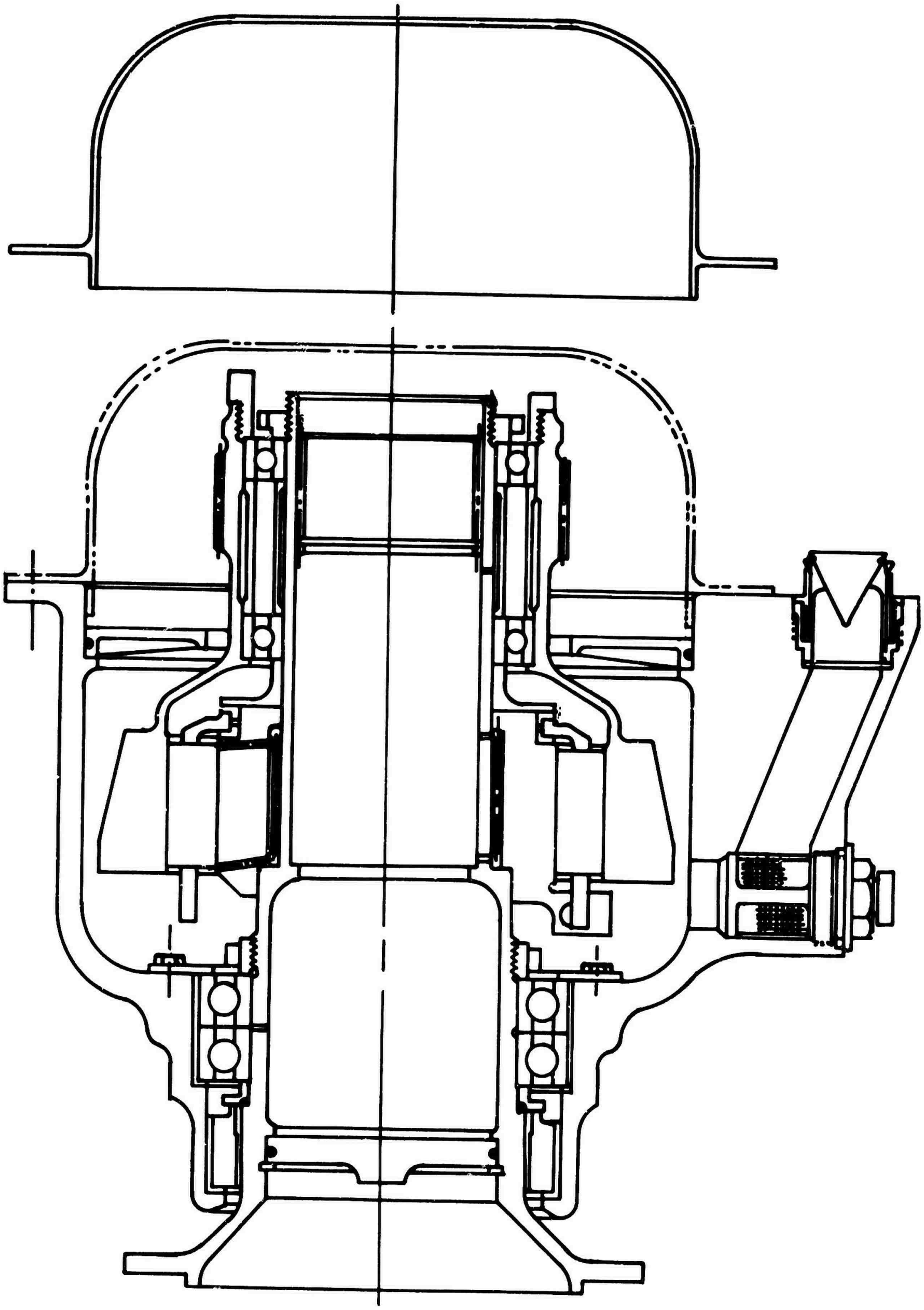


Figure 18. Typical Protective Cover Shown on Freewheel Unit Module.

Since the outer shaft of the main bevel gear need not be removed over the main shaft upper bearing, as in the seven-module version, the outer shaft has been reduced in diameter to its original baseline design size. The outer shaft upper roller bearing and back-to-back tapered roller bearings have also been reduced to their original baseline design size. The associated bearing support housings and the spline attachment of the first-stage sun gear to the outer shaft have also been reduced. Therefore, the weight and cost of the outer shaft and associated support bearings, main shaft, and main housing are less in the six-module design than in the seven-module design. The three, "drawer" type chip detector screens located at the main bevel to planetary interface have been removed. Failures in the main bevel or planetary sections will be detected by the chip detector located in the main sump.

The design considerations of the tail-takeoff, freewheel unit, oil drain interface couplings, torsional interface couplings and protective cover, which were discussed above for the seven-module configuration, also apply to the six-module configuration and all subsequent configurations.

A five-module version of the CH-54B main transmission, consisting of left and right input bevels, left and right freewheel units and a main module of planetary, main bevel, and tail-takeoff, is feasible but has not been designed for this study. The tail-takeoff module, which requires frequent maintenance, should be a separate unit for optimum cost savings. Proof that a combined tail/main section is not good design practice is shown in the three-module version to be discussed in later paragraphs.

Description of the Four-Module Design

The four-module CH-54B main transmission consists of left- and right-hand input bevel/freewheel unit modules, a tail-takeoff module, and a combined planetary/main bevel module. The planetary/main bevel module is identical in the four- and six-module designs. The tail-takeoff module is identical in the four-, six-, and seven-module designs. All trade-off studies pertaining to oil drain interface considerations, torsional interface couplings, and the tail-takeoff module which were discussed above for the seven module configuration also apply to the four-module design.

An exploded isometric drawing of the four-module design is shown in Figure 22. An exploded cross section and an assembled cross section of the four-module design are shown in Figures 23 and 24 respectively.

The freewheel unit module and input bevel module of the six- and seven-module designs have been combined to form single units for the four-module version. The bolted connection and housing of the freewheel unit module has been eliminated and the freewheel unit is located deeper inside the input bevel gear shaft, as in the baseline. Unlike the baseline design, the freewheel unit is no longer an integral part of the second-stage bevel pinion. An additional splined shaft has been added at the interface between the freewheel unit and main bevel pinion. Support for the freewheel unit is now provided by the first-stage bevel output gear shaft. The chip detector/drain for the freewheel unit is eliminated, as is the shield separating the input and freewheel modules of the six- and seven-module designs. The rotor brake flange and supports of the combined freewheel/input bevel module are identical to the baseline CH-54B. Torque is transmitted across the module interface by a splined quill shaft connected to the inner cam member of the freewheel unit. The second-stage bevel pinion contains the internal spline member. As in previous interface designs, the oil distribution tube, located inside the freewheel unit and second-stage bevel pinion, has been designed in concentric sections which transfer oil by spillage across the noncontacting interface.

The freewheel unit/input bevel module of the four-module main transmission has an additional feature. After the input bevel/freewheel module has been removed and is exposed, the freewheel unit itself can easily be removed. The freewheel unit is not considered a module, however, because it does not contain its own chip detector and chip isolation system. It is a smaller, more compact unit than the freewheel unit module of the six- and seven-module designs because the housing, shield, chip detector, and oil drain disconnects are not attached. This unit can be removed by the direct support field maintenance crew using one special wrench. Since it is smaller in size than the freewheel unit module of the six- and seven-module designs, special shipping containers are not required. In short, this design has many of the advantages of the six- and seven-module design, but does not have the disadvantage of special shipping containers and special handling. The freewheel unit can now be changed at the option of the field maintenance personnel. In the analysis of the four-module design this additional feature has conservatively been disregarded.

Description of the Three-Module Design

The three-module CH-54B main transmission consists of left- and right-hand input bevel/freewheel unit modules and a combined main module containing main bevel, planetary, and the tail-takeoff. The left- and right-hand combined input bevel/freewheel unit modules are identical in the three- and four-module configurations.

An exploded isometric drawing, exploded layout, and assembled layout of the three-module design are presented in Figures 25, 26, and 27, respectively. The tail-takeoff and accessory section of this version is similar in design to the baseline design. The chip detector located in the lower section of the tail-takeoff of the four-module design has been eliminated. The separate casting which provided an enclosure for drive components of the rear cover has been made integral with the main housing.

As in the baseline design the oil pump is driven from the accessory case and has been relocated to its original position. The drive gear located on the lower plate of the second-stage planetary, and the oil pump connecting drive shaft and supports have been eliminated.

As with the five-module design, the three-module design is not considered an optimum choice for modularization because tail or accessory failures will require removal of the main section of the transmission. It has been included as a modularized design option to provide more data for comparison.

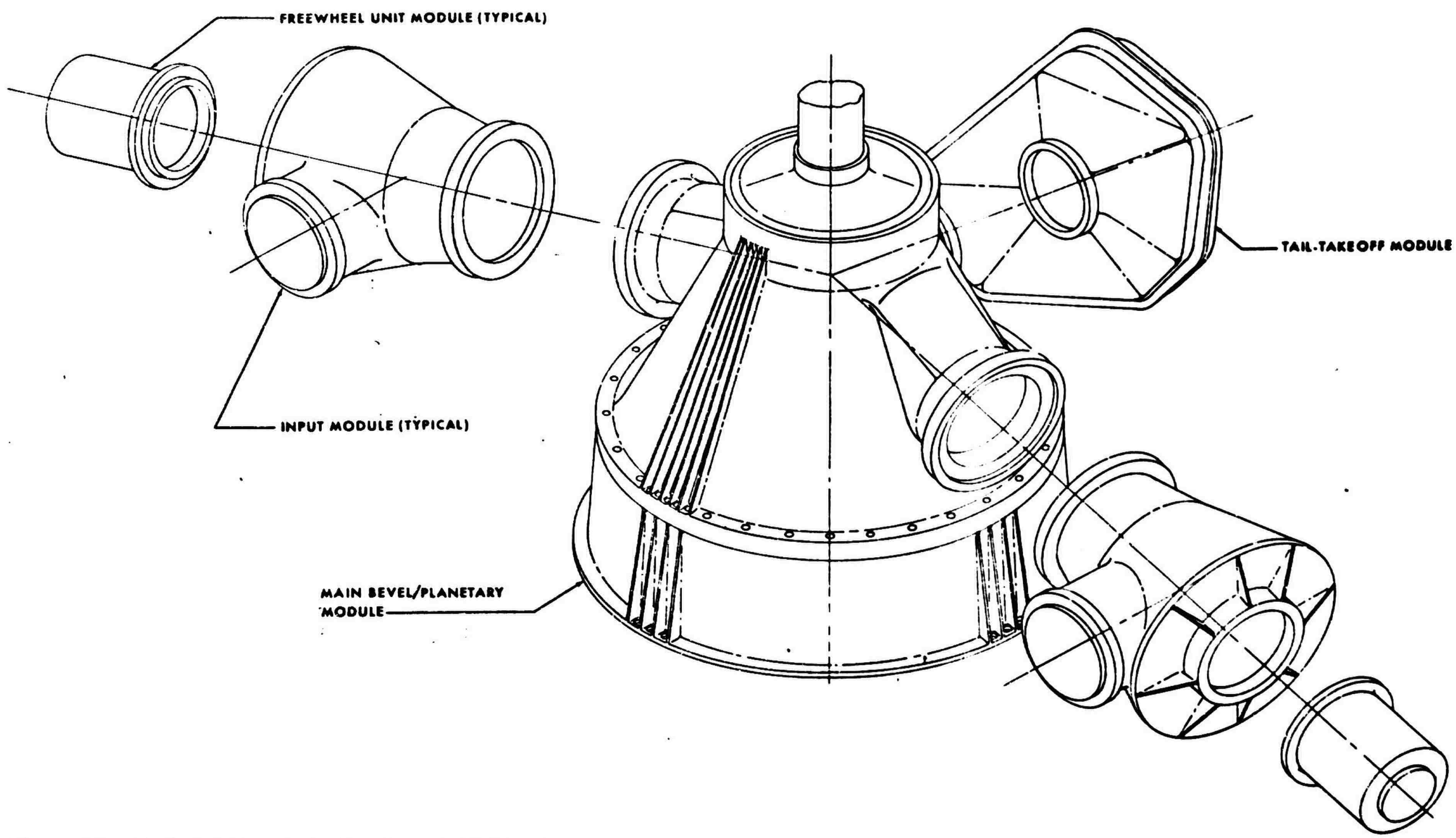


Figure 19. Exploded Isometric Drawing of CH-54 Main Transmission, Six-Module Configuration.

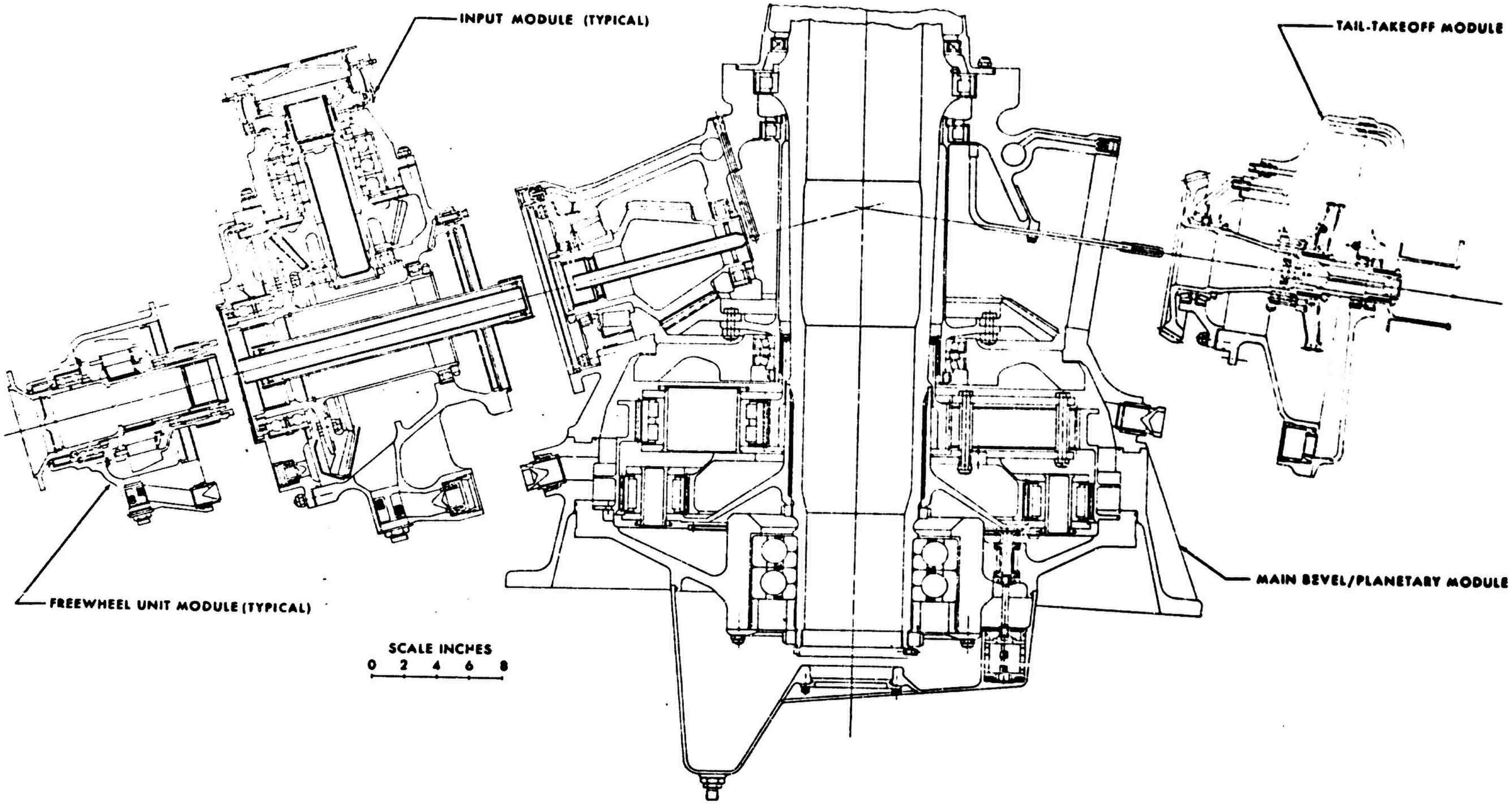


Figure 20. Exploded Cross Section of CH-54B Main Transmission, Six-Module Configuration.

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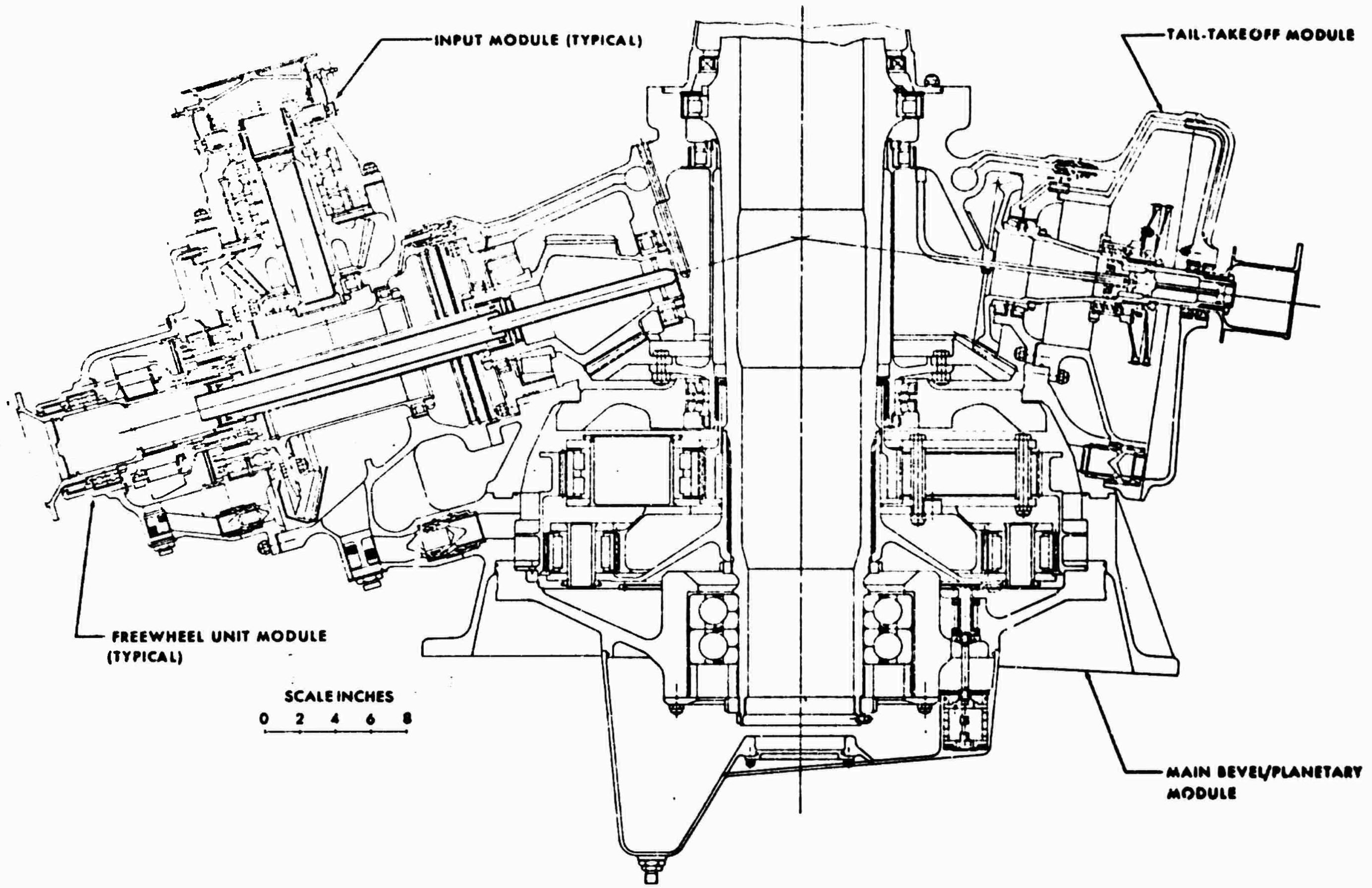

Figure 21. Assembled Cross Section of CH-54B Main Transmission, Six-Module Configuration.

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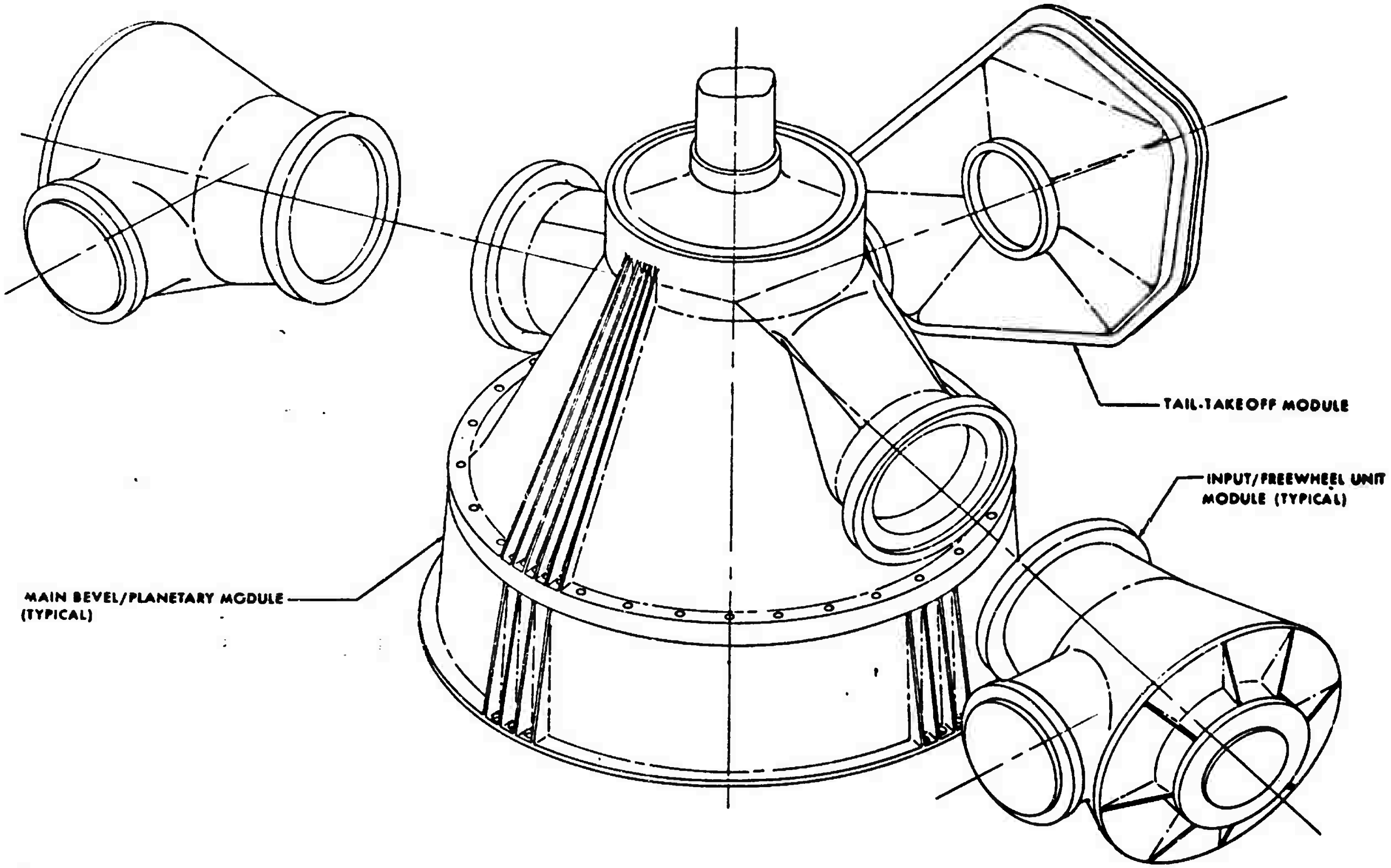

Figure 22. Exploded Isometric Drawing of CH-54B Main Transmission, Four-Module Configuration.

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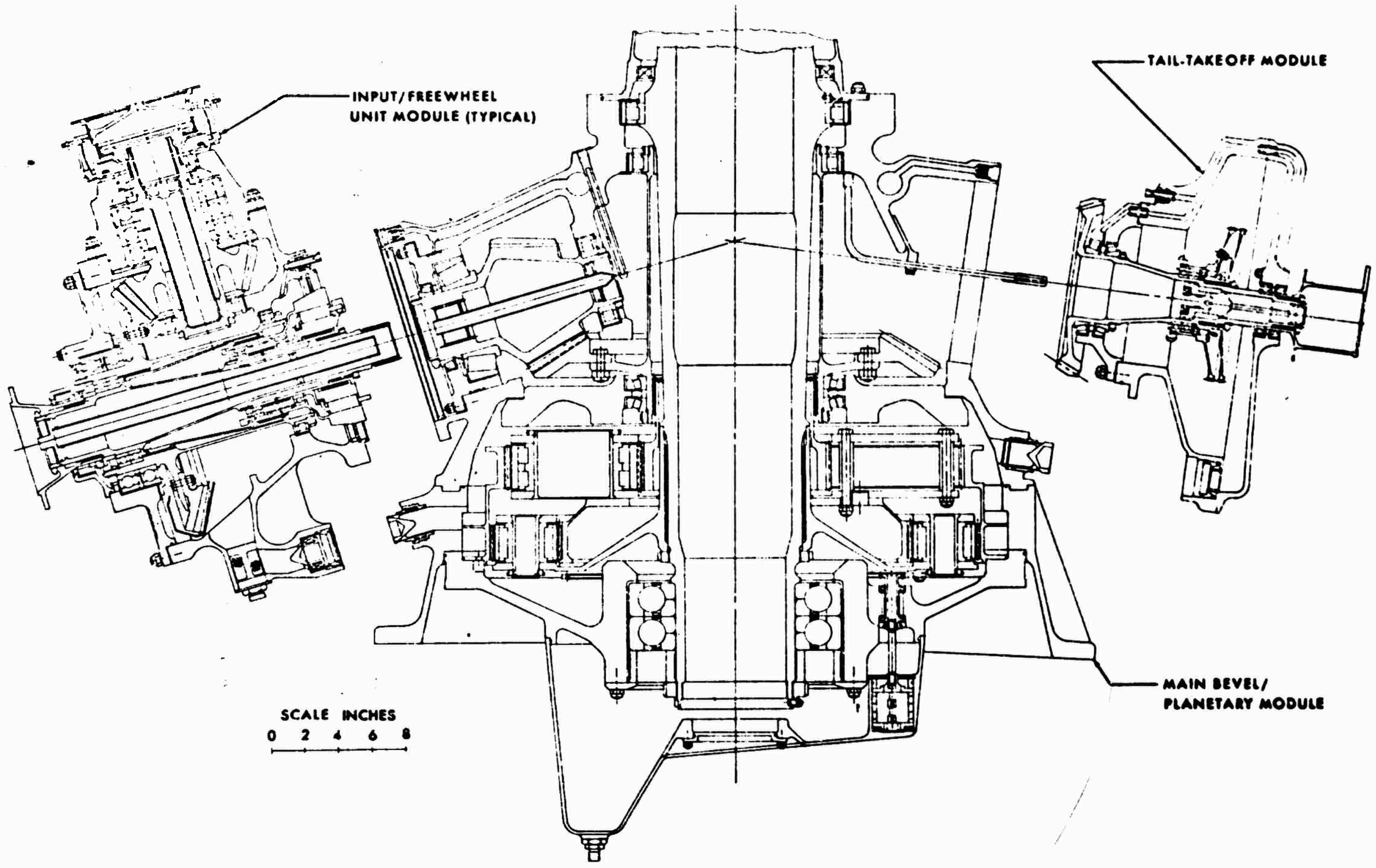

Figure 23. Exploded Cross Section of CH-54B Main Transmission, Four-Module Configuration.

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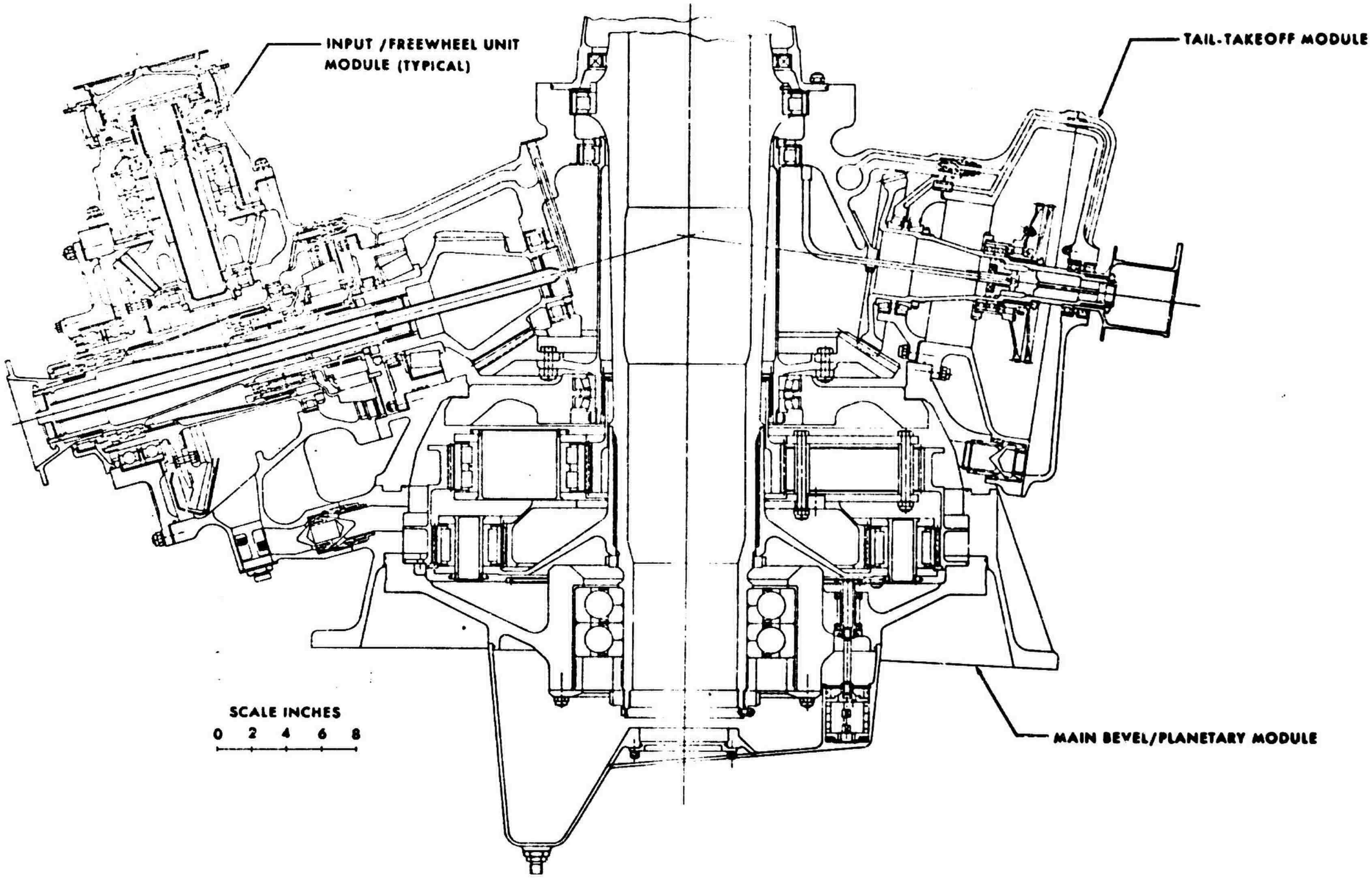

Figure 24. Assembled Cross Section of CH-54B Main Transmission, Four-Module Configuration.

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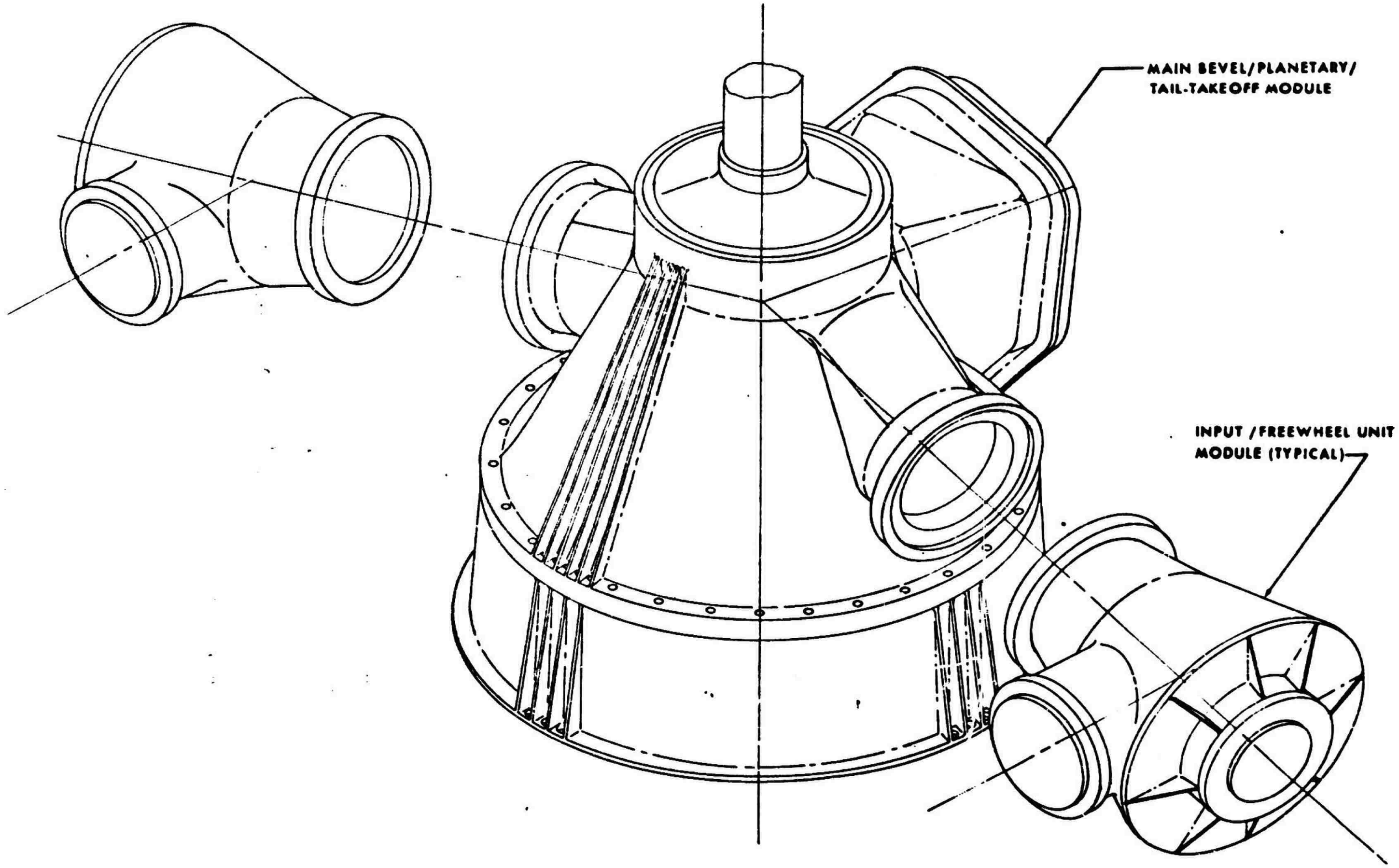

Figure 25. Exploded Isometric Drawing of CH-54B Main Transmission, Three-Module Configuration.

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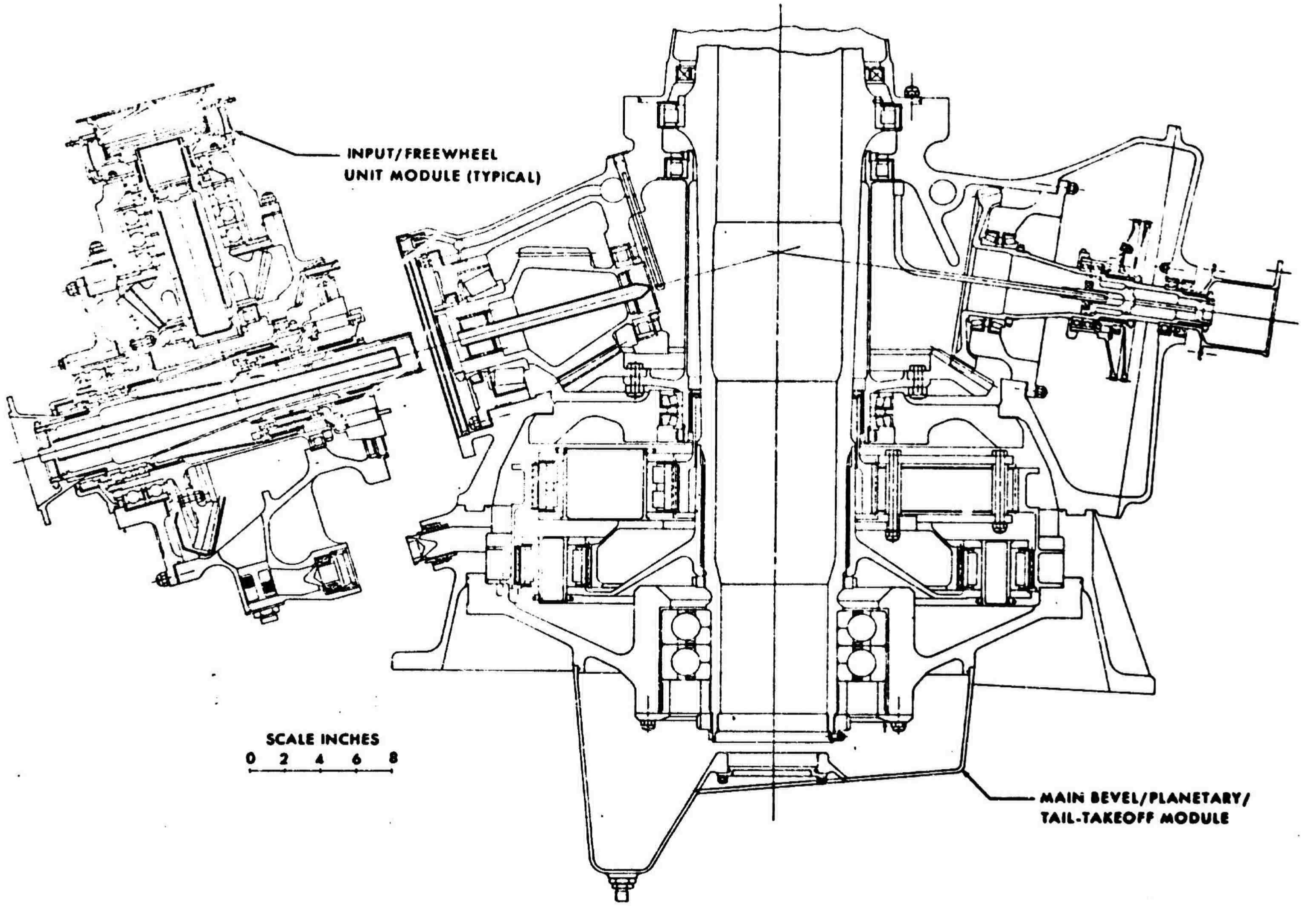

Figure 26. Exploded Cross Section of CH-54B Main Transmission, Three-Module Configuration.

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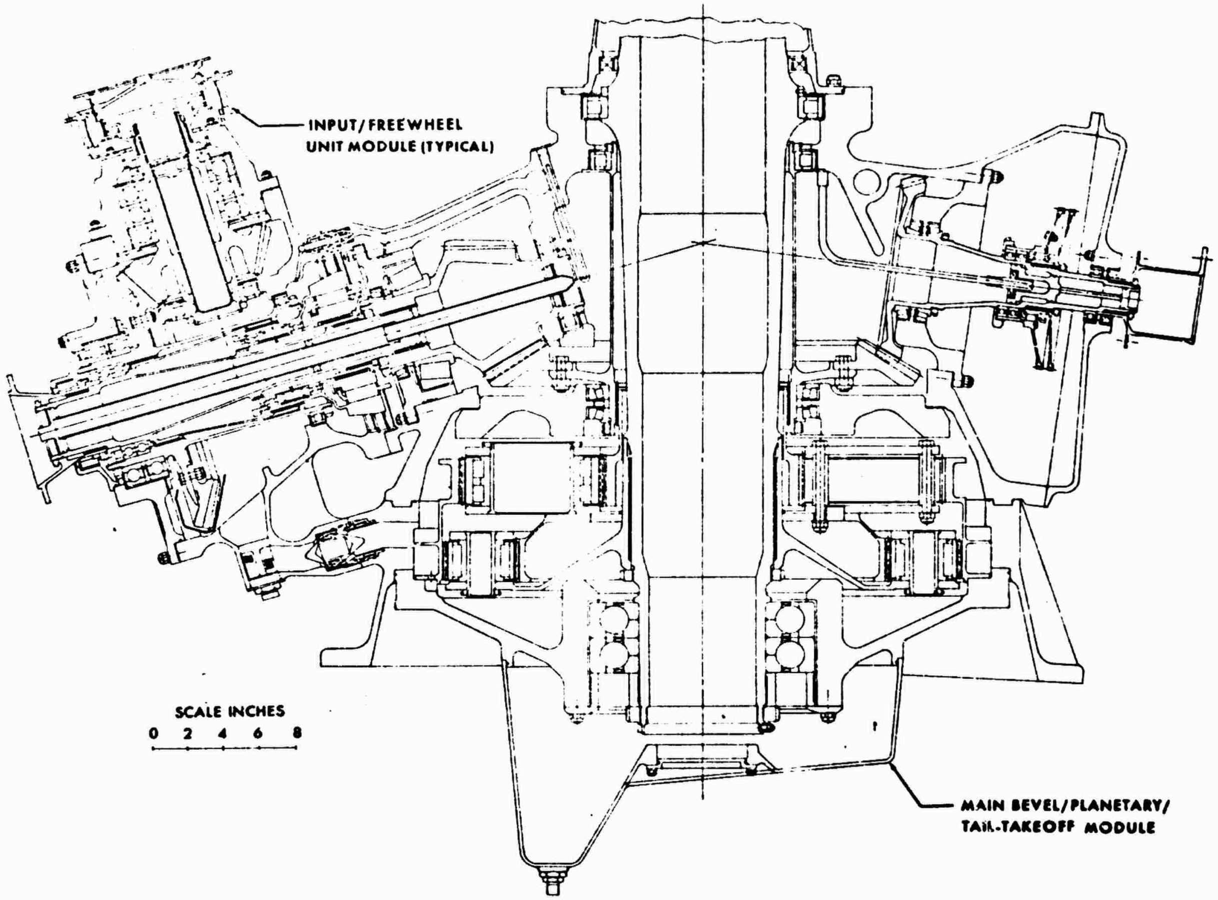

Figure 27. Assembled Cross Section of CH-54B Main Transmission, Three-Module Configuration.

INPUT DATA

This section of the report discusses in detail the input data required for the mathematical model. These data are classified under three general headings: aircraft, transmission cost, and transmission reliability and maintainability. Each type of data is discussed in terms of definition, derivation, and use of each factor in the mathematical model. Tables and figures are provided, where applicable, of the values used for the CH-54B analysis, with explanations of any changes in these values that may have occurred between different modular and baseline configurations. The transmission input data are shown for the candidate seven-module, six-module, four-module, and three-module design, as well as for the baseline design.

AIRCRAFT INPUT DATA

Aircraft Unavailability

Aircraft mission abort rate is given as the average number of aborts per flight hour and is used in the calculation of aircraft reliability, aircraft mission effectiveness, and aircraft cost effectiveness. The mission abort rate for the CH-54B baseline, from Reference (1), is .0125 aborts per flight hour. The CH-54B baseline aircraft down-hours per flight-hour (DHFHBA) are used in the calculation of down-hours per flight-hour of the aircraft with candidate transmission, which in turn is used in the calculation of aircraft mission availability, aircraft mission effectiveness, and aircraft cost effectiveness. The down-hours per flight-hour value for the CH-54B, from Reference (1), is 2.3.

Baseline Aircraft Data

Mission capability is a measure of the aircraft's performance in its primary mission, assuming that the aircraft is available and does not abort the mission due to system failure. For cargo transport aircraft, such as the CH-54B, performance is measured by aircraft mission productivity in ton-knots expressed as the product of mission payload and mission block speed.

To determine mission productivity representative of the wide range of conditions in which the CH-54B is required to operate, a probabilistic mission environment was established, and 1000 simulated missions were flown. The mission environment used in the simulation was defined by the cumulative probability distributions of the following parameters:

(1) Takeoff pressure altitude

(2) Sea level temperature (standard altitude lapse rate was assumed)

(3) Cruise pressure altitude increment above takeoff

(4) Takeoff hover power margin (ratio of actual to hover OGE power required)

(5) Sortie radius

(6) Required payload

(7) Payload drag

(8) Hover time per sortie

The cumulative probability distributions used are shown in Figures 28 through 35. Takeoff pressure altitude and sea level temperature variations are from CORG Memo 185 of June 1965 for regions of operating interest. The takeoff pressure altitude distribution ranges from sea level to 10,000 feet with a mean altitude of 2055 feet. The sea level temperature ranges from 20°F to 110°F with a mean 76.4°F. Cruise elevation averages 2000 feet above takeoff up to a maximum of 6000 feet above takeoff.

Takeoff hover power margin, which is the ratio of actual power to required hover power at the appropriate altitude, temperature, and gross weight is based on results of analysis of data obtained from SEA operations with the CH-54A. It is assumed that the CH-54B will be operated in the same way. The power margin ranges from .5 to 1.0, with a mean value of .72.

Sortie radius, distributed about a mean of 22 nautical miles up to a maximum radius of 90 nautical miles, is based on CH-54A operation in Southeast Asia. Required payload, assumed to be carried one way on the outbound leg, is a demand function independent of aircraft capability; it averages 19.6 tons and exceeds the cable loading limit of 25,000 pounds for 80% of the time. Payload drag, estimated to range from 6 sq ft for aircraft retrievals up to 160 sq ft for equipment and bulk supplies, is distributed about a mean of 58 sq ft. Hover time per sortie is assumed to range from zero to three minutes. All loads are assumed to be rigged and ready for pick-up prior to arrival of the helicopter and are dropped with minimum of exposure time to hostile threat. The mean hover time per sortie is one minute, which is approximately 5% of average flight time.

Other inputs to the mission analysis include CH-54B rotor parameters, engine performance, basic operating weight, power efficiencies, and constraints imposed by drive system rating, design gross weight, cable load, fuel capacity, red line speed limit, and load stability speed envelope. These inputs are shown in Table II.

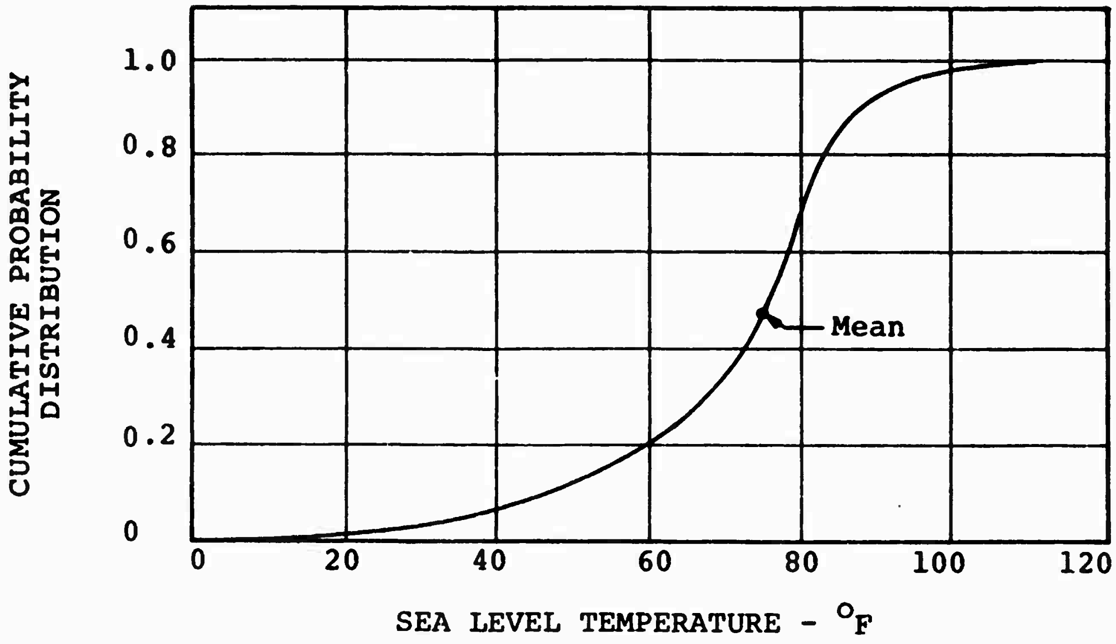

Figure 28. Cumulative Probability Distributation, CH-54B Mission Environment Sea Level Temperature.

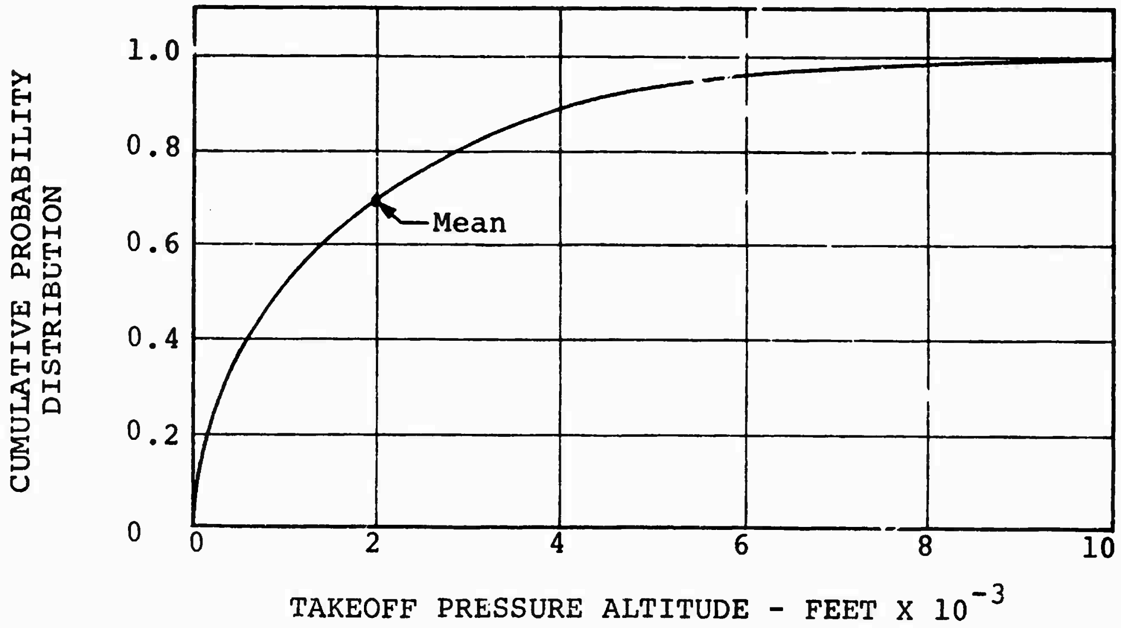

Figure 29. Cumulative Probability Distributation, CH-54B Mission Environment Takeoff Pressure Altitude.

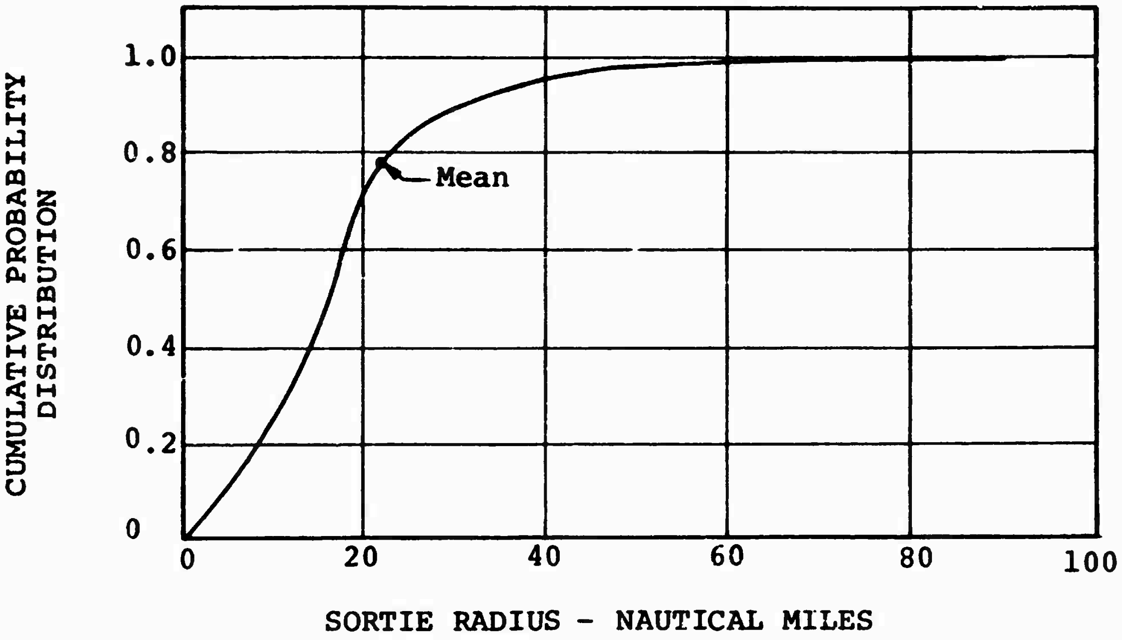

Figure 30. Cumulative Probability Distribution, CH54B Mission Environment Sortie Radius.

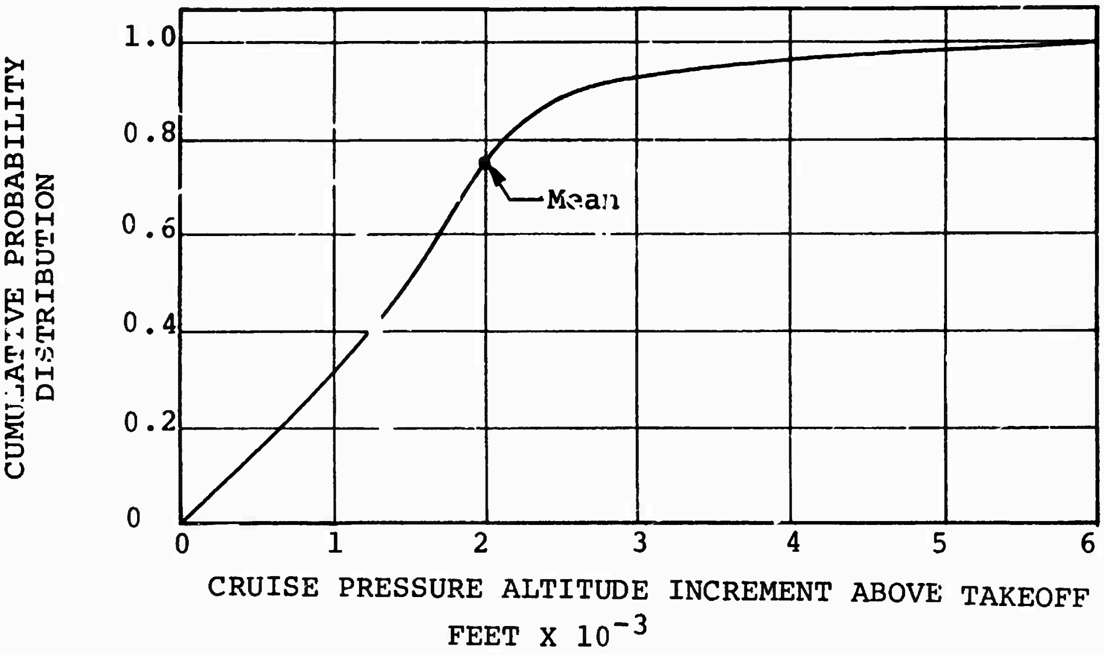

Figure 31. Clumalative Probability Distribution, CH54B Mission Environment Cruise Pressure Altitude Increment Above Takeoff.

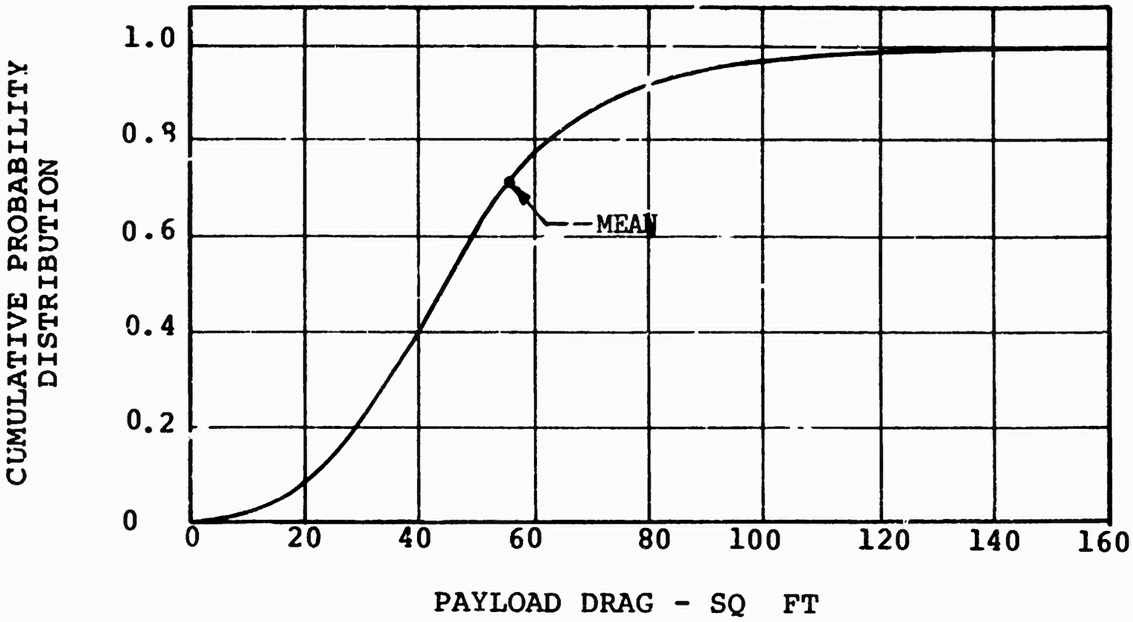

Figure 32. Cumulative Probability Distributation, CH-54B Mission Environment Payload Drag.

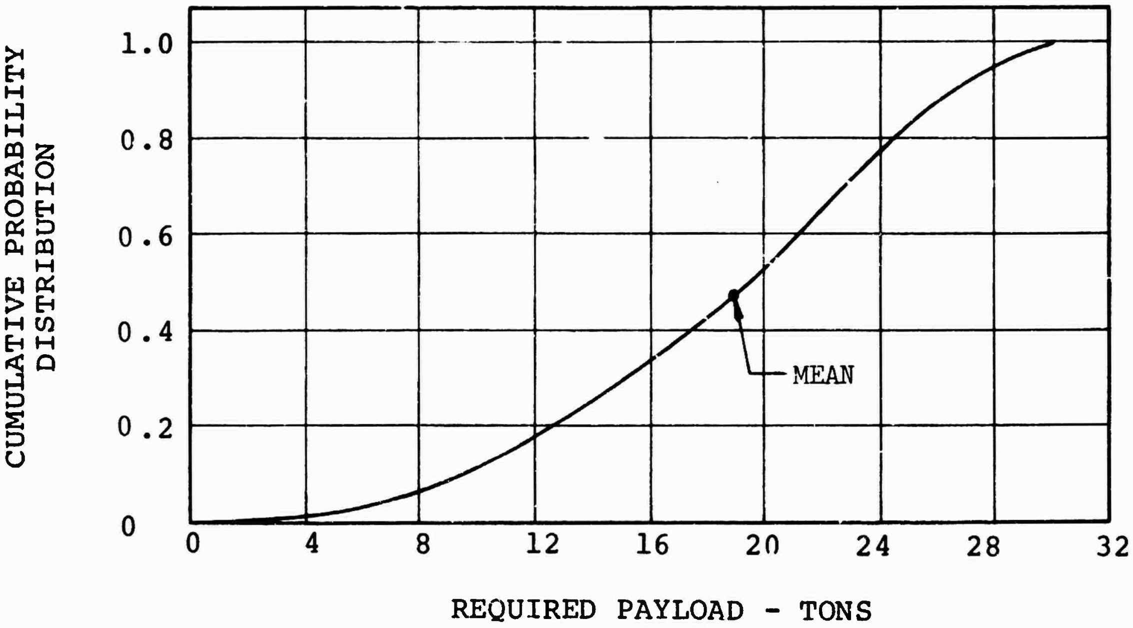

Figure 33. Cumulative Probability Distribution, CH-54B Mission Environment Required Payload.

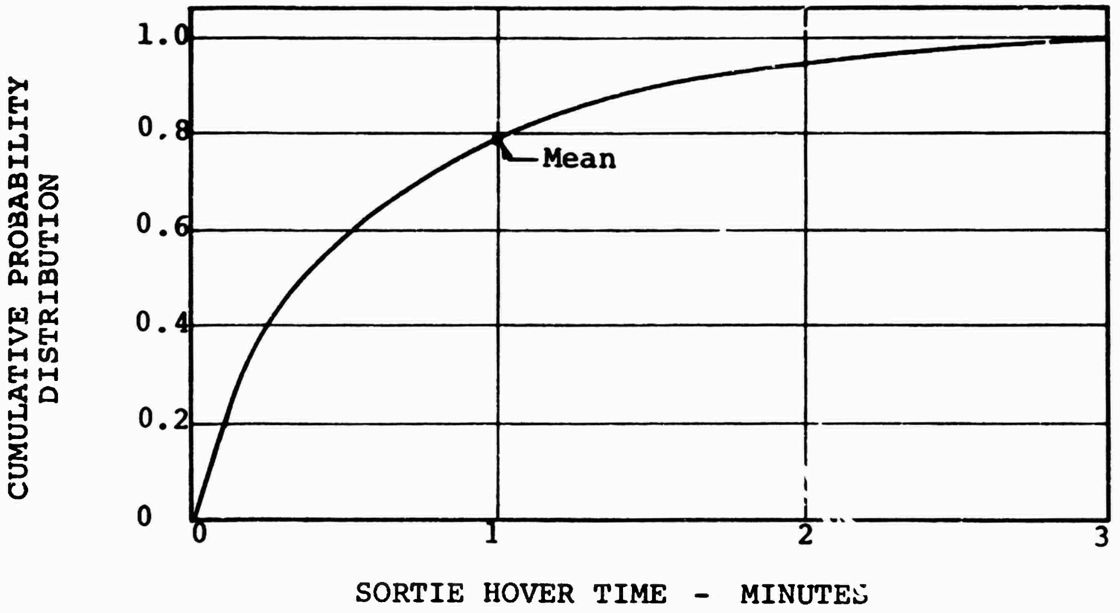

Figure 34. Cumulative Probability Distribution, CH54B Mission Environment Sortie Hover Time.

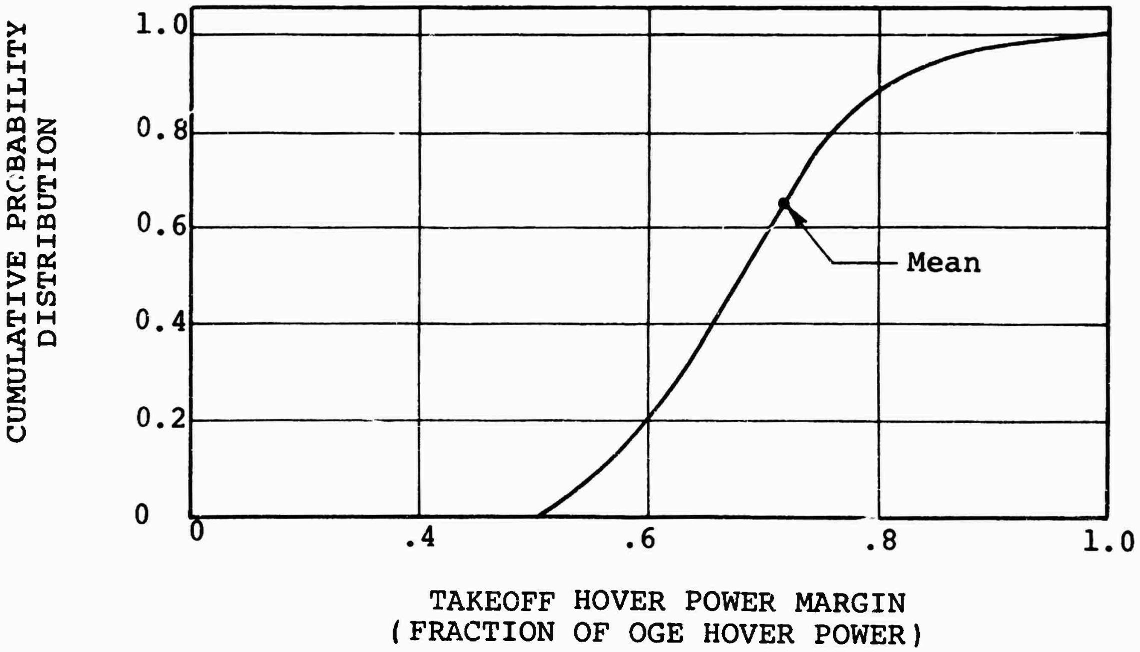

Figure 35. Cumulative Probability Distribution, CH-54B Mission Environment Takeoff Hover Power Margin, Fraction of OGE Hover Power.

TABLE II. CH-54B MISSION SIMULATION INPUT DATA

Input Data Item	Value
Rotor diameter	72 ft
Total blade area	468 sq ft
Rotor tip speed	700 fps
Basic operating weight, empty	21,330 lb
Engine	JFTD12A-5A
Drive system rating	7900 hp
Hover power efficiency	.85
Cruise power efficiency	.90
Maximum design gross weight	47,000 lb
Maximum cable load	25,000 lb
Fuel capacity	8750 lb
Red line speed	100 kt
Load stability speed envelope	$30 + .72 \frac{\text{payload}}{\text{payload drag}}$

Mission effectiveness is defined as aircraft mission capability downrated by aircraft unavailability to fly a mission on demand and by system failure aborting the mission after it is initiated. Simulation of the existing CH-54B in the established mission environment yielded the results shown in Table III.

TABLE III. RESULTS OF MISSION SIMULATION, CH-54B BASELINE AIRCRAFT

Name	Value
Average takeoff gross weight	45,042 lb
Average outbound payload	21,022 lb
Average mission fuel flow	3336.27 lb/hr
Average mission capability	503.386 ton-kt
Average mission sortie time	.344 hr

Average mission fuel flow, mission capability, and mission sortie time for the CH-54B baseline are used as input data to the mathematical model.

Cost of fuel per pound is used as an input. Multiplied by life-cycle flight hours and average mission fuel flow, cost of fuel per pound produces life-cycle fuel cost. The cost of fuel used for evaluation is \$.0181 per pound (\$0.11/gallon).

Fleet size is used to amortize nonrecurring costs, initial tooling cost, and initial spares cost. It is also used in the equation for fleet effective cost. The size of the fleet used in this report corresponds to the actual size of the U. S. Army CH-54 fleet presently in service, 60 aircraft. All the input data obtained have been determined for this number of aircraft.

Life-cycle cost represents the total cost to develop, acquire, and operate a single CH-54B over its service life (see Appendix II).

Development cost is the total nonrecurring cost of design, test, and manufacture amortized over the fleet size. It is assumed that the basic nonrecurring cost of the CH-54B has already been fully amortized. Nonrecurring cost associated with the main transmission is amortized over the specified fleet size of 60 aircraft plus required spares and is included, for convenience, in acquisition cost.

Baseline aircraft acquisition cost, consisting of recurring vehicle flyaway cost, initial spares cost, initial ground support equipment (GSE) cost, and initial personnel training cost, is estimated to be \$2,826,000.

The main transmission affects the flyaway, initial spares, and initial GSE costs. The contributions are given in the Transmission Cost Input Data section, page 75 (+).

Operating cost contributions to the aircraft life-cycle cost are based on the operating cost for fuel, maintenance, replenishment spares, flight crew, replacement GSE, and personnel replacement training, and is estimated at $491,200 annually, or $7,368,000 for the service life of the helicopter. The life-cycle cost of the CH-54B baseline is $10,194,000, the sum of total operating and acquisition costs for the life of the aircraft.

Efficiency and Weight

Transmission efficiency is found from test to be 98.17% for the baseline CH-54B (Reference 2). Efficiency of the modularized design is found from determination of changes in efficiency arising from addition or deletion of components. In each of the modular designs presented, there has been no change in bearing or gear mesh geometry. It is assumed, therefore, that heat losses from all these major components will be identical in the modular and baseline designs. For each chip detector added, a one horsepower loss has been assumed. Chip detectors present an additional restriction to oil drain flow, and losses generally result due to oil churning. In the tail takeoff module, removal of the baseline oil pump drive and associated bushings, gearing, etc., and installation of the oil pump driven from the second-stage planetary plate are assumed to present a net gain of one horsepower for designs that have a modularized tail takeoff/accessory section. Table IV summarizes the efficiency and total horsepower losses of the baseline and modularized designs.

TABLE IV. MAIN TRANSMISSION EFFICIENCY AND WEIGHT

Module	7 Module	6 Module	4 Module	3 Module	Baseline
L.H. Input (lb)	235.62	235.62	268.13	268.13	-
L.H. FWU (lb)	48.20	48.20			
R.H. Input (lb)	211.99	211.99	249.72	249.72	-
R.H. FWU (lb)	48.20	48.20			
T. T. O. (lb)	112.19	112.19	112.19		
Main Bevel (lb)	878.97	2483.62	2483.62	2585.15	-
Planetary (lb)	1616.49				
Total Weight (lb)	3151.66	3139.82	3113.66	3103.00	3096.00
Total HP Loss	6	5	2	1	-
Efficiency (%)	98.08	98.10	98.14	98.16	98.17

From the modularized layouts presented in the previous sections, weight can be derived. Weight of each modularized design is found by analysis of volume changes between the baseline design and the modularized designs. Total main transmission weight for each modularized design is presented in Figure 36.

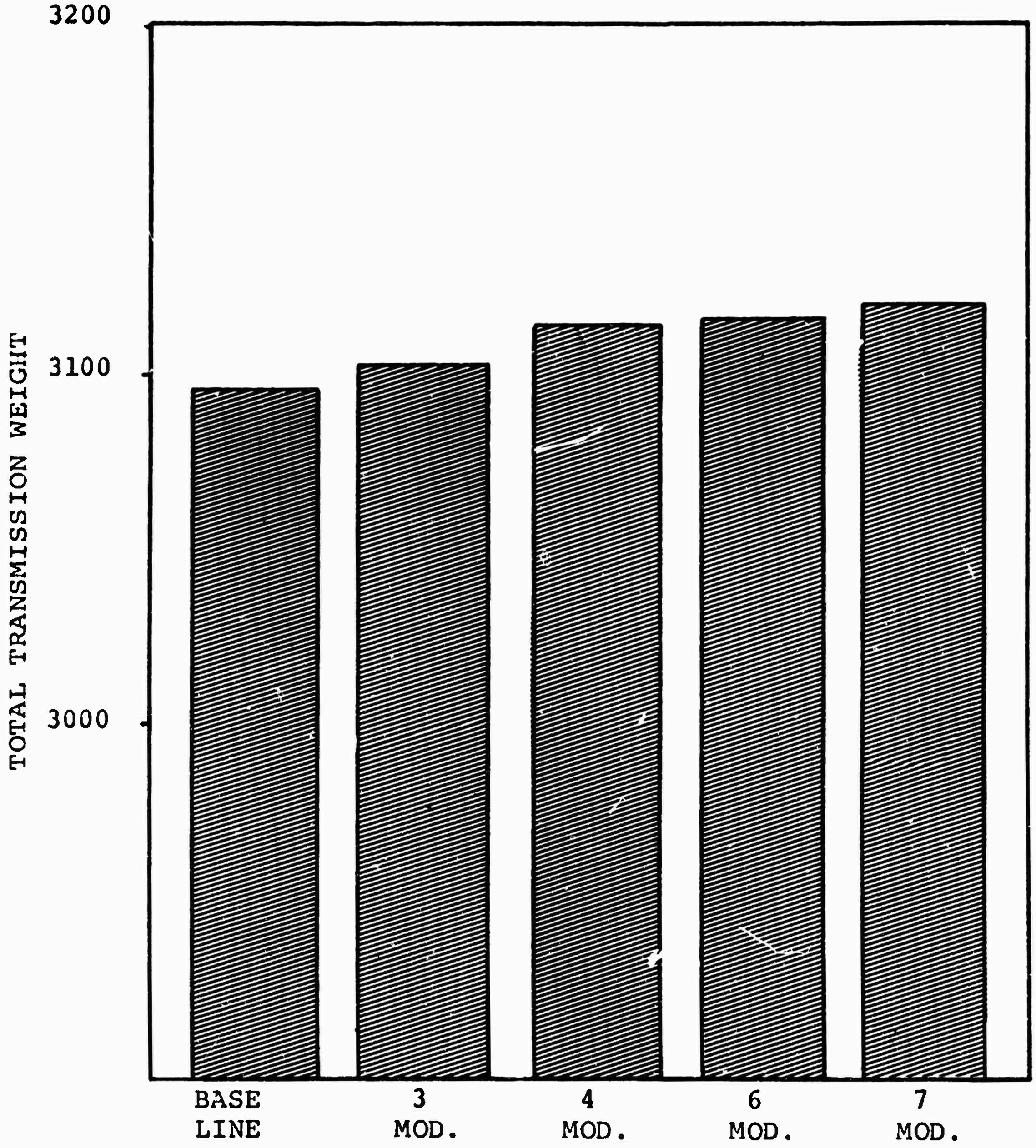

Figure 36. Total Main Transmission Weight, Modular Designs and Baseline CH-54B

Aircraft Usage Data

Aircraft usage input data are used in the mathematical model in the calculation of life cycle flight hours, transmission maintenance hours per flight hour at various maintenance levels, transmission shipping and maintenance costs, aircraft mission availability, aircraft mission reliability, aircraft mission effectiveness, aircraft life cycle cost, aircraft cost effectiveness, and fleet effective cost. The average mission time is found from the CH-54B mission simulation. Service life, average mission time, annual utilization, and daily utilization are shown in Table V.

TABLE V. CH-54B BASELINE AIRCRAFT USAGE

Name	Value
Service life	15 years
Average mission time	**.344 hr**
Annual utilization	280 flight hr
Daily utilization	1.13 flight hr

TRANSMISSION COST INPUT DATA

Transmission Maintenance Costs

Labor rates are used in the mathematical model to determine transmission maintenance costs at the various maintenance levels. The military labor rate is used to determine maintenance costs at the organizational and direct support maintenance levels, while the civilian labor rate is used to determine the transmission maintenance cost at the depot maintenance level. The civilian labor rate is assumed at the depot level, since service history has shown that all CH-54B overhauls have been conducted at Sikorsky Aircraft. For the baseline and modular designs, the labor rate does not change. The rates used as input data to the mathematical model are:

LRMIL = \$ 9.50 = Military Labor Rate \$/Hour
LRCIV = \$19.50 = Civilian Labor Rate \$/Hour

The source of the value for LRMIL was supplied by the Eustis Directorate, Army Air Mobility Laboratory at Fort Eustis. Cost of maintenance for the baseline transmission is an input data item that is used in the mathematical model to determine aircraft life-cycle costs. The maintenance cost is the total cost for the service lifetime of the aircraft. In the life-cycle cost equation in the mathematical model, the baseline CH-54B transmission maintenance cost is subtracted from the baseline CH-54B aircraft life-cycle cost, and the calculated candidate modularized transmission maintenance cost is added.

Certain transmission maintenance cost factors are determined with the mathematical model and computer programs of Appendixes II and III. These include:

(1) Cost of initial transmission spares.

(2) Cost of replenishment transmission spares.

(3) Cost of initial GSE transmission tooling.

(4) Cost of replenishment GSE transmission tooling.

(5) Cost of maintenance.

Initial values for these factors are assumed and entered in the program with the known baseline data. The program then computes new values for these factors. This iteration is repeated, using the outputs of the previous run as the new inputs. When the input values equal the output values, they are correct and are used in all subsequent runs.

All these items are found on a "per aircraft lifetime" basis. Spares costs are determined from acquisition cost and spares production run, which includes both initial and replenishment spares. Tooling costs are determined from total initial GSE tooling costs and the ratio of initial tooling to replenishment tooling.

Transmission maintenance cost is the sum of shipping costs between maintenance levels plus labor and material costs at each maintenance level. Labor cost includes inspecting, removing, requisitioning, installing, replacing, and scrapping man-hour charges.

Table VI lists the baseline CH-54B data that are calculated by the above iteration procedure.

TABLE VI. COMPUTED BASELINE CH-54B COST FACTORS

Baseline Factor	Cost - $
Initial Transmission Spares	78,508
Replenishment Transmission Spares	65,852
Initial Transmission Tooling	1,958
Replenishment Transmission Tooling	2,727
Total Cost of Maintenance	96,806

Transmission Shipping Costs

Although analysis of output results shows that transmission shipping costs form a small part of transmission maintenance cost and a small part of aircraft life cycle cost, shipping costs have been included in the mathematical model for the sake of completeness. Total shipping costs consists of cost of containers, cost to prepare to ship, and freight charges. The quantity of containers used is equal to the number of initial spares. The assumption is that once the initial spares get to the field, the containers are reused as replacements are made. The original transmission has no container, since it is installed on the aircraft. Container cost has been determined for the baseline CH-54B main transmission from Sikorsky purchasing records.

The modular design container costs are found by using recurring costs of existing transmission containers of approximately the same size as the module under consideration, and then adding a nonrecurring cost representing the engineering hours required to design the container, plus the cost of manufacturing tools and fixtures divided by the number of initial spares. These costs were found for the seven-module design. Lesser degrees were found by assuming that the combined module would fit in the container of approximately the same size as the largest component of the two being combined. For example, the planetary module of the seven-module design must have a container that extends from the main transmission sump to the top of the main rotor shaft. When the main bevel module is combined with the planetary module in the six-module design, the combined unit will fit in the same envelope as the planetary module alone. Hence, the cost of the planetary module container of the seven-module design can be used as the planetary/main bevel container cost of the six-module design. This is also true of the free-wheel unit/input module and combined planetary, main bevel, and tail-takeoff module. Modularized and baseline CH-54B container costs are listed in Table VII.

Also included as part of shipping cost is the cost to prepare the gearbox or module for shipment. Shipping preparation includes packaging of the components prior to shipment, placement in the container, bolting the container closed, moving the container to the loading point, and administrative duties required to prepare shipping records. The cost to prepare to ship has been determined for the modularized and baseline designs by estimating the man-hours required for shipping preparation and multiplying by the proper labor rate. At the organizational and direct support maintenance levels, the shipment preparation costs are assumed to be identical. At the depot level, it is assumed that the preparation requires 20 percent less man-hours, because the depot level will have more experience. Total shipping cost, however, is greater at depot, because the labor rate is higher. The hours and costs to prepare for shipment at organization, direct support, and depot are summarized in Table VIII.

TABLE VII. COST OF SHIPPING CONTAINERS, MODULARIZED AND BASELINE CH-54B MAIN TRANSMISSION

Module Name	Cost - $				
	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	871	871	871	871	3575
Left-Hand Freewheel	252	252			
Right-Hand Input	871	871	871	871	
Right-Hand Freewheel	280	280			
Tail-Takeoff	1075	1075	1075	2330	
Main Bevel	2290	2330	2330		
Planetary	2330				

The third item in shipping cost is the cost of freight. In the mathematical model of Appendix II, the freight cost input data are specified as follows:

(1) Cost to ship, U. S. to field

(2) Cost to ship, depot to field

(3) Cost to ship, field to depot

The term field, as used in the mathematical model, is defined as either direct support or organization maintenance level. The model has been arranged with the above shipping freight cost definitions so as to be general. For the CH-54B, all the three shipping costs are assumed to be the same:

U. S. to field = depot to field = field to depot

TABLE VIII. COST AND MAN-HOURS REQUIRED FOR SHIPMENT PREPARATION AT ORGANIZATION, DIRECT SUPPORT, AND DEPOT

Design	Name of Module	Organization or Direct Support		Depot	
		Hr to Prepare	Cost to Prepare ($)	Hr to Prepare	Cost to Prepare ($)
7	Left-Hand Input	3.0	29	2.4	47
	Left-Hand Freewheel	1.0	10	0.8	16
	Right-Hand Input	3.0	29	2.4	47
	Right-Hand Freewheel	1.0	10	0.8	16
	Tail-Takeoff	3.5	33	2.8	55
	Main Bevel	6.0	57	4.8	94
	Planetary	8.0	76	6.4	125
6	Left-Hand Input	3.0	29	2.4	47
	Left-Hand Freewheel	1.0	10	0.8	16
	Right-Hand Input	3.0	29	2.4	47
	Right-Hand Freewheel	1.0	10	0.8	16
	Tail-Takeoff	3.5	33	2.8	55
	Main Bevel/Planetary	8.0	76	6.4	125
4	Left Input/Freewheel	3.0	29	2.4	47
	Right Input/Freewheel	3.0	29	2.4	47
	Tail-Takeoff	3.5	33	2.8	55
	Main Bevel/Planetary	8.0	76	6.4	125
3	Left Input/Freewheel	3.0	29	2.4	47
	Right Input/Freewheel	3.0	29	2.4	47
	Main Bev./Plan/T.T.O.	10.0	95	8.0	156
1	Baseline	10.0	95	8.0	156

From an examination of Sikorsky overhaul records of 79 overhauls of the CH-54B main transmission, the number of main transmissions shipped to various field locations can be determined. This number, expressed as a percentage, is assumed to be the same for the modularized and baseline CH-54B main transmission. During the overhaul data sampling period, transmissions were shipped to seven different U. S. Army maintenance field locations. The main transmissions shipped to each field location are shown in Figure 37.

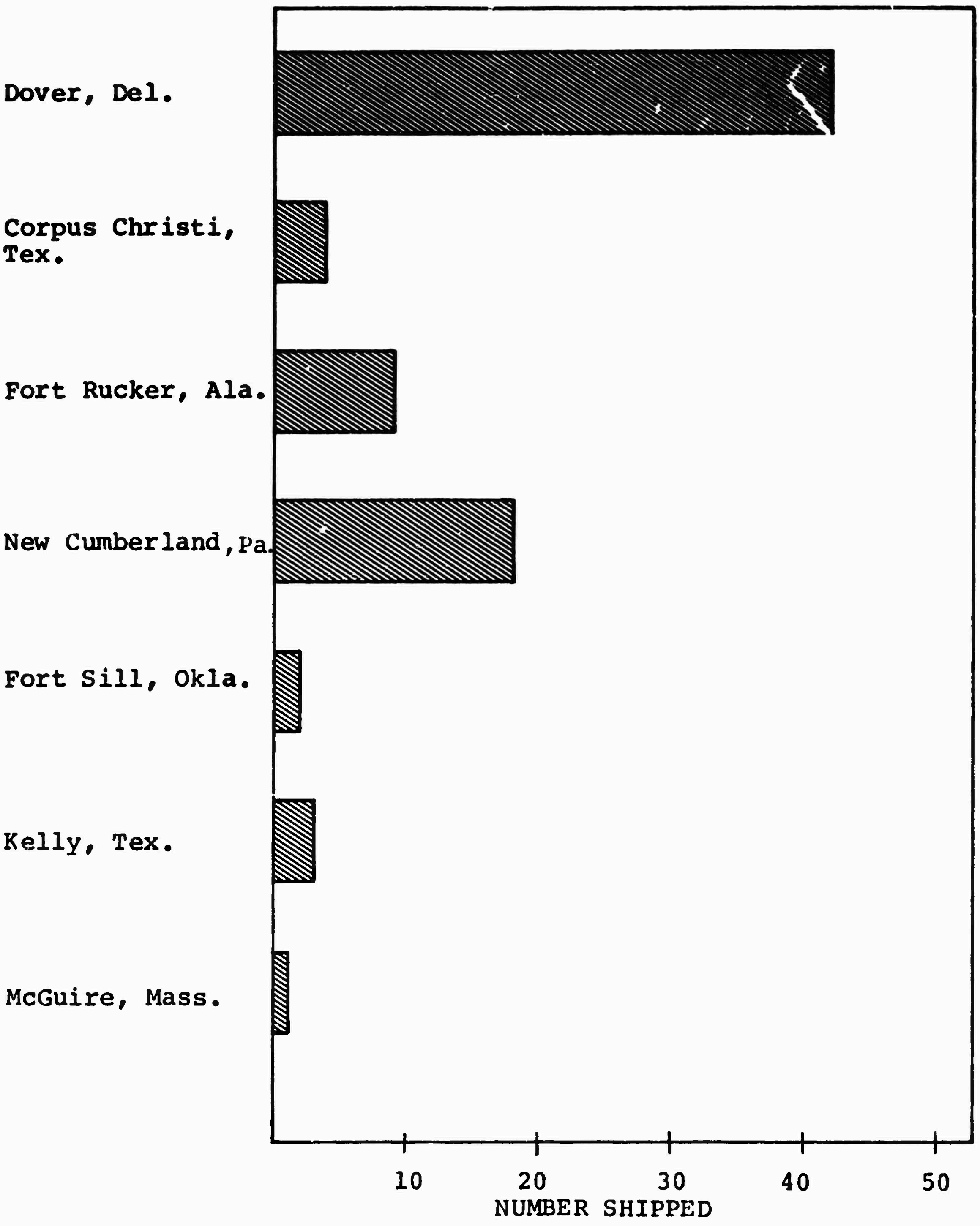

Figure 37. Total CH-54 Main Transmissions Shipped From Sikorsky to Various Field Maintenance Locations in the U.S.A.

From U. S. Army shipping records, the freight cost is found for each of the U. S. field locations shown in Figure 37. In addition, the assumption is made that 75% of the fleet aircraft are located in overseas areas. Shipping costs are then determined by a weighted average method, where the percentages shipped to each U. S. location are assumed to be as shown in Figure 37. It is further assumed that 75% of those shipped are sent to overseas locations. The average shipping cost for the baseline CH-54B transmission was found to be $377. To obtain the shipping costs for the modularized transmissions, the average shipping cost of $377 was divided by 4602 pounds, the weight of the baseline container plus weight of baseline main transmission. This yielded an average shipping cost of $.0819 per pound. Modularized design shipping costs were then found by multiplying this rate by the combined weight of container and module. A summary of these calculations of shipping freight cost is presented in Table IX. In Table IX, if the total weight of container plus module was under 200 pounds, the average rate was doubled to $.1638 per pound. This was true only of the left-hand and right-hand freewheel unit modules of the seven-module and six-module designs.

TABLE IX. COST TO SHIP FROM U. S. TO FIELD, DEPOT TO FIELD, OR FIELD TO DEPOT, CH-54B MAIN TRANSMISSION MODULARIZED AND BASELINE DESIGNS

Module Name	Freight Cost - $/Module				
	7 Module	6 Module	4 Module	3 Module	Base-line
Left-Hand Input	38	38	42	42	377
Left-Hand Freewheel	20	20			
Right-Hand Input	36	36	40	40	
Right-Hand Freewheel	20	20			
Tail-Takeoff	33	33	33	263	
Main Bevel	123	255	255		
Planetary	184				

Transmission Material Repair Costs

Material repair costs at the three maintenance levels are used in calculating transmission maintenance costs. Material repair cost refers only to the cost of the components that are replaced during unscheduled maintenance. Costs are divided into aircraft material repair costs, which are charged to the organizational maintenance level, direct support, and depot material repair costs. All material repair costs are input to the mathematical model on a per module basis. The material repair costs in the field (organization and direct support) are based on average material cost. Depot material repair costs are based on total cost. The assumption is that, in the field, the baseline transmission will require a certain average cost for material repair. When the baseline transmission is divided into modules, the average material repair cost remains the same. At the depot, however, the material repair cost is substantially increased, since the transmission is generally given a complete overhaul. Here the total material cost for the modularized transmission will be comparable to the total material cost for the baseline. The average depot material repair cost per overhaul for the baseline transmission has been determined to be $4464 from Sikorsky overhaul and accounting records. The modularized transmission depot material repair cost is found by assuming additional costs associated with overhaul of the components added to the modularized designs. The material repair costs on the aircraft are found from the costs of the replacement components. These components are listed in the ORME report of Reference 1. The direct support material repair costs are found by examination of Discrepancy/Corrective Action Reports to determine the components replaced. Individual component costs are found from Sikorsky purchasing records. Table X shows material costs for on-aircraft repairs, direct support repairs, and depot repairs for both baseline and modularized transmissions.

Transmission Tooling Costs

Transmission tooling used in the mathematical model of Appendix II refers to ground support equipment (GSE) tooling. This tooling consists of assembly/disassembly tools and fixtures. Special GSE tools include wrenches, bearing pullers, gages, torquing fixtures, and main transmission rollover stands. Manufacturing tools and fixtures are included in acquisition costs and are not considered part of GSE tooling.

Tooling costs in the mathematical model are divided into initial and replenishment tooling. There are four basic input data items pertaining to transmission GSE tooling:

(1) Total cost of initial GSE tooling for candidate transmission modules

(2) Ratio of GSE replenishment tooling to GSE initial tooling for candidate main transmission

(3) Cost of initial tooling for baseline transmission, per aircraft

(4) Cost of replenishment tooling for baseline transmission, per aircraft.

TABLE X. MATERIAL COST TO REPAIR MODULARIZED AND BASELINE CH-54B MAIN TRANSMISSION ON AIRCRAFT, AT DIRECT SUPPORT, AND AT DEPOT

No. of Modules	Module Name	Material Cost - $		
		On Aircraft	Direct Support	Depot
7	Left-Hand Input	19	31	641
	Left-Hand Freewheel	1	13	74
	Right-Hand Input	12	18	570
	Right-Hand Freewheel	1	13	74
	Tail-Takeoff	7	248	1010
	Main Bevel	66	590	791
	Planetary	29	36	1500
6	Left-Hand Input	19	31	641
	Left-Hand Freewheel	1	13	74
	Right-Hand Input	12	18	570
	Right-Hand Freewheel	1	13	74
	Tail-Takeoff	7	248	1010
	Main Bevel/Planetary	34	104	2263
4	Left Input/Freewheel	13	25	687
	Right Input/Freewheel	11	18	616
	Tail-Takeoff	7	248	1010
	Main Bevel/Planetary	34	104	2263
3	Left Input/Freewheel	13	25	687
	Right Input/Freewheel	11	18	616
	Main Bev./Plan/T.T.O.	22	134	3245
1	Baseline	17	30	4464

The baseline transmission total initial GSE tooling cost is estimated to be $117,500. The ratio of replenishment tooling to initial tooling for the baseline transmission is 1.392. To determine the baseline transmission initial and replenishment tooling costs per aircraft, the total initial tooling is divided by the fleet size to obtain the initial, which in turn is multiplied by the ratio of replenishment to initial to obtain the replenishment costs per aircraft. These costs are found to be as follows:

(1) Cost of initial tooling for baseline transmission, per aircraft = $1958

(2) Cost of replenishment tooling for baseline transmission, per aircraft = $2727

To obtain the modularized transmission tooling costs, the assumption is made that the ratio of replenishment tooling to initial tooling will be the same as for the baseline design. For the seven-module designs, $2500 is added to the total initial tooling costs to account for the additional components. The initial tooling cost for each module is assumed to be the same percentage of the total initial tooling costs as the modular recurring costs are of the total recurring costs. Initial GSE tooling costs for both the baseline and modular versions are shown in Table XI.

TABLE XI. TOTAL INITIAL GSE TOOLING COST, MODULAR AND BASELINE CH-54B MAIN TRANSMISSION

Module Name	Cost - $				
	7 Module	6 Module	4 Module	3 Module	Base-line
Left-Hand Input	16,600	16,600	18,100	18,100	117,500
Left-Hand Freewheel	2,000	2,000			
Right-Hand Input	14,800	14,800	16,300	16,300	
Right-Hand Freewheel	2,000	2,000			
Tail-Takeoff	26,000	26,000	26,000	83,600	
Main Bevel	20,500	58,100	58,100		
Planetary	38,100				
TOTALS	120,000	119,500	118,500	118,000	117,500

Transmission Acquisition Costs

Transmission acquisition costs are inputs to the mathematical model of Appendix II and are used in determining aircraft life cycle cost. Acquisition cost is the sum of recurring and nonrecurring costs. Nonrecurring costs include design engineering, test facilities, testing, prototype manufacturing, and other costs associated with development of the first transmission from inception to production. The total nonrecurring cost is divided by the total quantity of transmissions produced per aircraft during the aircraft lifetime and includes initial and replenishment spares as well as the original transmission delivered with the aircraft. Recurring costs are those costs associated with manufacturing. The baseline CH-54B transmission acquisition cost of $181,500 is determined from Sikorsky purchasing records. The recurring costs of the modularized designs are found by adding the costs of all baseline components common to the modularized designs and by the addition of the cost of extra components or modifications to existing components required for modularization. The quantities of common and additional transmission components required are determined by examination of the layouts of the candidate modular designs. Manufacturing costs are determined for new components by comparison with existing components of similar size, configurations, materials, tolerances, and complexities. Recurring transmission costs for the modularized and baseline CH-54B are listed in Table XII.

TABLE XII. RECURRING COSTS, MODULARIZED AND BASELINE CH-54B TRANSMISSION

Name of Module	Recurring Cost - $				
	7 Module	6 Module	4 Module	3 Module	Base-line
Left-Hand Input	18,890	18,890	21,059	21,059	135,848
Left-Hand Freewheel	2,300	2,300			
Right-Hand Input	16,400	16,400	18,609	18,609	
Right-Hand Freewheel	2,300	2,300			
Tail-Takeoff	27,340	27,340	27,340	96,585	
Main Bevel	24,760	69,416	69,416		
Planetary	44,940				
TOTALS	136,970	136,686	136,424	136,253	135,848

Nonrecurring costs for modularized transmission designs will be increased by the amount required for additional test facilities, engineering, and tooling. For the seven-module design, an additional $185,000 has been assumed. Lesser degrees of modularization have proportionately less additional nonrecurring costs. Nonrecurring cost for each module is assumed to be the same percentage of the total nonrecurring cost as the modular recurring costs are of the total recurring cost. The nonrecurring costs for the modularized and baseline CH-54B transmission are listed in Table XIII in thousands of dollars.

TABLE XIII. NONRECURRING COSTS, MODULARIZED AND BASELINE CH-54B TRANSMISSION

Nonrecurring Cost - Thousands of Dollars					
Name of Module	7 Module	6 Module	4 Module	3 Module	Base-line
Left-Hand Input	253	253	256	256	1,650
Left-Hand Freewheel	29	29			
Right-Hand Input	224	224	227	227	
Right-Hand Freewheel	29	29			
Tail-Takeoff	398	398	398	1,246	
Main Bevel	312	875	875		
Planetary	589				
TOTALS	1,835	1,808	1,756	1,729	1,650

TRANSMISSION RELIABILITY/MAINTAINABILITY INPUT DATA

Transmission Maintenance Man-Hour Burden

The U. S. Army organizational maintenance level performs a daily CH-54B aircraft and transmission inspection and an intermediate aircraft and transmission inspection every 25 flight hours. A periodic inspection is performed at the U. S. Army Direct Support Maintenance level every 100 aircraft flight hours. The hours required for these scheduled transmission inspections are included in the maintenance man-hours per flight hour at organization (Appendix II) and at direct support levels.

The inspection man-hours, as used in the mathematical model, refer only to main transmission inspection hours. The scheduled daily inspection procedure of Reference 3 shows that, for the CH-54B main transmission, the following items are checked daily at the U. S. Army organizational level:

(1) Main gearbox breather vent for obstructions, oil level dipstick for proper level, filler cap for spring tension.

(2) Main gearbox accessories for security, leakage, and condition.

(3) Rotor brake package for leakage, presence of water, and proper oil level. Hydraulic lines for chafing and leakage.

(4) Rotor brake housing support brackets for cracks and security.

(5) Main gearbox oil cooler core for leakage. Hydraulic lines for chafing and leakage.

(6) Main drive shaft for nicks and scratches, Thomas couplings for obvious damage and security, discoloration of input seal for leakage.

(7) Auxiliary power plant shaft for nicks and scratches. Thomas couplings for obvious damage and security.

(8) Auxiliary power plant adapter for obvious damage and security.

(9) External tubing, hoses, and electrical leads for security of all connections, clamps, and brackets. Evidence of chafing and wear. Evidence of oil leakage.

This daily procedure is estimated to require an average time of six minutes, or 0.10 hour, for a skilled U. S. Army organizational level mechanic. The scheduled daily inspection for the modular transmissions is assumed to take the same average time as for the baseline transmission. This is because the items inspected and the outer appearance and components of the main transmission are similar in the modular and baseline designs.

The intermediate transmission inspection is scheduled for every 25 flight hours and is also carried out at the U. S. Army organizational maintenance level (Reference 4). The items for the daily inspection are inspected more thoroughly in the intermediate inspection. Additionally, the following inspections are performed:

(1) Main gearbox oil cooler fan blades for cracks. Belts for excessive wear and proper tension.

(2) Oil strainer for metal particles and other foreign matter, damaged screens and spacers, and proper installation (disassemble and clean).

(3) Main gearbox housing and area around mating flanges for leaks, cracks, and corrosion.

This intermediate inspection plus a more thorough daily inspection is estimated to require 1.5 hours for a skilled maintenance man at the U. S. Army organizational level. For those items inspected, the modular transmission designs and the baseline design have similar external appearance and components. It is concluded that the scheduled intermediate inspection maintenance hours required for modular designs will be the same as for the baseline CH-54B main transmission.

A scheduled periodic inspection of the CH-54B main transmission is conducted after every 100 flight hours. The procedure for this inspection is shown in Reference 5. The periodic inspection is assumed to occur at the U. S. Army direct support maintenance level. The items inspected during the 25 hour intermediate inspection are re-inspected. Additionally, the following inspections are performed:

(1) Main rotor shaft for cleanliness (upper portion)

(2) Main gearbox mounting bolts for proper torque by torque wrench up to limit and detecting any turning of bolt.

(3) Gearbox torque meter for calibration.

(4) Chip detector wiring for security. Check chip detector.

The above inspection along with the items of the intermediate inspection are assumed to require 2.5 maintenance man-hours for a mechanic at the U. S. Army direct support maintenance level. As with previous scheduled inspections, there are no significant differences between the items inspected on the modular designs and the baseline CH-54B main transmission. As part of the periodic inspection, a chip detector check is required. Although the modularized designs have more chip detectors than the baseline design, the chip detector check consists only of an electrical system continuity check, for which the mechanic is not required to remove the chip detectors. The assumption is made, therefore, that the inspection hours are not significantly different for the modular and baseline designs.

The mean maintenance man-hours (MMH) required to remove and install modules are used to determine maintenance man-hours per flight-hour at the organizational maintenance level, which in turn is used to calculate organizational maintenance cost. Removal and installation MMH factors are also included in the mean MMH to repair on the aircraft. From the ORME data of Reference 1, the MMH required to install and remove the baseline CH-54 transmission is 37.8 hours. Changing the main transmission entails the following:

(1) Remove blades

(2) Remove rotor head

(3) Disconnect left and right engines from transmission

(4) Disconnect all accessories from rear case

(5) Disconnect tail drive system from transmission

(6) Remove all hydraulic and electrical lines that attach to the main transmission

(7) Remove main transmission

(8) Remove servos and assemble to new transmission

(9) Install main transmission

(10) Assemble all components removed

Using the baseline CH-54B main transmission removal/installation time of 37.8 man-hours, MMH for the modularized transmissions is estimated in relation to the components that must be assembled and disassembled. For example, removal of the planetary module of the seven-module design entails the same procedure as the baseline CH-54. Additionally, planetary module removal requires removal of all the other modules attached to the planetary module and, therefore, requires more time than CH-54B main transmission removal. It has been assumed that, of the total time required for removal and installation of modules, one-third is required for removal and two-thirds for installation.

From experience, installation requires more time than removal because components must be cleaned, and alignment of parts must be checked during installation. Table XIV summarizes the mean MMH required to remove the modules from the aircraft, and Table XV summarizes installation MMH.

TABLE XIV. MEAN MAINTENANCE MAN-HOURS REQUIRED TO REMOVE MODULE FROM AIRCRAFT, $MREM_i$

	MMH				
Module Name	7 Module	6 Module	4 Module	3 Module	Base-line
Left-Hand Input	2.16	2.16	1.82	1.82	12.60
Left-Hand Freewheel Unit	1.13	1.13			
Right-Hand Input	1.36	1.36	.98	.98	
Right-Hand Freewheel Unit	.33	.33			
Tail-Takeoff	2.67	2.67	2.67	13.50	
Main Bevel	14.13	14.83	14.83		
Planetary	15.50				

The mean MMH required to repair the main transmission on the aircraft consists of removals and installations of components with internal failures, as well as repairs of seals, fittings, "O" rings, and other small items that can be diagnosed and repaired on-the-spot. These on-the-spot field repairs are done on the aircraft. The module is not replaced, but an individual component of the module is repaired or replaced. In the Operations Reliability/Maintainability Engineering (ORME) data of Reference 1, there is a list of transmission components that have been replaced in the field. This list represents data from a 33-month, 47,993 flight-hour study. The transmission components that have been replaced during this period have been arranged by modules of the seven-module design and are presented along with number of occurrences, total aircraft down-hours, and total maintenance man-hours in Tables XVI through XXI. The right-hand freewheel unit module did not experience any small component failures during the ORME program and has, therefore, not been included in the tables.

TABLE XV. MEAN MAINTENANCE MAN-HOURS REQUIRED TO INSTALL MODULE ON AIRCRAFT, $MINST_i$

Module Name	MMH				
	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	4.34	4.34	3.65	3.65	25.20
Left-Hand Freewheel Unit	2.27	2.27			
Right-Hand Input	2.74	2.74	1.97	1.97	
Right-Hand Freewheel Unit	.67	.67			
Tail-Takeoff	5.33	5.33	5.33	27.00	
Main Bevel	28.27	29.66	29.66		
Planetary	30.00				

The man-hours for each module of Table XIV represent the total time needed to remove that module. This includes the time needed to remove those modules which must be removed prior to the removal of the subject module. The man-hours of Table XV represent the time required to install not only the subject module, but also those modules which must be installed after the installation of the subject module to complete assembly of the main transmission. For example, if it is desired to remove a defective main bevel module from the seven-module design and install a new main bevel module, Tables XIV and XV show that a total of 42.4 hours would be required (14.13 removal +28.27 installation). To remove the main bevel module in the seven-module design, the left and right-hand inputs, left and right-hand freewheel units, and the tail-takeoff module would first be removed. The main bevel module would then be removed and replaced with a new unit. The left and right-hand inputs, left and right-hand freewheel units, and tail-takeoff module would then be reinstalled. The total time required for this procedure is 42.4 hours and includes all the above module removal and installation as well as removal and installation of rotor head, servos, blades, engines, lines, etc.

TABLE XVI. SAMPLING OF REPAIRED OR REPLACED COMPONENTS, LEFT-HAND INPUT SECTION MODULE

Part Number	Name	Quantity of Occurrences	Total Down-Hours	Total MMH
C40-801606-2	Seal	1	2.0	4.0
C40-801644-2	Seal	3	163.0	308.8
MS 29561-258	"O" Ring	6	11.7	23.3
NAS 1593-156	"O" Ring	15	74.1	153.9
6435-20004-020	Input Assembly	9	20.7	27.2
6435-20032-104	Liner	1	1.5	1.5
6435-20041-100	"O" Ring	5	8.5	12.9
6435-20041-104	"O" Ring	4	5.8	16.8
6435-20140-100	Coupling	7	20.5	37.4
6435-20140-100	Plug	1	3.0	6.0
6435-20150-100	Coupling	4	16.2	27.7
6435-20189-101	Plate	4	3.4	5.4
6435-20455-101	Gasket	10	12.6	13.9
Misc. Small Components		20	16.4	21.0
TOTALS - Left-Hand Input		120	359.4	659.8

TABLE XVII. SAMPLING OF REPAIRED OR REPLACED COMPONENTS, LEFT-HAND FREEWHEEL UNIT MODULE

Part Number	Name	Quantity of Occurrences	Total Down-Hours	Total MMH
C40-801605-2	Seal	64	194.6	353.7
6435-20011-014	Rotor Brake Pad	2	3.8	4.8
6435-20064-100	Flg, Rotor Brake	1	2.0	2.0
TOTALS - Left-Hand Freewheel		67	200.4	360.5

TABLE XVIII. SAMPLING OF REPAIRED OR REPLACED COMPONENTS, RIGHT-HAND INPUT SECTION MODULE

Part Number	Name	Quantity of Occurrences	Total Down-Hours	Total MMH
MS 29561-258	"O" Ring	5	9.7	19.5
NAS 1593-156	"O" Ring	15	74.1	137.9
SS5075-12	Lockwasher	1	1.0	3.0
6435-20004-021	Input Assembly	2	3.5	3.5
6435-20041-100	"O" Ring	5	8.5	12.9
6435-20041-104	"O" Ring	4	5.8	16.8
6435-20042-040	Spacer	1	1.2	1.2
6435-20140-100	Coupling	7	20.5	37.4
6435-20150-100	Coupling	4	16.2	27.7
6435-20189-101	Plate	4	3.4	5.4
Misc. Small Components		20	16.4	21.0
TOTALS - Right-Hand Input		68	160.3	286.3

TABLE XIX. SAMPLING OF REPAIRED OR REPLACED COMPONENTS, TAIL-TAKEOFF MODULE

Part Number	Name	Quantity of Occurrences	Total Down-Hours	Total MMH
AN 2025JF	Gasket	1	0.8	1.0
CB 93-4	Seal	1	1.8	3.5
CB 94-4	Seal	3	10.0	11.0
CB 96-4	Seal	1	1.8	3.2
21708-1H08	Seal	1	1.2	2.2
Misc. Small Components		13	11.0	14.0
TOTALS - Tail-Takeoff		20	26.6	34.9

TABLE XX. SAMPLING OF REPAIRED OR REPLACED COMPONENTS, MAIN BEVEL MODULE

Part Number	Name	Quantity of Occurrences	Total Down-Hours	Total MMH
NAS-617-6	"O" Ring	1	0.9	0.9
6435-20195-012	Tube Assembly	1	1.0	1.0
6435-20195-020	Tube Assembly	1	1.5	1.5
6435-20195-028	Tube Assembly	1	1.0	2.0
6435-20197-012	Manifold Assembly	1	1.8	1.6
AN 617-16	Nipple Fitting	1	0.4	0.4
Misc. Small Components		13	11.0	14.0
TOTALS - Main Bevel		19	17.6	21.4

TABLE XXI. SAMPLING OF REPAIRED OR REPLACED COMPONENTS, PLANETARY MODULE

Part Number	Name	Quantity of Occurrences	Total Down-Hours	Total MMH
F911F	Cap	1	0.5	0.5
21688-0301	Seal	1	1.2	2.2
6435-20007-010	Oil Pump Assembly	13	40.1	77.0
6435-20009-012	Cover Assembly	10	5.9	6.4
6435-20078-014	Shaft Assembly	2	0.9	0.9
6435-20116-010	Strainer Assembly	3	2.7	2.7
6435-20129-100	Quill Shaft	1	1.5	1.5
6435-20209-101	Plug, Sump	3	7.4	15.4
6435-20248-010	Switch Assem, Oil	4	3.0	3.1
6435-20248-011	Switch, Oil Press	27	17.6	18.9
6435-20254	Tubing, Flex	8	7.8	8.3
6435-11282-044	Filter Assembly	7	10.7	10.7
TOTALS - Planetary		80	99.3	147.4

The repaired components listed in Tables XVI through XXI are segregated into seven modules and are easily combined to any lower degree by adding totals.

During the ORME program, 82 main transmissions wer [illegible] for scheduled and unscheduled reasons. To determine th [illegible] H required to repair the transmission on the aircraft, removals and replacements must be included. The ORM [illegible] of Reference 1 show that there have been 82 main transmission removals, but do not reveal the trouble that demanded removal. The causes of removal can be ascertained from Sikorsky overhaul records. A sampling of overhaul records from August, 1968 to January, 1972 showed that, of the 56 CH-54B main transmissions overhauled, 32 were for high time (scheduled removal), while 24 were for various other causes. A summary of the 24 unscheduled transmission removals with the primary mode of failure assigned to modules of the seven module version is presented in Table XXII.

TABLE XXII. SUMMARY OF CH-54 MAIN TRANSMISSIONS OVERHAULED AS A RESULT OF UNSCHEDULED REMOVALS FROM AUGUST 1968 TO JANUARY 1972 WITH FAILURES ASSIGNED TO MODULES

Serial Number	Left-Hand Input	Left-Hand Freewheel Unit	Right-Hand Input	Right-Hand Freewheel Unit	Tail-Takeoff	Main Bevel	Planetary
031					X		
038					X		
022	X	X	X	X	X	X	X
053					X		
043	X	X	X	X	X	X	X
049					X		
053					X		X
040							X
057						X	
021					X		
037	X	X	X	X	X	X	X
093	X				X		
042							X
081							X
039							X
019							X
035					X		
084					X		
040			X				
056	X						X
125			X				
073	X						
094							X
103					X		
TOTALS	6	3	5	3	13	4	11

Table XXII shows a peculiarity of modularized transmission replacement practice. Although only 24 baseline main transmissions were overhauled, resultant assignment of failures to a seven-module design shows that 45 modules were replaced. This is caused by the overhauls of serial numbers 022, 043, and 037, in which all seven modules were replaced. These three main transmissions experienced overtemperatures or overtorques. In such conditions, all modules of the modularized transmission are affected, since oil paths and torque paths are not isolated.

All factors used in calculating MMH burdens must be scaled to the 82 transmission removals over 47,993 flight hours of the ORME study. While 47 of these 82 transmission removals were scheduled because of high time, all 82 are treated as if they were unscheduled. The assumption is made that the transmissions subjected to scheduled removal at 500 hours would have had to be removed for unscheduled reasons at some time during the life of the study. This assumption is made to accommodate the on-condition-removal, or infinite time-between-overhaul (TBO), factor of the study. This factor implies that a transmission is removed only if there is a failure in the transmission. (See Transmission Frequency of Maintenance section, page 106(+), for further explanation of TBO factor.)

Since unscheduled-removal repair data were collected for only 24 cases, each number in Table XXII must be scaled appropriately to the 82 removals per 47,993 flight hours base of the study. Table XXIII lists the module replacements of Table XXI, appropriately scaled to the 47,993 ORME base. A sample calculation for Table XXIII appears below for the left-hand input module.

$$\mathrm{NREM} = \frac{A \times B}{C}$$

$$= \frac{82 \times 6}{24}$$

$$= 20$$

Where: NREM = Number of left-hand input modules removed scaled to the ORME study of 47,993 flight hours, rounded to nearest whole number

A = 82 = Number of main transmission removals for ORME study of 47,993 flight hours

B = 6 = Number of left-hand input failures occurring in the 24 transmission removals of Table XXII

C = 24 = Total number of main transmissions removed in Table XXII.

In combining modules, another factor must be taken into account. As explained previously, three of the overhauls accounted for in Table XXII occurred because of overheating or overtorque, which led to removal of all modules. When combining two modules for calculation of Table XXIII removals, simply adding the total failures of the two modules from Table XXII would produce three additional removals. This happens because, in the three overheating or overtorque removals, both modules had to be removed. Had the two modules been combined, the combined module would have required removal only three times for these reasons, not six times as would be indicated by simple addition of module removal totals from Table XXII. Hence, three is subtracted from the module removal total when combining two modules. A sample calculation appears below.

Combining left-hand input and freewheel units for conversion of 6 module to 4 module configuration:

$$\text{NREM} = \frac{A \times (B1 + B2 - 3)}{C}$$

$$= \frac{82 \times (6 + 3 - 3)}{24}$$

$$= 20$$

Where: NREM = Number of left-hand input/freewheel unit modules removed for ORME study of 47,993 flight hours, rounded to nearest whole number

A = 82 = Number of transmission removals during ORME study of 47,993 flight hours

B1 = 6 = Number of left-hand input failures occurring in 24 transmission removals of Table XXII.

B2 = 3 = Number of left-hand freewheel unit failures occurring in 24 transmission removals of Table XXII.

C = 24 = Total number of main transmissions removed in Table XXII.

\- 3 = Adjustment factor for overtorque or overheating transmission removals.

TABLE XXIII. NUMBER OF MODULES REPLACED DURING 47,993 FLIGHT HOUR ORME STUDY

Name	LH Output	LH FWU	RH Input	RH FWU	Tail-Takeoff	Main Bevel	Plan
7 Module	20	10	17	10	44	14	37
6 Module	20	10	17	10	44	41	
4 Module	20		17		44	41	
3 Module	20		17		75		
Baseline	82						

The mean time to repair the transmission on the aircraft is then found from:

$$MRON_i = \underbrace{(MREM_i + MINST_i)}_{\text{MMH for unscheduled removals and installation of modules}} NREM_i + \underbrace{MREP_i}_{\text{MMH to repair small items}}$$

where:

$MRON_j$ = Mean MMH to repair any module on aircraft

$MREM_i$ = Mean MMH to remove any module (see Table XIV)

$MINST_i$ = Mean MMH to install any module (see Table XV)

$MREP_i$ = Mean MMH to repair small components on aircraft (see Tables XVI through XXI)

$NREM_i$ = Number of modules replaced (see Table XXIII)

The mean MMH required to repair small components on the aircraft is found by dividing the total maintenance hours by the occurrences from Tables XVI through XXI.

All the on-aircraft repairs have thus far delt with the seven-module design. To obtain values for other modularized versions, the average MMH of each module comprising the combined module is weighted by occurrences. On-aircraft repair hours (MRON) represent an average time to repair and do not reflect quantity of occurrences. The assumption is made, therefore, that the same average types of failures will occur in the modularized and baseline designs. Thus, the data are directly applicable to on-aircraft repair hours.

A summary of the mean MMH for on-aircraft repairs derived by the method presented herein is shown in Table XXIV.

TABLE XXIV. MEAN MAINTENANCE MAN-HOURS TO REPAIR MODULARIZED AND BASELINE TRANSMISSIONS ON AIRCRAFT

	MMH				
Module Name	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	5.49	5.49	5.45	5.45	10.04
Left-Hand Freewheel Unit	5.12	5.12			
Right-Hand Input	4.19	4.19	3.85	3.85	
Right-Hand Freewheel Unit	1.00	1.00			
Tail-Takeoff	6.05	6.05	6.05	12.69	
Main Bevel	18.64	14.24	14.24		
Planetary	14.67				

After modules have been removed, they are inspected and the disposition of the modules is determined. These inspections are carried out at each of the U. S. Army maintenance levels: organization, direct support, and depot. The inspection increases in complexity and, hence, in time required as the module proceeds from organization to depot. At each level, the inspector decides if the module should be scrapped, repaired at that level, or shipped to a higher maintenance level for repair or scrappage. The inspection itself may require partial disassembly of major components to discover worn, broken, or failed parts or other causes of removal. At the depot level, the CH-54B main transmission inspection is estimated to require 40 hours. Direct support and organizational level inspections occupy considerably less time. Figures 38, 39, and 40 depict unscheduled MMH for transmission inspection at organization, direct support, and depot maintenance levels.

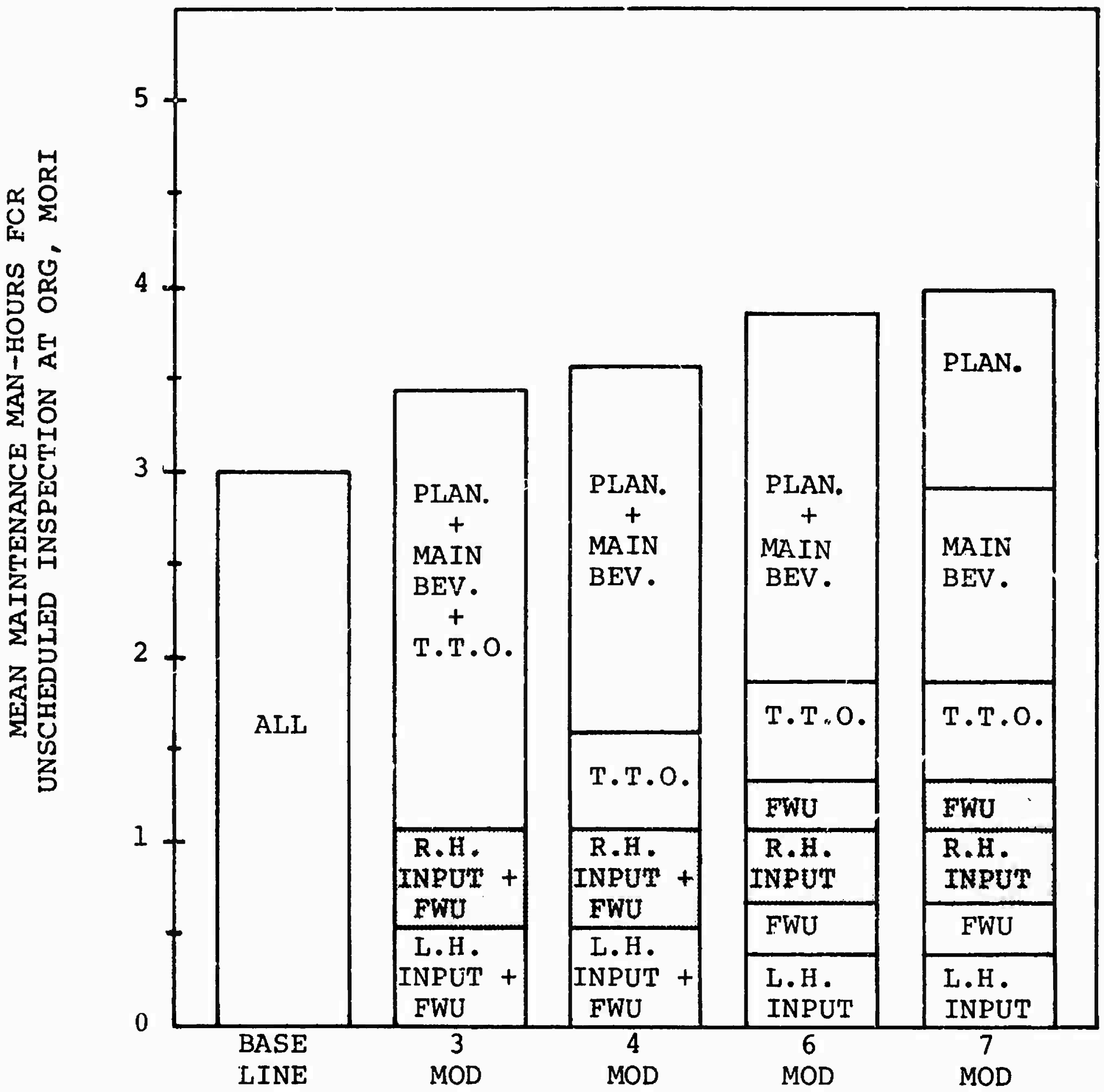

Figure 38. Mean MMH for Unscheduled Inspection at Organizational Maintenance Level for Modular and Baseline CH-54B Transmission Designs.

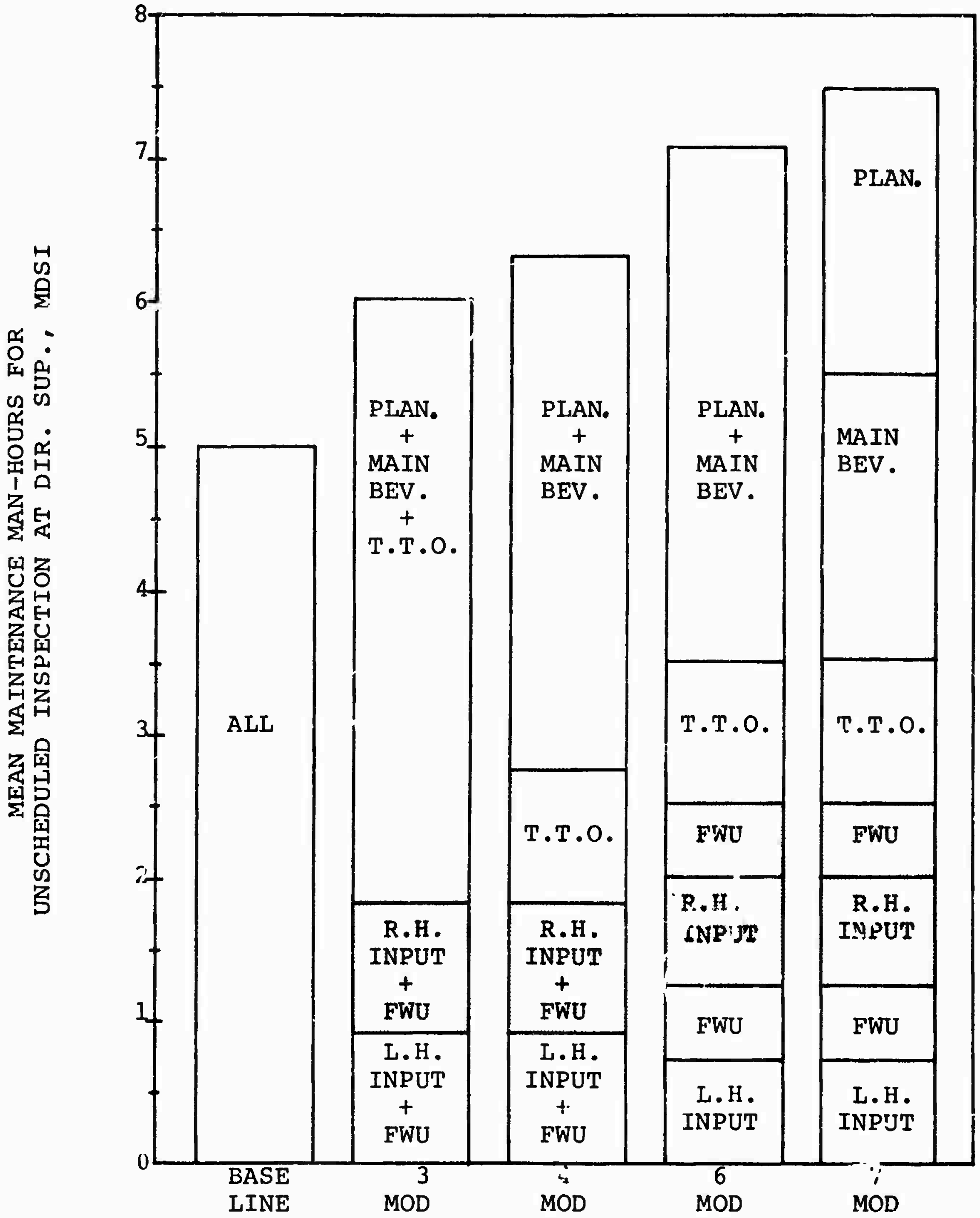

Figure 39. Mean MMH for Unscheduled Inspection at Direct Support Maintenance Level for Modular and Baseline CH-54B Transmission Designs.

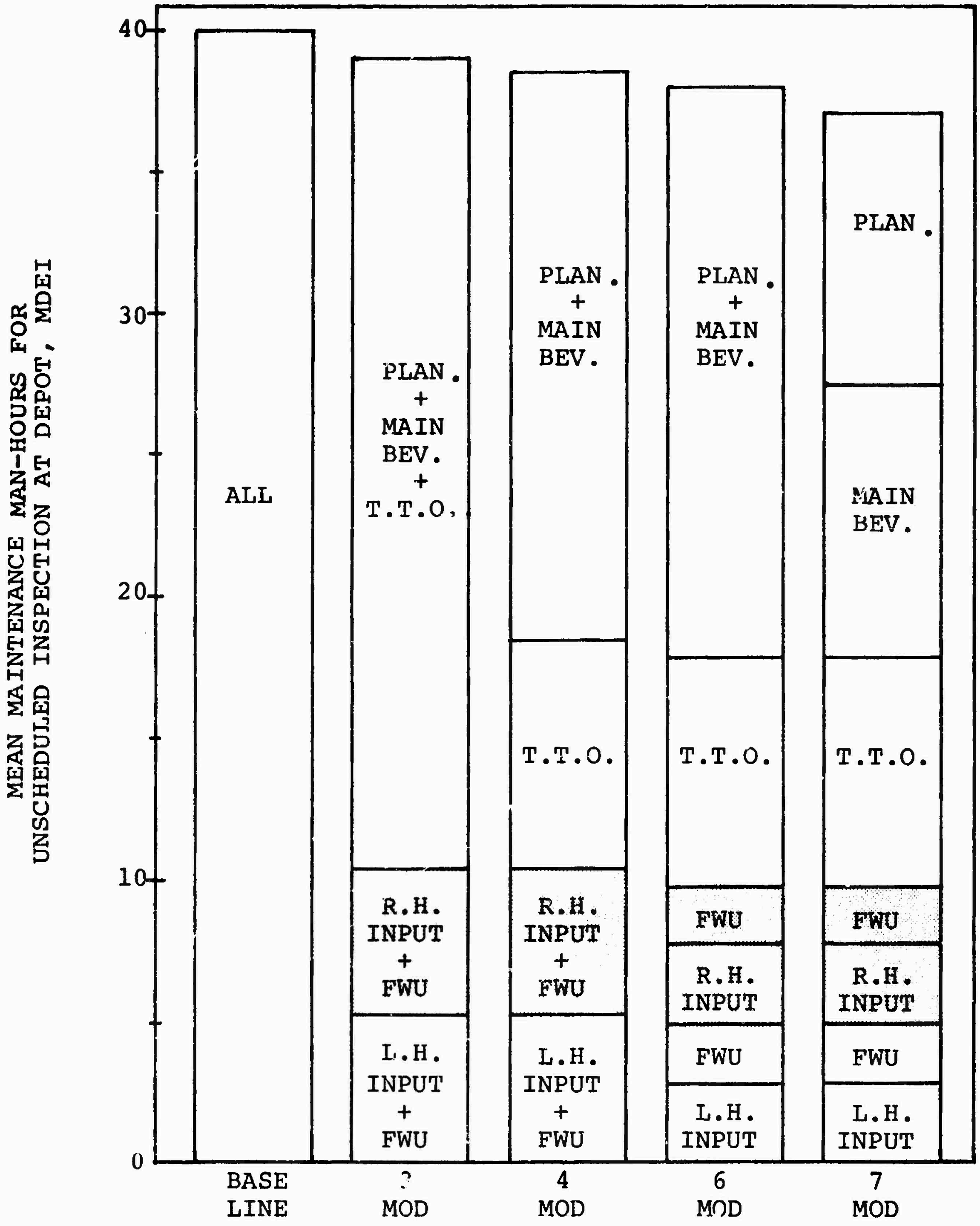

Figure 40. Mean MMH for Unscheduled Inspection at Depot Maintenance Level for Modularized and Baseline CH-54B Transmission Designs.

In the figures, total inspection hours increase with an increasing number of modules at organization and at direct support maintenance levels. Inspection hours decrease with increasing number of modules at the depot maintenance level. This is because, with higher degrees of modularization, more items will be inspected in the field, since the components being inspected will be in a higher state of disassembly and will be open to view. Conversely, the disassembly inspection is a normal part of depot inspection. Depot inspection time will decrease with increasing degrees of modularization, since the components will already be partially disassembled.

The mean MMH required to repair the main transmission at the U. S. Army direct support maintenance level consists of the same types of repairs as done on the aircraft. At direct support, removals and installations are performed, as well as repairs of a minor nature, such as seals, "O" rings, snap rings, and other small standard parts. The data for the direct support repairs are obtained from Discrepancy/Corrective Action Reports, Sikorsky forms developed for the U. S. Army for field data collection during the ORME program. These reports list the direct support maintenance hours and the components repaired. By methods similar to those used for determination of on-aircraft repairs, the direct support mean MMH to repair modules are calculated. The results are shown in Table XXV.

TABLE XXV. MEAN MAINTENANCE MAN-HOURS TO REPAIR MODULARIZED AND BASELINE TRANSMISSIONS AT DIRECT SUPPORT

Module Name	MMH				
	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	5.08	5.08	4.70	4.70	19.73
Left-Hand Freewheel Unit	4.41	4.41			
Right-Hand Input	7.77	7.77	7.77	7.77	
Right-Hand Freewheel Unit	1.00	1.00			
Tail-Takeoff	.80	.80	.80	33.02	
Main Bevel	37.60	33.02	33.02		
Planetary	31.64				

At the depot maintenance level, the transmission is completely disassembled and inspected. New parts or repairs are incorporated. Bearings are replaced if they show signs of deterioration. During depot overhaul, revisions of designs are often incorporated to update assemblies. The depot mean MMH for repair are, therefore, much higher than the direct support and organization level field repair.

The baseline CH-54 main transmission depot repair MMH is found to be 377 hours from Sikorsky overhaul and accounting records. Data from the modularized designs, derived from the baseline value, are shown in Table XXVI.

TABLE XXVI. MEAN MAINTENANCE MAN-HOURS TO REPAIR MODULARIZED AND BASELINE TRANSMISSION AT DEPOT

Module Name	MMH				
	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	36.30	36.30	52.80	52.80	377.00
Left-Hand Freewheel Unit	14.50	14.50			
Right-Hand Input	29.00	29.00	41.90	41.90	
Right-Hand Freewheel Unit	10.90	10.90			
Tail-Takeoff	54.50	54.50	54.50	276.30	
Main Bevel	90.70	219.80	219.80		
Planetary	127.10				
TOTALS	363.00	365.00	369.00	371.00	377.00

The MMH to repair at depot shown above decrease with increasing number of modules. As the number of modules increases, the modules as received at depot are in a higher state of disassembly and, therefore, take less time to repair. Internally, the modularized designs and baseline designs have essentially identical components. As such, they require the same overhaul man-hours except for assembly/disassembly of the modules themselves.

The mean MMH required to scrap modules is input data for calculating MMH per flight hour at organization, direct support, and depot. MMH to scrap include partial disassembly of major components, inspection, maintenance disposition, disposal of parts, and administrative duties. It is assumed that MMH to scrap are the same at all maintenance levels, since procedures are essentially the same. As the number of modules increases, the sum of maintenance hours for each total main transmission increases, since complexity of the inspection increases. Total MMH to scrap and breakdown by module are depicted in the bar chart of Figure 41 for the modular and baseline designs. Figure 41 shows MMH for organization, direct support, or depot, since the assumption is that the hours are identical at every maintenance level.

The mean MMH required to requisition modules is a part of the MMH per flight-hour at the organizational level. Requisition involves administrative duties and is assumed to require two hours per module for all modular or baseline designs.

Maintenance required at the organizational level also includes mean MMH to perform on-aircraft unscheduled inspections. These unscheduled inspections occur after some sign of trouble is detected. A disposition is made as to what the problem may be and what is required to correct the problem. The inspection may involve, for instance, a decision on whether to repair on-the-spot or remove the module for shipment to a higher maintenance level. The average time for inspection is about the same for any module of any modularized design and varies only according to the complexity of the components. The sum of the MMH for each modularized main transmission, therefore, has no meaning. It is assumed that only one failure will occur at a time. The on-aircraft unscheduled MMH for the modularized and baseline designs are listed in Table XXVII.

Transmission Frequency of Maintenance Action

The mean elapsed time to repair (METTR) modules on aircraft is used to calculate aircraft unavailability and ultimately is a factor in aircraft mission availability, aircraft mission effectiveness, aircraft life cycle cost, aircraft cost effectiveness, and fleet effective cost. METTR is input to the mathematical model as aircraft down hours and represents the average time that the aircraft is down for repair. The value of METTR can never exceed the value of MMH to repair on aircraft. Examination of maintenance records shows that METTR for transmission components is generally less than one-half of the mean MMH. Thus, on the average, transmission repairs on aircraft are conducted by more than two men. As with the mean MMN to repair on aircraft, METTR consists of time for small repairs and time for removals and installations.

Beginning with the seven-module versions, METTRs for lesser degrees of modularization are found by combining data. The baseline value of 4.37 down hours is found from analysis of the

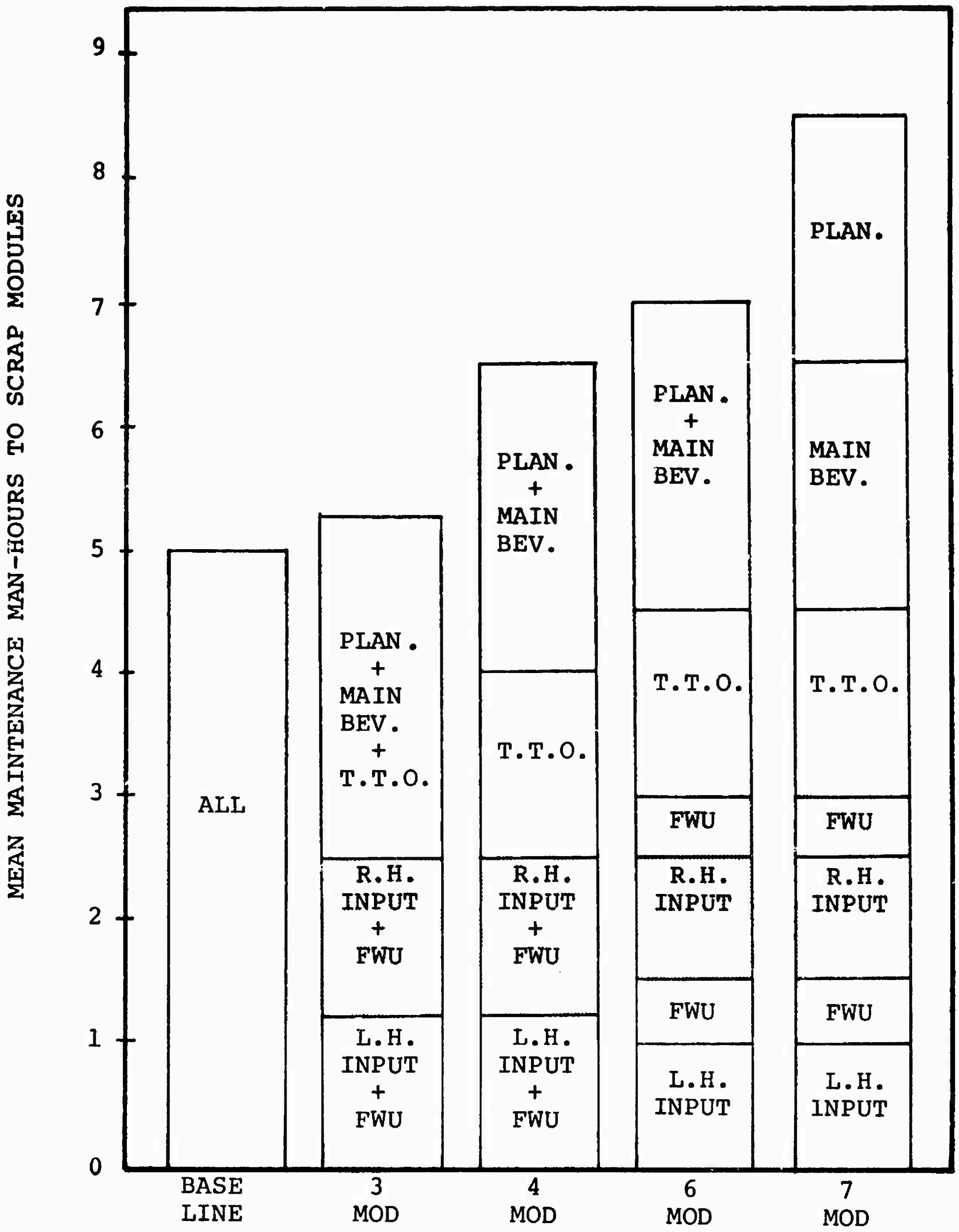

Figure 41. Mean Maintenance Man-Hours to Scrap Modules and Baseline Transmission at Organization, Direct Support, and Depot.

data from the ORME program (Reference 1) and consists of 374 occurrences of minor repairs and 82 installations and removals of main transmission. With the modularized transmission, the installations and removals total more than 82, because of nonscheduled overtorques and excessive temperatures when all modules were replaced (see Table XXIII). A summary of METTR in down-hours is presented in Table XXVIII. Also included in Table XXVIII are the unscheduled small repair down-hours, the module removal and installation down-hours, and the quantity of occurrences based on the ORME data sample.

TABLE XXVII. MAINTENANCE MAN-HOURS TO PERFORM UNSCHEDULED INSPECTIONS ON AIRCRAFT

Module Name	MMH				
	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	0.40	0.40	0.41	0.41	0.48
Left-Hand Freewheel Unit	0.44	0.44			
Right-Hand Input	0.40	0.40	0.41	0.41	
Right-Hand Freewheel Unit	0.44	0.44			
Tail-Takeoff	0.48	0.48	0.48	0.52	
Main Bevel	0.60	0.60	0.60		
Planetary	0.60				

TABLE XXVIII. SUMMARY OF DOWN HOURS FOR MODULAR AND BASELINE CH-54 TRANSMISSION BASED ON 47,993 FLIGHT-HOUR ORME DATA SAMPLING STUDY (REFERENCE 1)

Name of Design	Name of Module	Unscheduled Module Repairs		Unscheduled Module Removals & Installations		Mean Elapsed Time to Repair
		QTY	Down Hr	QTY	Down Hr	Down Hr
7 Module	Left-Hand Input	120	359.4	20	48.0	2.91
	Left-Hand Freewheel	67	200.4	10	12.9	2.77
	Right-Hand Input	68	160.3	17	25.8	2.19
	Right-Hand Freewheel	-	-	10	3.7	0.37
	Tail-Takeoff	20	26.6	44	130.2	2.45
	Main Bevel	19	17.6	14	218.7	7.16
	Planetary	80	99.3	37	578.1	5.79
6 Module	Left-Hand Input	120	359.4	20	48.0	2.91
	Left-Hand Freewheel	67	200.4	10	12.9	2.77
	Right-Hand Input	68	160.3	17	25.8	2.19
	Right-Hand Freewheel	-	-	10	3.7	0.37
	Tail-Takeoff	20	26.6	44	130.2	2.45
	Main Bevel/Planetary	99	116.9	41	640.6	5.41
4 Module	Left-Hand Input/FWU	187	559.8	20	40.6	2.90
	Right-Hand Input/FWU	68	160.3	17	18.6	2.10
	Tail-Takeoff	20	26.6	44	130.2	2.45
	Main Bevel/Planetary	99	116.9	41	640.6	5.41
3 Module	Left-Hand Input/FWU	187	559.8	20	40.6	2.90
	Right-Hand Input/FWU	68	160.3	17	18.6	2.10
	Main Bevel/Plan/TTO	119	143.5	75	731.8	4.51
Base-line	Main Transmission	374	863.6	82	1133.6	4.37

Mean time between unscheduled removals is an input data item used in calculating spares production run. This in turn, is used to calculate quantity of containers, cost of containers, transmission nonrecurring cost, transmission acquisition cost, and spares cost. These items are used in calculating transmission maintenance cost. From the ORME program, the baseline unscheduled removal time for the CH-54B main transmission is 615 flight hours (47,993 flight hours with 78 unscheduled removals). The modularized transmission mean time between unscheduled removals is found from:

$$\text{MTBURi} = \frac{\text{FH}}{\text{NREM}_i}$$

where:

MTBURi = Any module mean time between unscheduled removals

FH = Flight hours during which data sampling was taken

NREMi = Number of modules removed during data sampling

Table XXIII, previously shown, lists the number of modules removed during the 47,993 flight hours of the ORME study. Mean time between unscheduled removals for the modularized versions is listed in Table XXIX below.

TABLE XXIX. MEAN TIME BETWEEN UNSCHEDULED MODULE REMOVAL FOR MODULARIZED AND BASELINE DESIGNS - FLIGHT HOURS

Module Name	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	2400*	2400*	2400	2400	615**
Left-Hand Freewheel Unit	4800	4800			
Right-Hand Input	2824	2824	2824	2824	
Right-Hand Freewheel Unit	4800	4800			
Tail-Takeoff	1091	1091	1091	640	
Main Bevel	3429	1170	1170		
Planetary	1297				

* Left-hand input includes rotor brake.
** Reference formula (3) of Appendix II.

The overall mean time between unscheduled removals (MTBUR) for the modular designs is much lower than the baseline. The overall MTBUR can be calculated from equation (2) of Appendix II using the individual removal times from Table XXIX. The seven-module design is calculated to be 315 hours, and the overall MTBUR increases with decreasing degree of modularization up to 615 hours for the baseline. For a modular design, this number has little meaning. Although, on the average, more modules are being removed, each one is smaller, less expensive, and requires less time to remove and replace. The reason that more modules are removed than baseline transmissions can be traced to those instances where all the modules are removed at once. This occurs during an overtemperature or overtorque condition wherein all modules are affected since oil paths are not temperature isolated and torque paths are connected between modules. From overhaul records, the overtorque or overtemperature condition accounts for approximately 12% of failures. Thus in the seven-module design, all seven modules are removed 12% of the time there are any removals. This accounts for the overall MTBUR being 315 hours in the seven-module design as compared to 615 hours for the baseline. The overall MTBUR for the six-module design is 338 hours, for the four-module design is [illegible]93 hours, and for the three-module design is 429 hours.

Transmission module attrition rates are an input to the mathematical model and are used in calculating spares production run. The spares production run then is used in calculating quantity and cost of transmission shipping containers, transmission nonrecurring cost, transmission acquisition cost, and transmission spares cost. These data are used to calculate transmission maintenance cost.

Transmission attrition is defined as components that are lost or damaged to the extent that they are irrecoverable. These losses are a result of theft, combat loss, crashes, misplacement, fire, etc. During the CH-54B ORME study program, nine aircraft were lost during 47,993 flight hours. The main transmission average attrition rate is, therefore, .000187 transmission lost per flight hour. Had the main transmission been modularized, all modules would have been lost; therefore, the attrition rate is the same for the modularized transmission and baseline transmission. The assumption has been made that, for the freewheel unit module, which is used on the seven-module and six-module design, an additional module will be lost in shipment or for some other reason. Then ten freewheel units will be lost in 47,993 flight hours, giving a rate of .000208 module lost/flight hour. The additional module lost has been assumed, because the freewheel unit forms a relatively small package that can easily be misplaced. Table XXX lists the modularized and baseline transmission module attrition rates.

TABLE XXX. MODULE ATTRITION RATE, MODULES LOST PER FLIGHT HOUR, BASELINE AND MODULARIZED TRANSMISSION

Module Name	MODULES LOST/FLIGHT HOUR				
	7 Module	6 Module	4 Module	3 Module	Baseline
Left-Hand Input	.000187	.000187	.000187	.000187	.000187
Left-Hand Freewheel Unit	.000208	.000208			
Right-Hand Input	.000187	.000187	.000187	.000187	
Right-Hand Freewheel Unit	.000208	.000208			
Tail-Takeoff	.000187	.000187	.000187	.000187	
Main Bevel	.000187	.000187	.000187		
Planetary	.000187				

Transmission time between overhaul (TBO) is a specified time period at the end of which the transmission is removed from the aircraft for scheduled inspection and overhaul. Initially, TBO is specified at some value based on experience or on testing at accelerated load levels. After service experience builds up, TBO may be extended as a measure of cost savings. To present a valid comparison of modularized transmissions, TBOs for all modularized and baseline designs are assumed to be infinite. The common term for infinite TBO is "on condition": the transmission is never removed for scheduled overhaul, but is left on the aircraft until a failed condition dictates its removal.

Unscheduled maintenance frequency is used to calculate transmission MMH per flight hour at the organization and direct support maintenance levels. These hours are then used to calculate maintenance costs at these levels. Unscheduled maintenance frequency is determined by dividing the number of unscheduled repairs during a sampling period by the flight hour in that period. As used in the mathematical model, unscheduled maintenance frequency refers to removals requiring overhaul and also includes on-the-spot aircraft repairs. Modular transmission unscheduled removals were listed in Table XXII for the 47,993 flight hour ORME study program. Using those data, the unscheduled maintenance frequency is calculated. The results of the calculations are then used as input data to the mathematical model. A summary is shown in Table XXXI.

TABLE XXXI. UNSCHEDULED MAINTENANCE FREQUENCY, MODULARIZED AND BASELINE CH-54B TRANSMISSION, EVENTS PER FLIGHT HOUR

Module Name	7 Module	6 Module	4 Module	3 Module	Base-line
Left-Hand Input	.0029	.0029	.0043	.0043	.0097
Left-Hand Freewheel Unit	.0016	.0016			
Right-Hand Input	.0018	.0018	.0018	.0018	
Right-Hand Freewheel Unit	.0002	.0002			
Tail-Takeoff	.0013	.0013	.0013	.0040	
Main Bevel	.0007	.0029	.0029		
Planetary	.0024				

Transmission Maintenance Disposition

After a transmission module has been removed in the field, it is routed through the various maintenance levels, where decisions are made to scrap, repair, or ship to a higher level. The flow of the decision process is depicted in Figure 42. In the mathematical model, these decisions are input as percentage of modules received and scrapped at direct support. The sum of the percentage alternatives at any one maintenance level must, of course, equal 100%. The computer program of the mathematical model, shown in Appendix III, adds the percentages at each level and checks that they equal 100% (within an allowable error of 0.1%). If an error in the input data results in a total other than 100%, a diagnostic message is printed.

At the organization maintenance level, the following questions are answered concerning modules removed from the aircraft:

(1) Should module be scrapped?

(2) Should module be shipped to direct support?

(3) Should module be shipped to depot?

Repairs are not made at the organizational level once the module has been removed. At the direct support maintenance level, after modules have been received, the following questions are answered:

(1) Should module be scrapped?

(2) Should module be repaired at direct support?

(3) Should module be shipped to depot?

At the depot maintenance level, after a module is received, there are only two alternatives:

(1) Should module be scrapped?

(2) Should module be repaired?

The percentages of received modules that are scrapped, repaired, or shipped are used as input for calculating spares production run. It, in turn, is used in calculating quantity and cost of containers, transmission nonrecurring cost, transmission acquisition cost, and initial spares cost. Additionally, the percentage disposition inputs are used in calculating MMH per flight hour at organization, direct support, and depot; shipping costs between maintenance levels; and transmission maintenance cost. Tables XXXII through XXXIV list the maintenance dispositions at the organizational, direct support, and

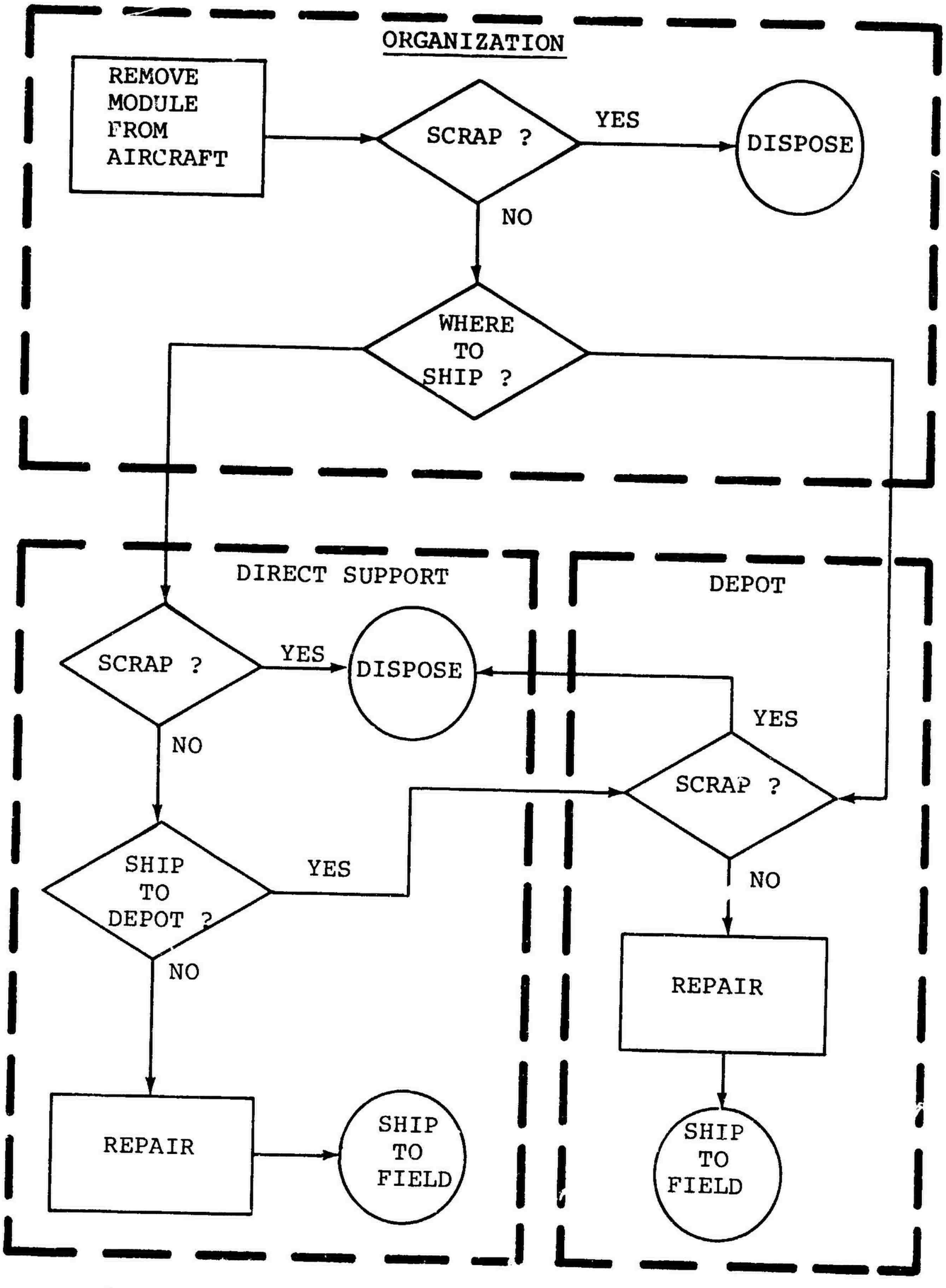

Figure 42. Disposition of Removed Modules at the Various Maintenance Levels.

depot maintenance levels.

Field experience has shown that few modules are scrapped. Therefore, the percentage scrapped at organization and direct support is assumed to be zero for all modularized and baseline designs. At the organizational level, the percentage shipped to depot increases with increased complexity of the modularized design. Thus, 90% of main bevel and planetary modules are shipped from organization to depot, since they are large, complex modules requiring special disassembly tooling. Again, 90% of the freewheel units are shipped from organization to direct support, since the freewheel is a small unit that can be repaired at a level below depot.

Similarly, at the direct support maintenance level, the percentage repaired decreases with increasing complexity of modular design.

At the depot maintenance level, it is assumed that 10% of the freewheel unit modules received are scrapped. All other modules are repaired.

All on-aircraft repairs are performed at either the organizational or direct support maintenance level. These on-aircraft repairs must also total 100% for the two maintenance levels. As for maintenance level disposition, the computer program prints a diagnostic message if the total is not 100%.

The percentage of on-aircraft repairs done at direct support and organization is used in the mathematical model in calculating organization and direct support MMH and maintenance costs.

A summary of the percentages of transmission repaired on the aircraft at each maintenance level is presented in Figure 43. From Discrepancy/Corrective Action Reports of CH-54B transmissions in the field, approxiamtely 65% of on-aircraft repairs are done by the organizational level and 35% by the direct support level. In the modularized transmission designs, the percentages repaired at organization and direct support were also found by examination of the field reports. The items repaired at each level were assigned to a module of the seven-module design. Lower degrees were calculated by combining the results of the seven-module version.

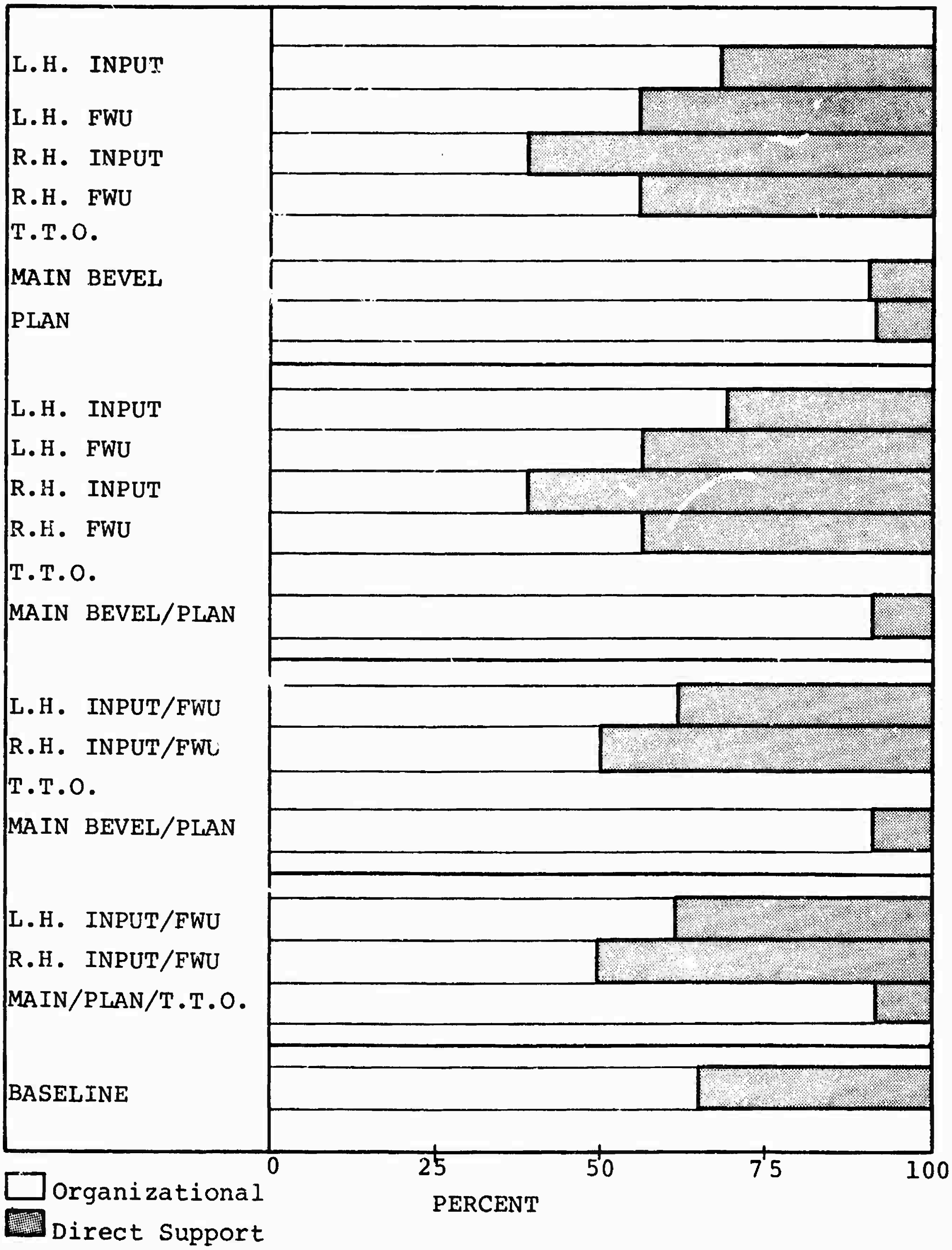

Figure 43. Percentage of On-Aircraft Repairs at Organization and Direct Support Maintenance Levels.

TABLE XXXII. DISPOSITION OF MODULES REMOVED, ORGANIZATIONAL MAINTENANCE LEVEL

Number of Modules	Module Name	% Scrapped	% Shipped to Direct Support	% Shipped to Depot
7	Left-Hand Input	0	30	70
	Left-Hand Freewheel	0	90	10
	Right-Hand Input	0	30	70
	Right-Hand Freewheel	0	90	10
	Tail-Takeoff	0	35	65
	Main Bevel	0	10	90
	Planetary	0	10	90
6	Left-Hand Input	0	30	70
	Left-Hand Freewheel	0	90	10
	Right-Hand Input	0	30	70
	Right-Hand Freewheel	0	90	10
	Tail-Takeoff	0	35	65
	Main Bevel/Planetary	0	10	90
4	Left Input/Freewheel	0	30	70
	Right Input/Freewheel	0	30	70
	Tail-Takeoff	0	35	65
	Main Bevel/Planetary	0	10	90
3	Left Input/Freewheel	0	30	70
	Right Input/Freewheel	0	30	70
	Main Bevel/Plan/TTO	0	10	90
1	Baseline	0	49.2	50.8

TABLE XXXIII. DISPOSITION OF MODULES RECEIVED, DIRECT SUPPORT MAINTENANCE LEVEL

Number of Modules	Module Name	% Scrapped	% Shipped to Depot	% Repaired
7	Left-Hand Input	0	80	20
	Left-Hand Freewheel	0	10	90
	Right-Hand Input	0	80	20
	Right-Hand Freewheel	0	10	90
	Tail-Takeoff	0	60	40
	Main Bevel	0	90	10
	Planetary	0	90	10
6	Left-Hand Input	0	80	20
	Left-Hand Freewheel	0	10	90
	Right-Hand Input	0	80	20
	Right-Hand Freewheel	0	10	90
	Tail-Takeoff	0	60	40
	Main Bevel/Planetary	0	90	10
4	Left Input/Freewheel	0	80	20
	Right Input/Freewheel	0	80	20
	Tail-Takeoff	0	60	40
	Main Bevel/Planetary	0	90	10
3	Left Input/Freewheel	0	80	20
	Right Input/Freewheel	0	80	20
	Main Bevel/Plan/TTO	0	90	10
1	Baseline	0	80	20

TABLE XXXIV. DISPOSITION OF MODULES RECEIVED, DEPOT MAINTENANCE LEVEL

Number of Modules	Module Name	% Scrapped	% Repaired
7	Left-Hand Input	0	100
	Left-Hand Freewheel	10	90
	Right-Hand Input	0	100
	Right-Hand Freewheel	10	90
	Tail-Takeoff	0	100
	Main Bevel	0	100
	Planetary	0	100
6	Left-Hand Input	0	100
	Left-Hand Freewheel	10	90
	Right-Hand Input	0	100
	Right-Hand Freewheel	10	90
	Tail-Takeoff	0	100
	Main Bevel/Planetary	0	100
4	Left Input/Freewheel	0	100
	Right Input/Freewheel	0	100
	Tail-Takeoff	0	100
	Main Bevel/Planetary	0	100
3	Left Input/Freewheel	0	100
	Right Input/Freewheel	0	100
	Main Bevel/Plan/TTO	0	100
1	Baseline	0	100

Transmission Availability and Reliability

Mission abort rates for the baseline transmission and candidate modular transmissions are input data to the mathematical model and used to calculate aircraft mission reliability. This, in turn, is used to calculate aircraft mission effectiveness, aircraft cost effectiveness, and fleet effective cost.

The transmission abort rate is based on 19 transmission-caused aborts observed during a 47,993-flight-hour period of ORME data. Table XXXV lists the components that caused these aborts and the number of failures observed for each part.

Dividing the 19 observed aborts by the 47,993-flight-hour data sample gives an abort rate of .00040 abort per flight hour. For the modularized designs, two additional aborts have been assigned for the seven-module and six-module designs, and one additional abort has been assigned for the four-module and three-module designs. These aborts are assigned because of the higher number of components resulting from modularization. The abort rates for the baseline and candidate modular designs are shown in Table XXXVI below.

TABLE XXXV. MISSION ABORT CAUSES, BASELINE TRANSMISSION

Part Number	Component	Number of Aborts
MS 9021-156	"O" Ring	2
35016C	Seal	2
S6135-20091	Shaft	1
MS 28777-3	Washer	1
6435-20140-100	Coupling, Splined	1
6435-20150-100	Coupling, Male	3
6435-20248-011	Switch, Oil Pressure	3
6435-20040-047	Main Gearbox	5
6435-20209-101	Plug MGB Sump	1
TOTAL		19

TABLE XXXVI. AIRCRAFT MISSION ABORT RATE CAUSED BY TRANSMISSION FAILURES, BASELINE AND MODULARIZED CH-54B MAIN TRANSMISSION

Transmission Design	Aborts/Flight Hour
Baseline	.00040
3 Module	.00042
4 Module	.00042
6 Module	.00044
7 Module	.00044

CALCULATED FACTORS

This section of the report deals with results that are calculated using the input data previously listed and using the equations of the mathematical model. Although, in themselves, these data are results, they are only the intermediate steps taken before computing the final results used for evaluating the modularized designs. Yet these intermediate results yield insight into the nature of the data of the final results.

The calculated data section is in three parts: calculated aircraft data, calculated transmission cost factors, and calculated transmission reliability/maintainability factors. The data are shown in tables or illustrations. The relationship to the mathematical model is discussed, and the results are analyzed.

CALCULATED AIRCRAFT FACTORS

Aircraft Cost and Reliability/Maintainability

The total cost of fuel is the product of fuel cost per pound, lifetime flight-hours, and average mission fuel flow. This cost is used in the life-cycle cost equation. Since the percentage change in fuel flow is small for the various modularized and baseline designs, the change in total fuel cost is also small. Total cost of fuel increases with higher degrees of modularization, because transmission weight increases and efficiency decreases. Figure 44 portrays the total cost of fuel for the CH-54B with baseline and modularized transmissions.

Aircraft down-hours per flight-hour for a design is found from the baseline down-hours per flight-hour by subtracting baseline transmission down-hours per flight-hour and then adding transmission down-hours of a particular design. Aircraft down-hours is then used to calculate aircraft mission availability, aircraft mission effectiveness, aircraft cost effectiveness, and fleet effective cost. Down-hours per flight-hour are shown in Figure 45 for the modular designs and the baseline CH-54B.

Mission Simulation

Using the mission simulation technique, the rate of change of mission capability with respect to weight and efficiency, and the rate of change of mission fuel flow with respect to weight and efficiency are determined. These derivatives are found by assuming incremental changes in transmission weight and efficiency and by flying 1000 simulated missions to determine average fuel flow and average mission capability. The high and low values of weight and efficiency used for these mission simulations were above and below the expected bounds of the modularized transmission designs. For the range of weight and

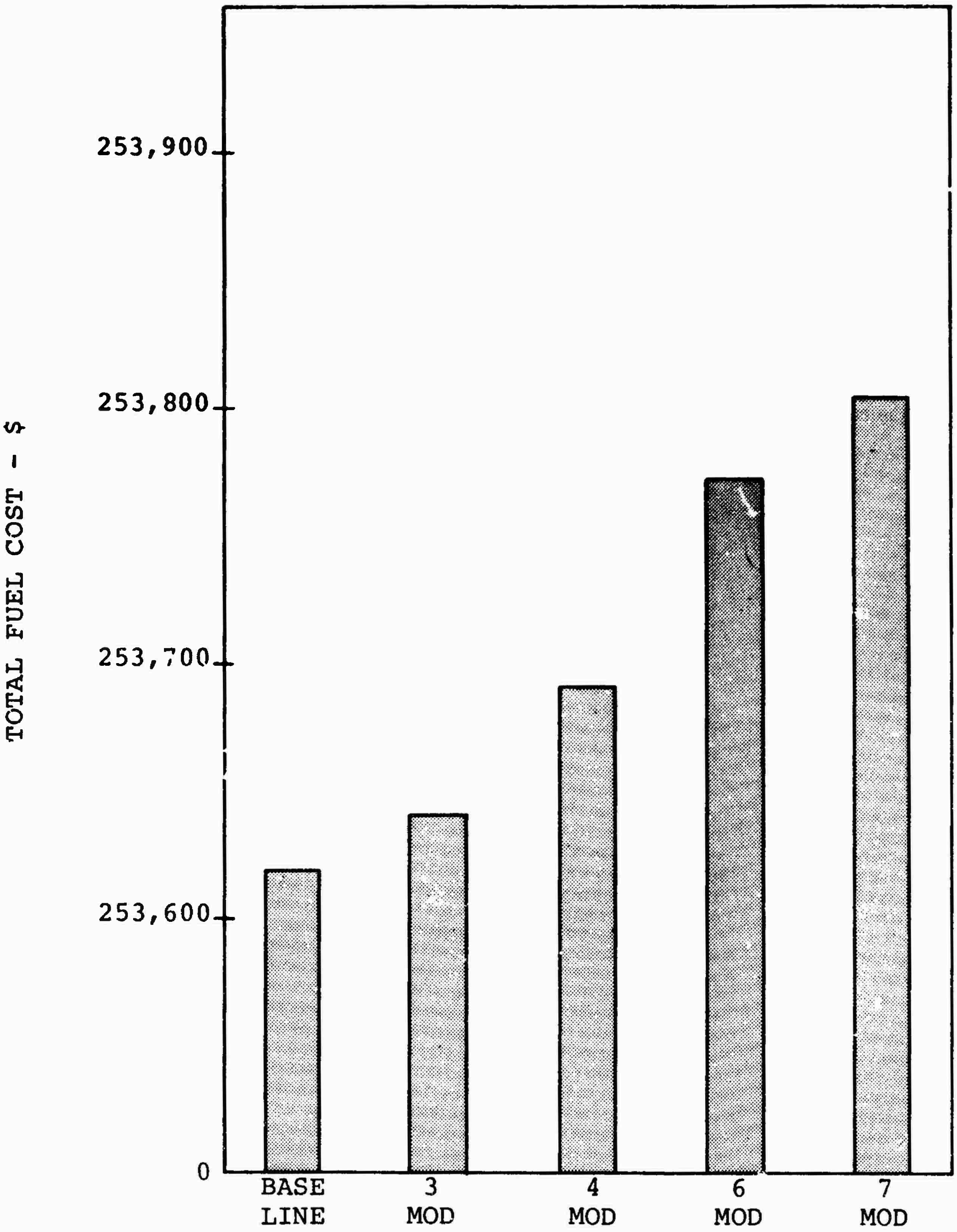

Figure 44. Total Life Cycle Fuel Cost, Modularized and Baseline CH-54B.

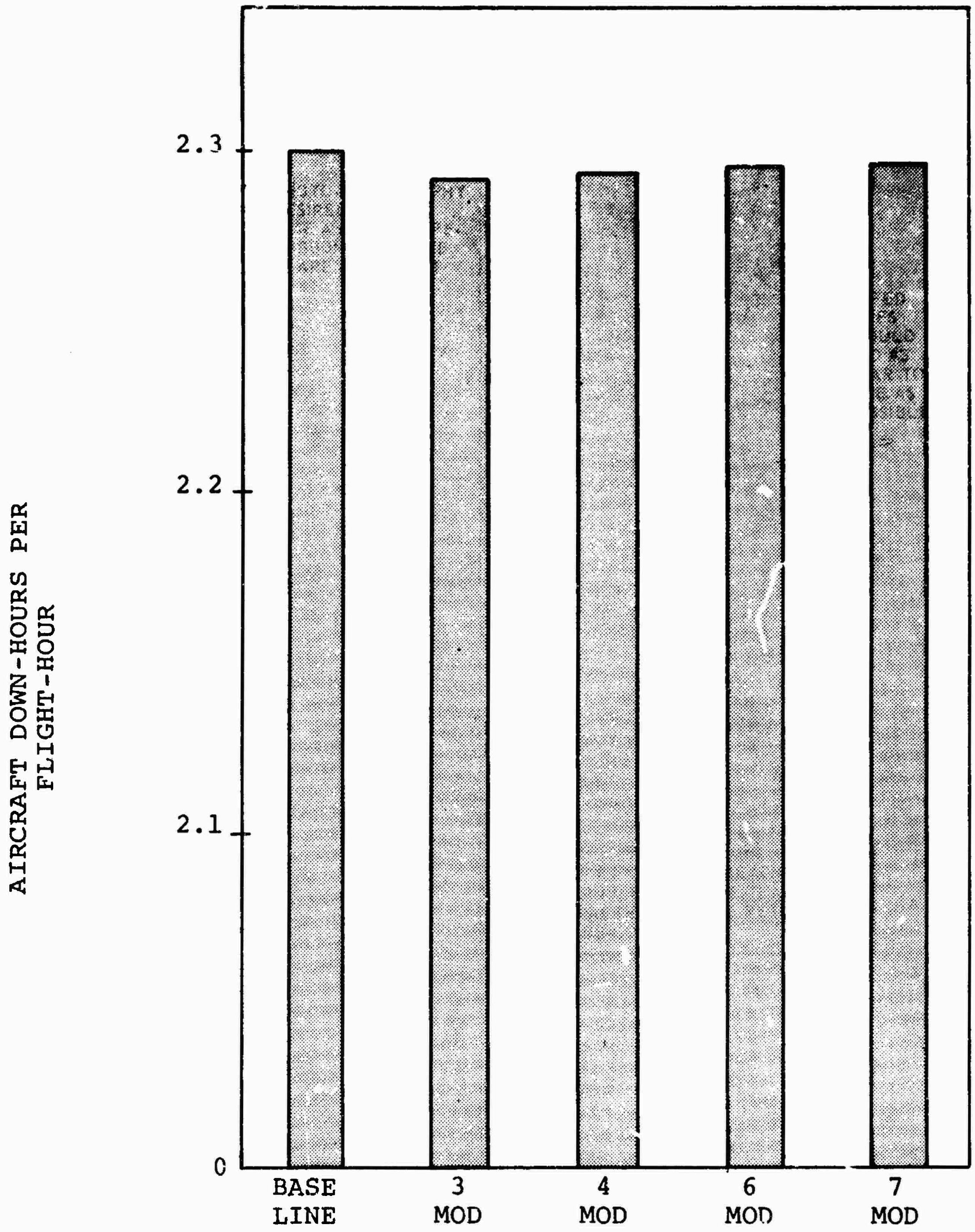

Figure 45. Aircraft Down-Hours per Flight Hour, Modularized and Baseline CH-54B.

efficiency of the modular designs, the rate of change of fuel flow was essentially constant, and fuel flow varied linearly with transmission weight and efficiency. Similarly, for the range of weight and efficiency of the modular designs, the rate of change of mission capability was essentially constant. Multiplication of these derivatives by changes in weight or efficiency between the baseline CH-54B and the modular designs gives the incremental change in mission capability or mission fuel flow. The derivatives are listed in Table XXXVII.

TABLE XXXVII. DERIVATIVES OF MISSION CAPABILITY AND FUEL FLOW WITH RESPECT TO WEIGHT AND EFFICIENCY, CH-54B AIRCRAFT

DERIVATIVE	VALUE
$\frac{\text{Average Mission Capability}}{\text{Efficiency}}$	+0.404 $\frac{\text{ton-kts}}{\%}$
$\frac{\text{Average Mission Capability}}{\text{Weight}}$	-0.02163 $\frac{\text{ton-kts}}{\text{lb.}}$
$\frac{\text{Average Mission Fuel Flow}}{\text{Efficiency}}$	-21.39 $\frac{\text{lbs fuel}}{\text{hr. }\%}$
$\frac{\text{Average Mission Fuel Flow}}{\text{Weight}}$	+0.0109 $\frac{\text{lbs fuel}}{\text{hr. lb.}}$

Aircraft Mission Results

Aircraft abort rates for the candidate modular designs are found by using the baseline CH-54B aircraft abort rate, subtracting the baseline transmission abort rate, and adding the modularized transmission abort rate. Two additional aborts per 47,993 flight-hours more than the baseline transmission have been assumed for the seven-module and six-module transmission, and one additional abort per 47,993 flight-hours has been assumed for the four-module and three-module versions. The aircraft mission aborts are shown in Figure 46 for the modularized designs and baseline CH-54B.

The effect on mission fuel flow of the main transmission modular design is obtained by adding to the aircraft baseline value of 3336.27 lb/hr the incremental change in fuel flow due to changes in gearbox efficiency and gearbox weight (see Appendix II). The partial derivatives of fuel flow, with respect to efficiency and weight, obtained from the mission

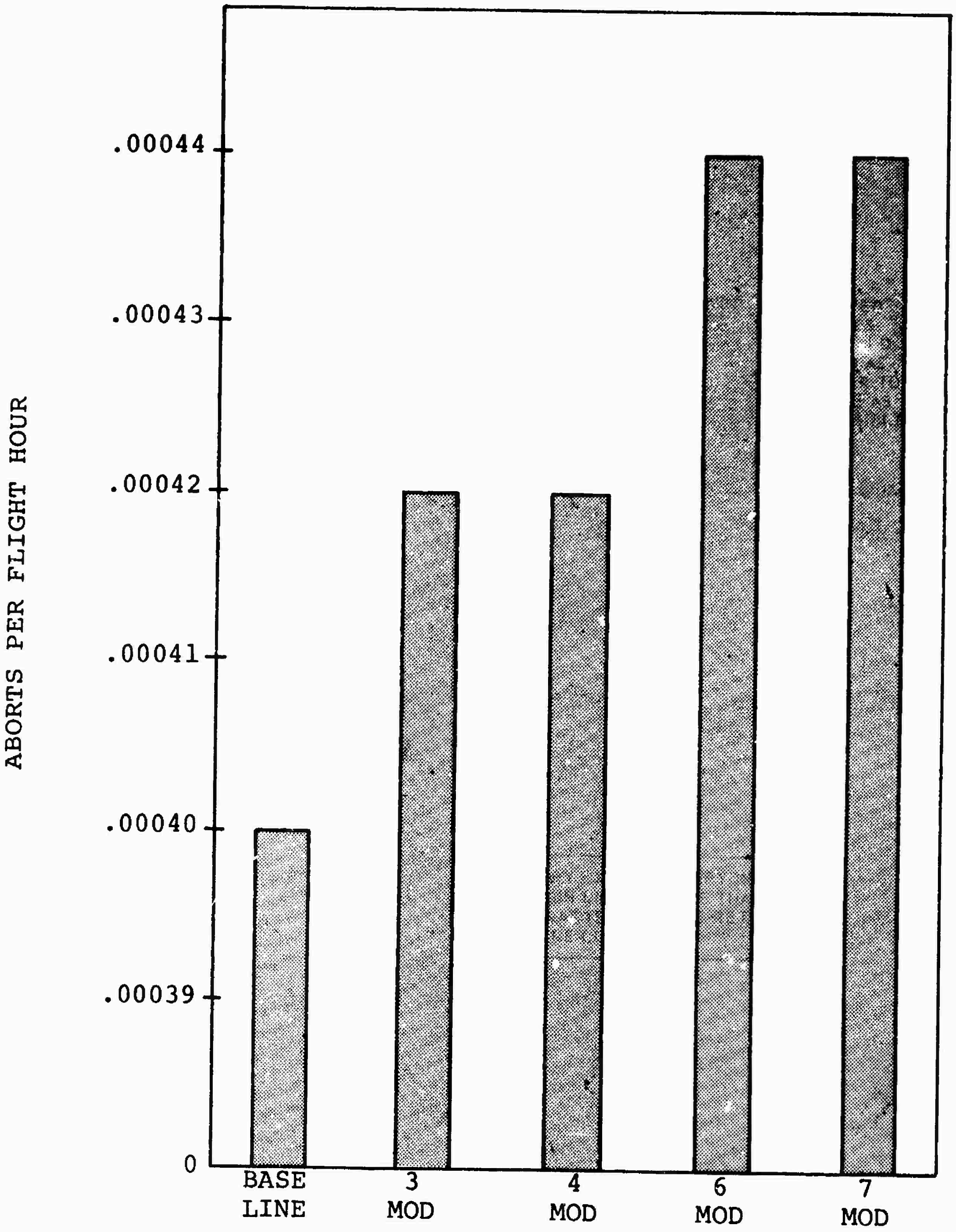

Figure 46. Mission Abort Rates Due to Transmission Malfunction.

simulation are multiplied by the incremental changes in weight and efficiency between the baseline and candidate transmissions. The data and results are summarized in Table XXXVIII.

TABLE XXXVIII. SUMMARY OF MISSION FUEL FLOW DATA

Design Version	Trans. Weight (lb)	Trans. Effic. (percent)	Δ Weight (lb)	Δ Effic. (percent)	Average Missio Fuel Flow (lb/hr)
Baseline	3096	98.170	0	0	3336.27
3 Module	3103	98.161	7	-.009	3336.54
4 Module	3113.66	98.136	17.66	-.034	3337.19
6 Module	3139.82	98.098	43.82	-.072	3338.29
7 Module	3151.66	98.085	55.66	-.085	3338.69

A life-cycle flight-hours factor is used in calculating spares production run, transmission maintenance cost at the various maintenance levels, and transmission shipping cost between various maintenance levels. These items are then used in most equations leading to calculation of total transmission maintenance cost. Life-cycle flight-hours is the product of annual utilization and service life. For the modularized and baseline CH-54B, the life-cycle flight-hours are calculated to be 4200 flight hours.

CALCULATED TRANSMISSION COST FACTORS

Candidate Transmission Costs

The main transmission contribution to aircraft life-cycle cost is divided into contribution to acquisition cost and contribution to operating cost. Calculated transmission cost factors falling under acquisition costs include transmission recurring and nonrecurring costs, initial spares, and initial tooling. Contributions to operating costs include transmission maintenance, replenishment spares, and replenishment tooling. As previously noted, the basic aircraft development cost is assumed to have been fully amortized and any additional modular transmission development cost is assumed to be amortized over the sixty baseline aircraft and included in transmission acquisition cost.

Recurring and nonrecurring transmission costs, initial and replenishment spares cost, and initial and replenishment tooling costs have been listed for the baseline CH-54B in the Input Data section. The candidate transmission recurring costs are found by multiplying total recurring costs (Table XI) by a general overhead and administrative factor. The resulting candidate transmission recurring costs are shown in Figure 47. Nonrecurring costs for the various modular configurations are shown in Figure 48.

Initial spares costs, which include acquisition costs, shipping container costs, and costs to ship from the continental United States to the field, are shown in Figure 49 for baseline and modular configurations. Replenishment spares costs are calculated with the same factors as initial spares costs, except for container costs. The assumption is that there will be one container for each initial spare, and replenishment spares will use the initial spares containers. The replenishment spares contributions to life-cycle costs are shown in Figure 50.

Cost of initial and replenishment tooling is amortized over the sixty aircraft fleet. They are summarized in Figures 51 and 52.

Transmission Shipping Costs

The quantity of shipping containers required for the modular transmission designs is equal to the number of initial spares, which is based on attrition rates and scrap rates. As the degree of modularization increases, the quantity of shipping containers increases.

The quantity of containers per module is, however, essentially constant, since the sum of attrition rates for each main transmission design is essentially constant. The quantity of shipping containers for the modularized and baseline CH-54B transmission is shown in Figure 53.

Total shipping cost is divided among organization to depot, direct support to depot, and depot to field, where "field" defines organization and direct support maintenance levels. The shipping cost at each level includes cost of preparation to ship, cost of freight, and cost of containers. Tables VII, VIII, and IX have previously shown cost of containers, cost to prepare for shipment, and cost of freight for the modularized and baseline CH-54B. These costs are on a per-module basis. Total shipping cost accounts for the quantity shipped, which is a function of mean time between unscheduled module removals and the percentages of modules received at each level.

As the degree of modularization increases, shipping costs decrease at all levels of maintenance. Although more containers are being shipped, the shipping cost per container is reduced, since the size of the container decreases with increased

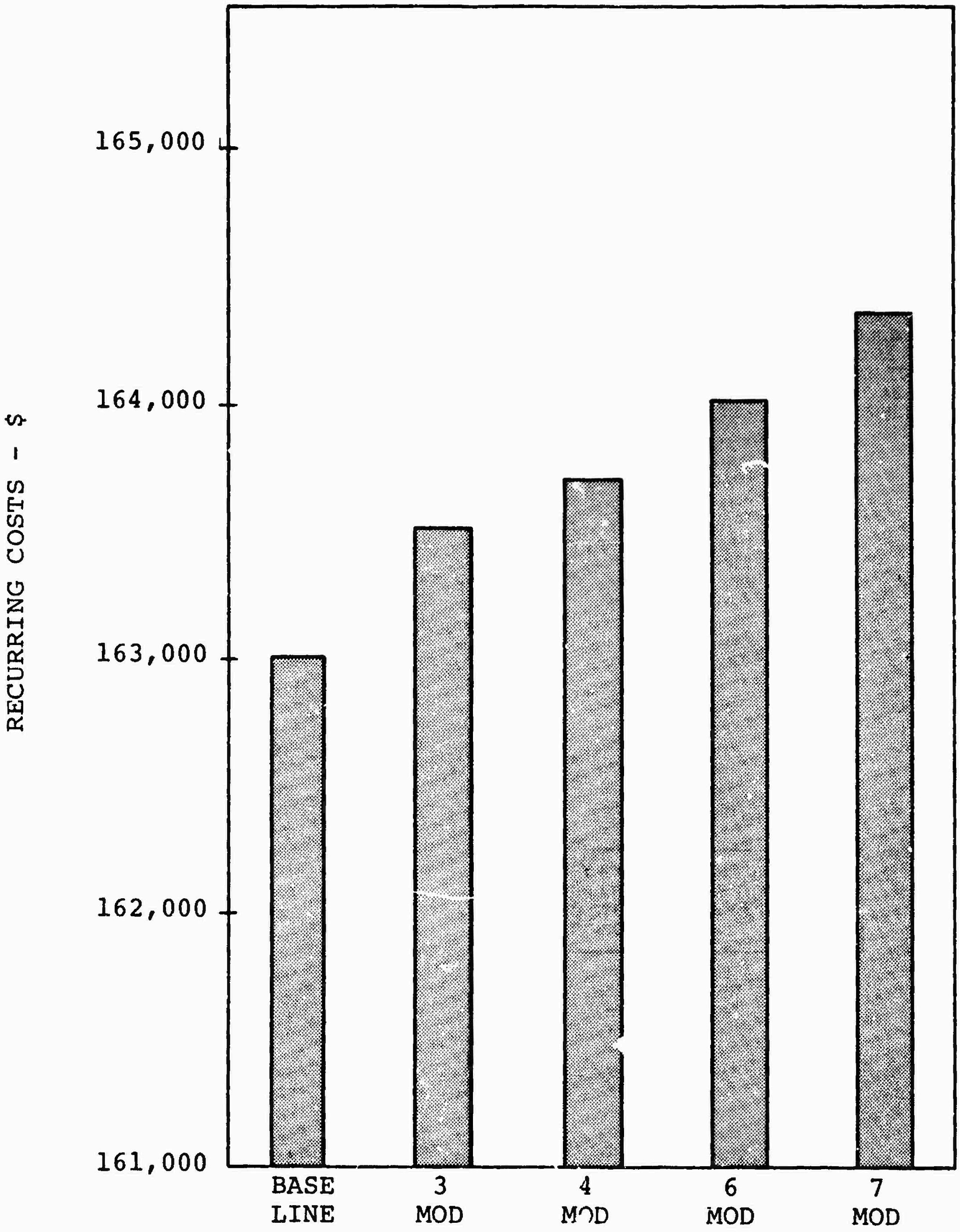

Figure 47. Recurring Costs, Modularized and Baseline CH-54B Transmission.

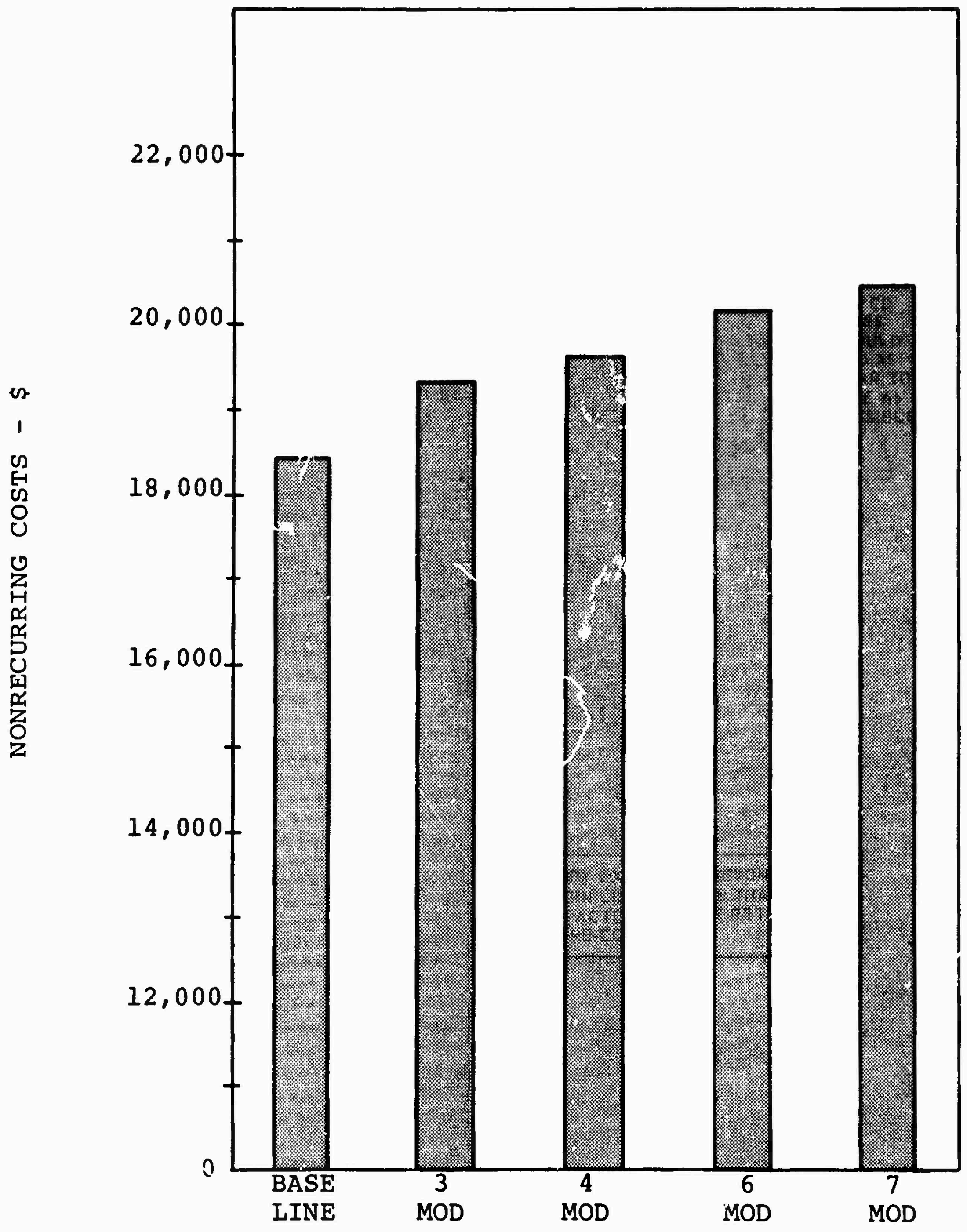

Figure 48. Nonrecurring Costs, Modularized and Baseline CH-54B Transmission.

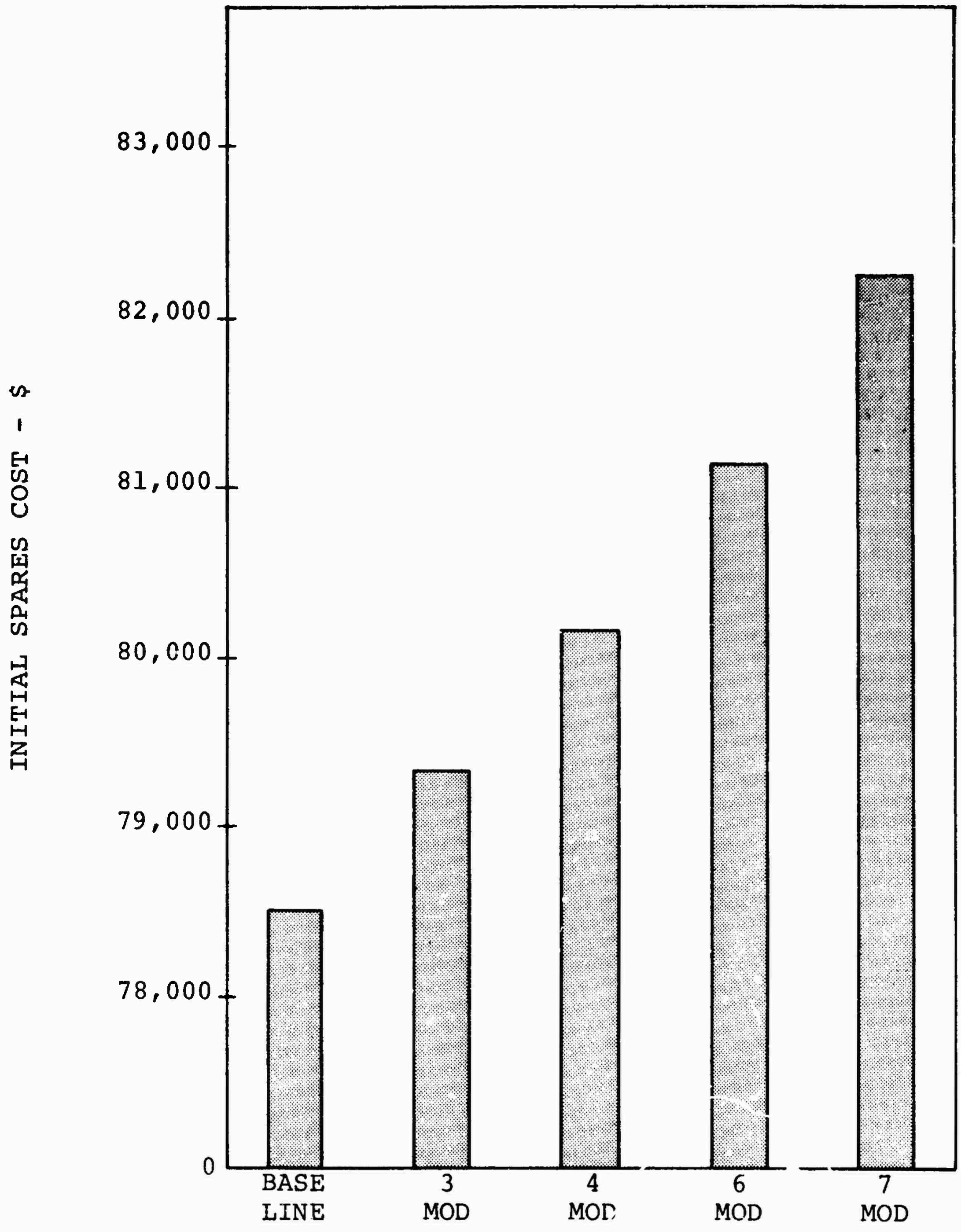

Figure 49. Initial Spares Cost, Modularized and Baseline CH-54B Transmission.

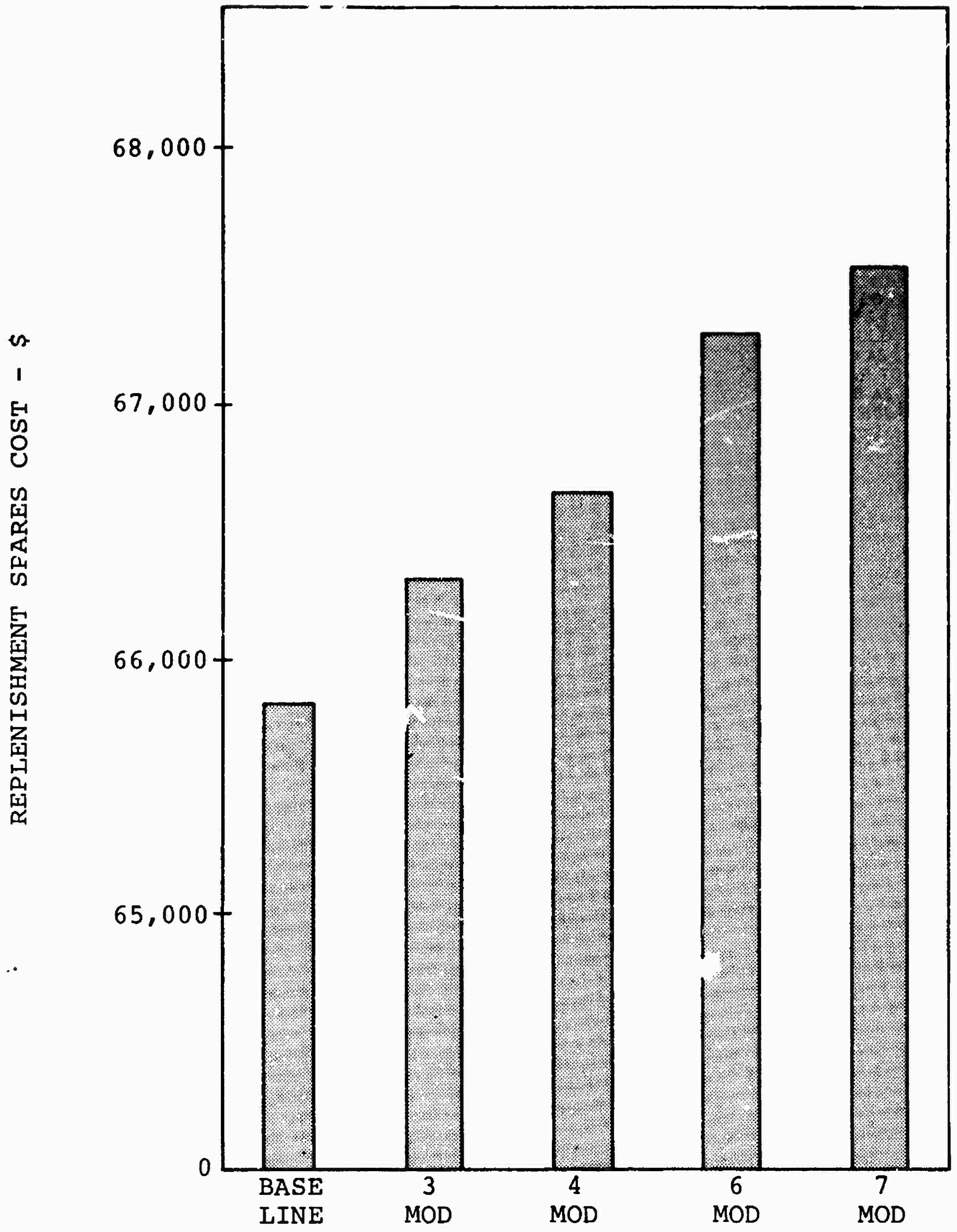

Figure 50. Replenishment Spares Cost, CH-54B Transmission.

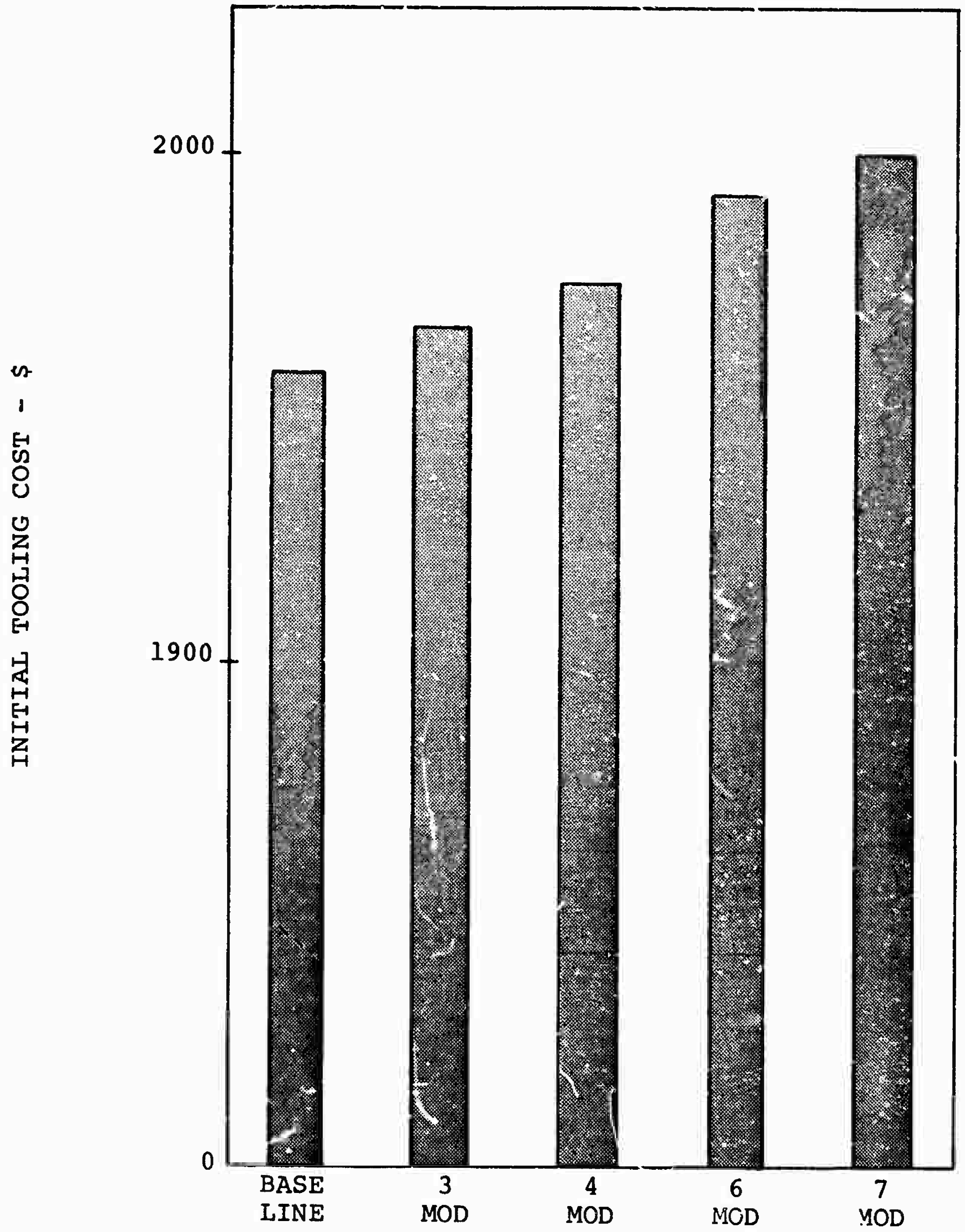

Figure 51. Initial Tooling Cost, Modularized and Baseline CH-54B Transmission.

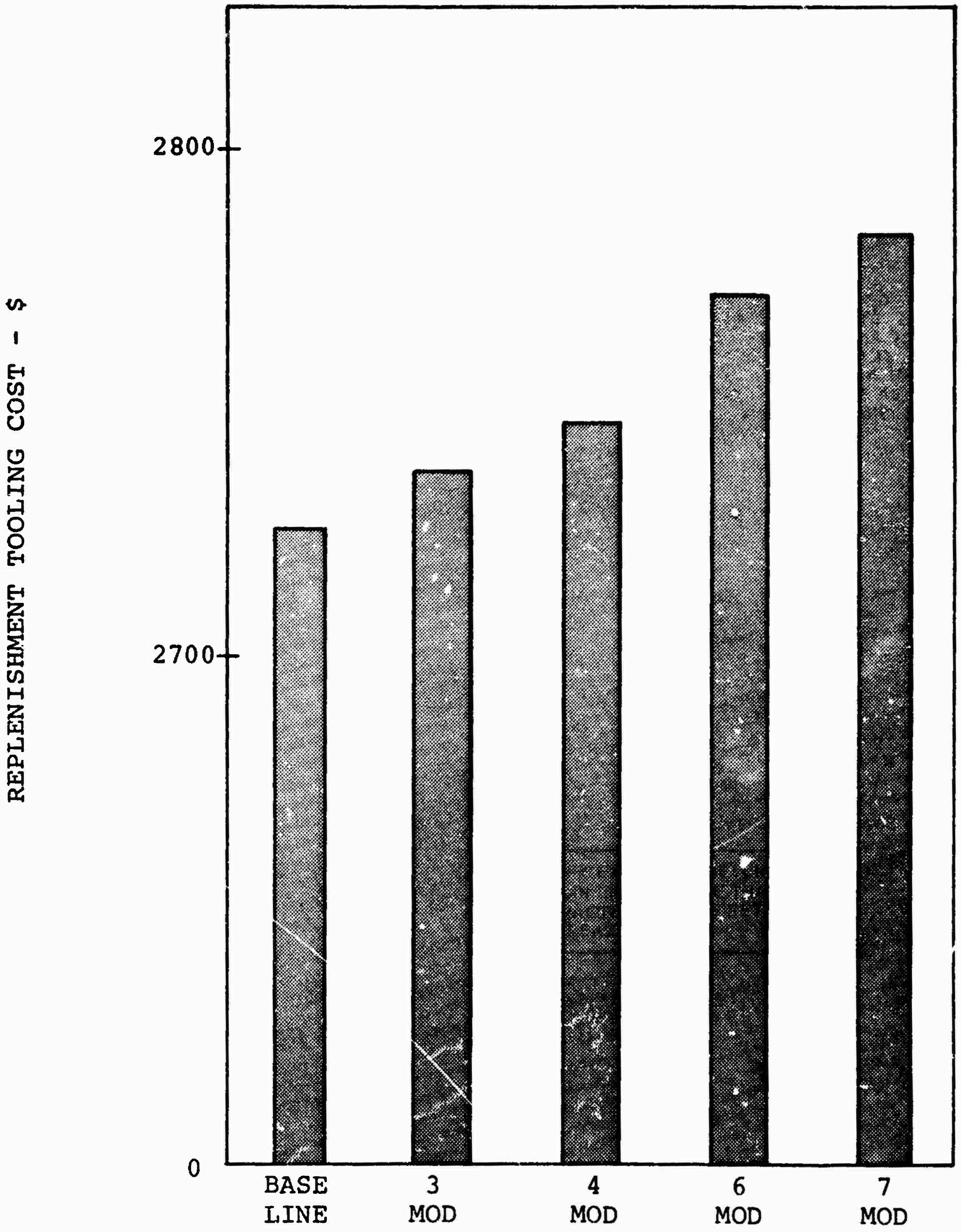

Figure 52. Replenishment Tooling Cost, Modularized and Baseline CH-54B Transmission.

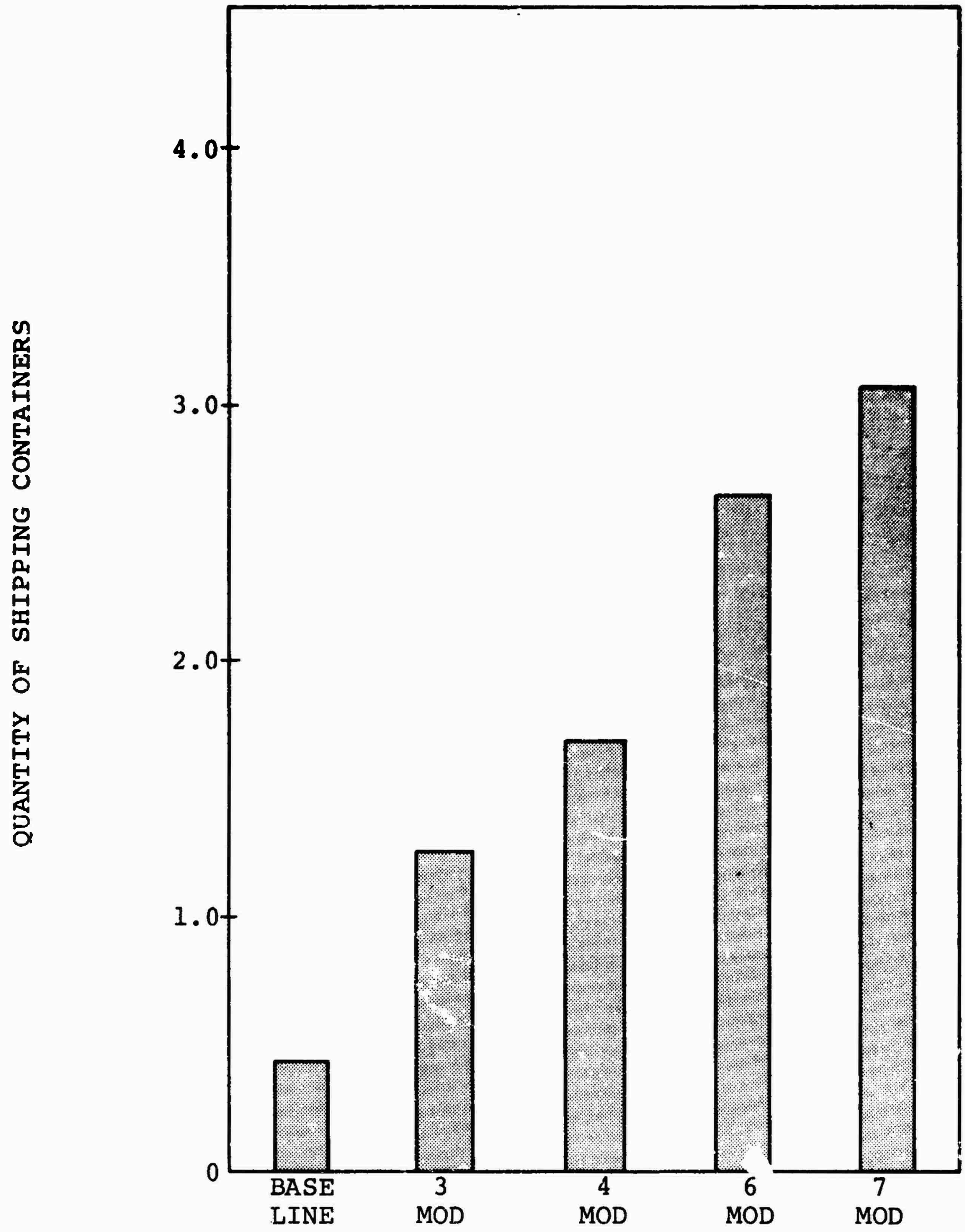

Figure 53. Required Quantity of Shipping Containers Modularized and Baseline CH-54B Transmission.

modularization.

The overall result is a reduction of shipping cost at each maintenance level, as shown in Figure 54.

CALCULATED TRANSMISSION RELIABILITY/MAINTAINABILITY FACTORS

Transmission Frequency of Maintenance Action Results

Overall modularized transmission unscheduled maintenance frequency is the sum of the unscheduled maintenance frequency of each module and is shown in Figure 55. As the degree of modularization increases, unscheduled maintenance frequency increases. This is caused by the additional unscheduled removals of modules from over temperature or overtorque of the transmission in which all modules must be removed.

Transmission mean time between unscheduled removal (MTBUR) for overhaul is found by summing the reciprocals of the individual module mean time between unscheduled removals. As the degree of modularization increases, MTBUR decreases, which in effect means that more modules are removed. When comparing MTBUR between modular and baseline designs, the size of the component being removed must be considered. For example, almost twice as many modules of the seven-module design are removed compared with the baseline transmission. The average module weight of the seven-module design is roughly one-seventh of the baseline, and the module requires less time to remove and install. In terms of total work done, then, the modularized transmission requires less work even though more are removed. The MTBUR is shown in Figure 56.

The aircraft down-hours per flight-hour factor due to transmission malfunctions is calculated from unscheduled maintenance frequency and mean elapsed time to repair for the individual modules. With the modularized transmission designs, the down-hours per flight-hour are reduced from the baseline value. The three-module version has the lowest down-hours per flight-hour as shown in Figure 57.

Transmission Maintenance Man-Hour Results

The transmission mean elapsed time to repair is the transmission down-hours per flight-hour divided by the sum of the maintenance frequencies of the modules. Mean elapsed time to repair is a minimum with the six-module version, but is nearly equal for all modularized designs, as shown in Figure 58.

An important factor in calculating total transmission maintenance cost is mean MMH per flight-hour, which is used to calculate the labor costs portion of transmission maintenance cost. To calculate this factor, it is necessary to know the functions of the maintenance personnel at the three levels of

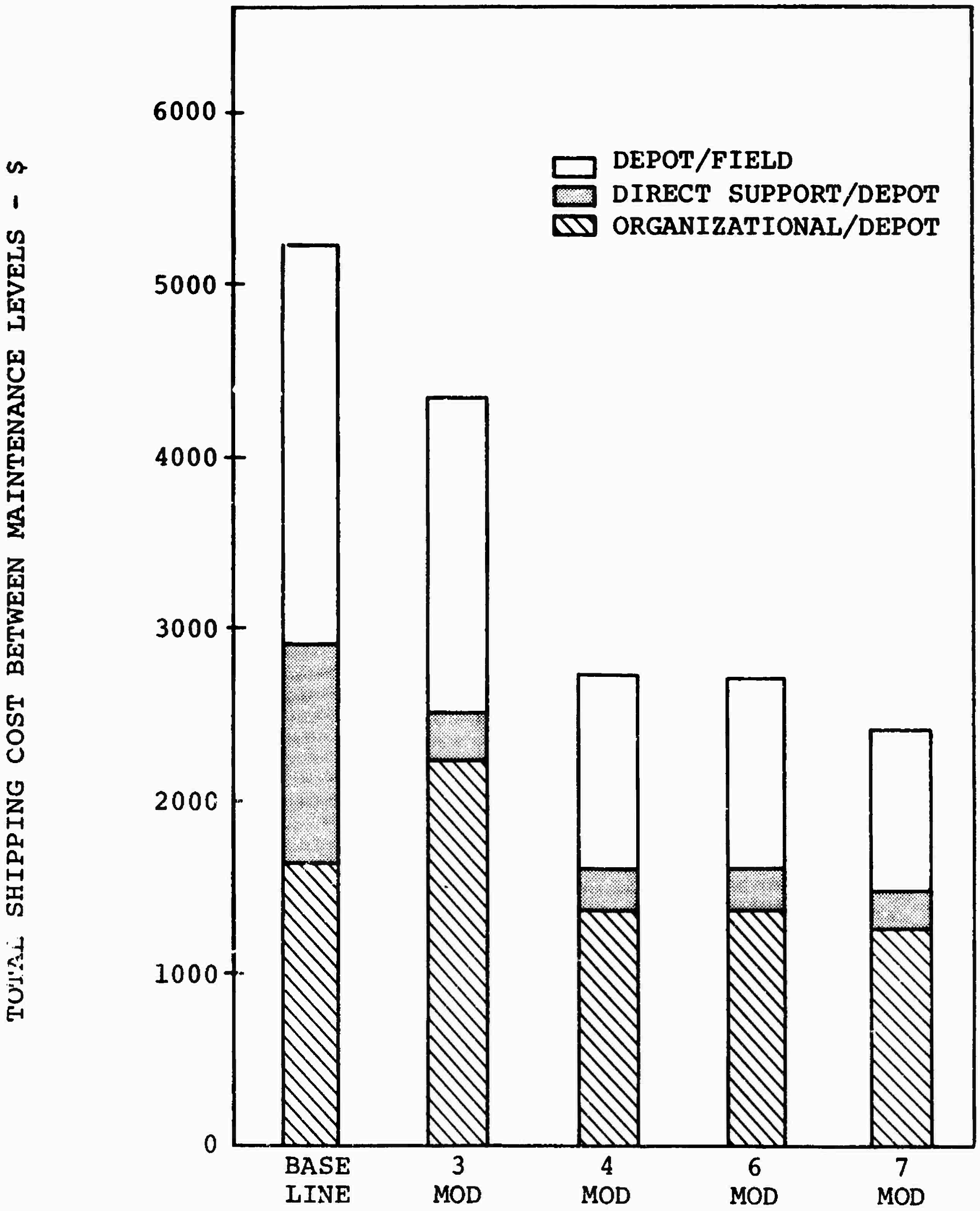

Figure 54. Total Life-Cycle Shipping Cost, Modularized and Baseline CH-54B Transmission.

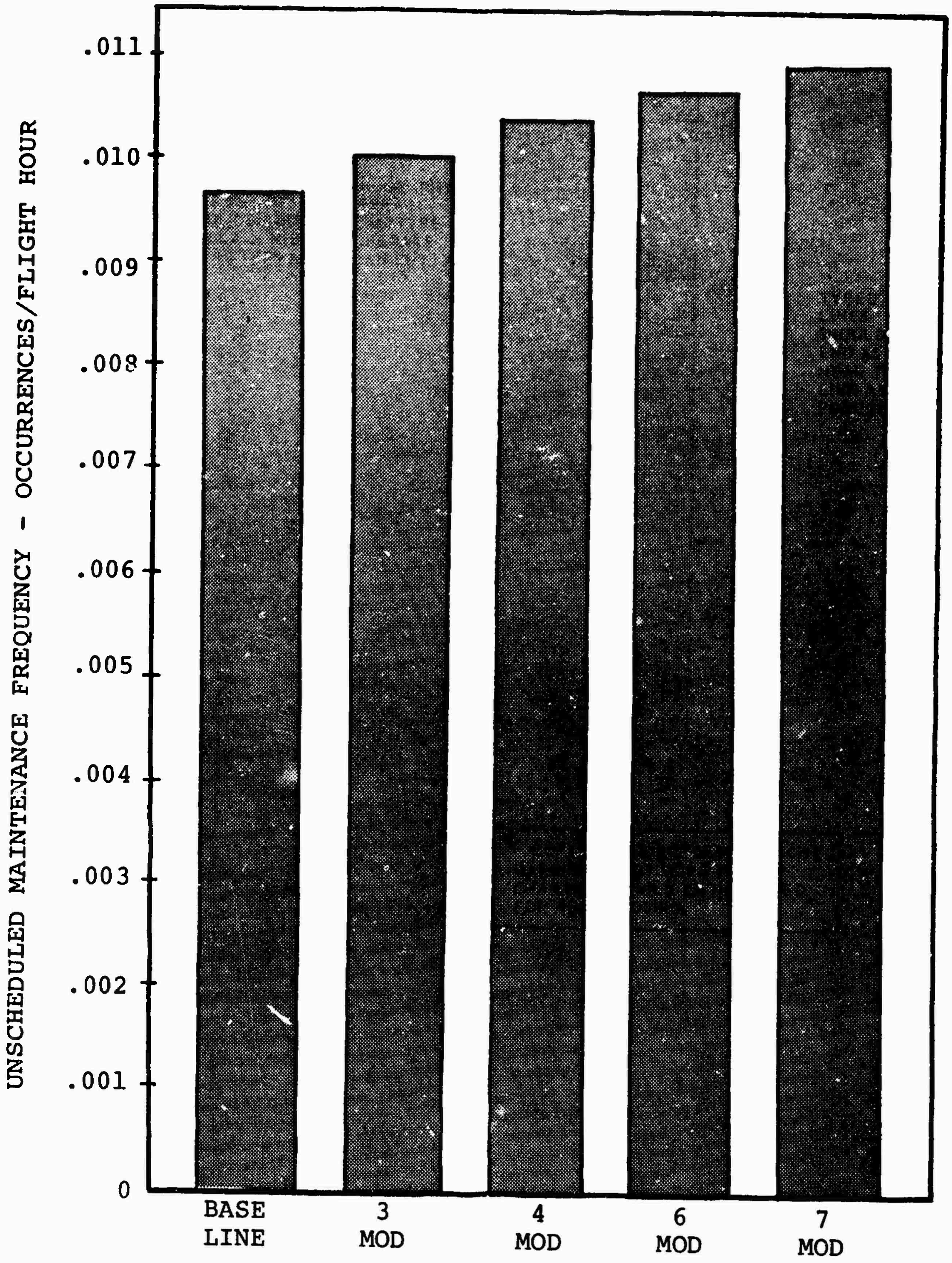

Figure 55. Unscheduled Maintenance Frequency, Modularized and Baseline CH-54B Transmission.

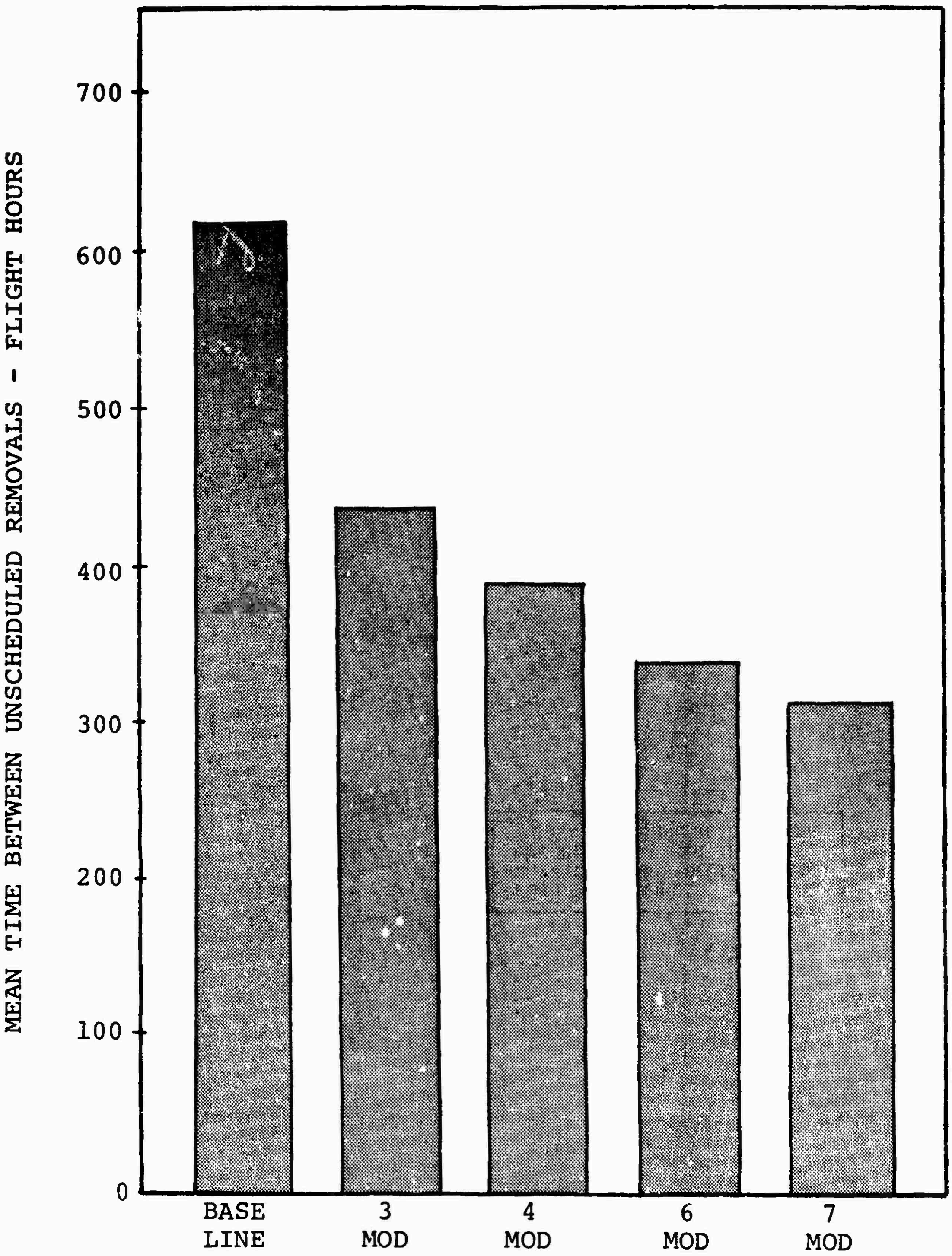

Figure 56. Mean Time Between Unscheduled Removals, Modularized and Baseline CH-54B Transmission.

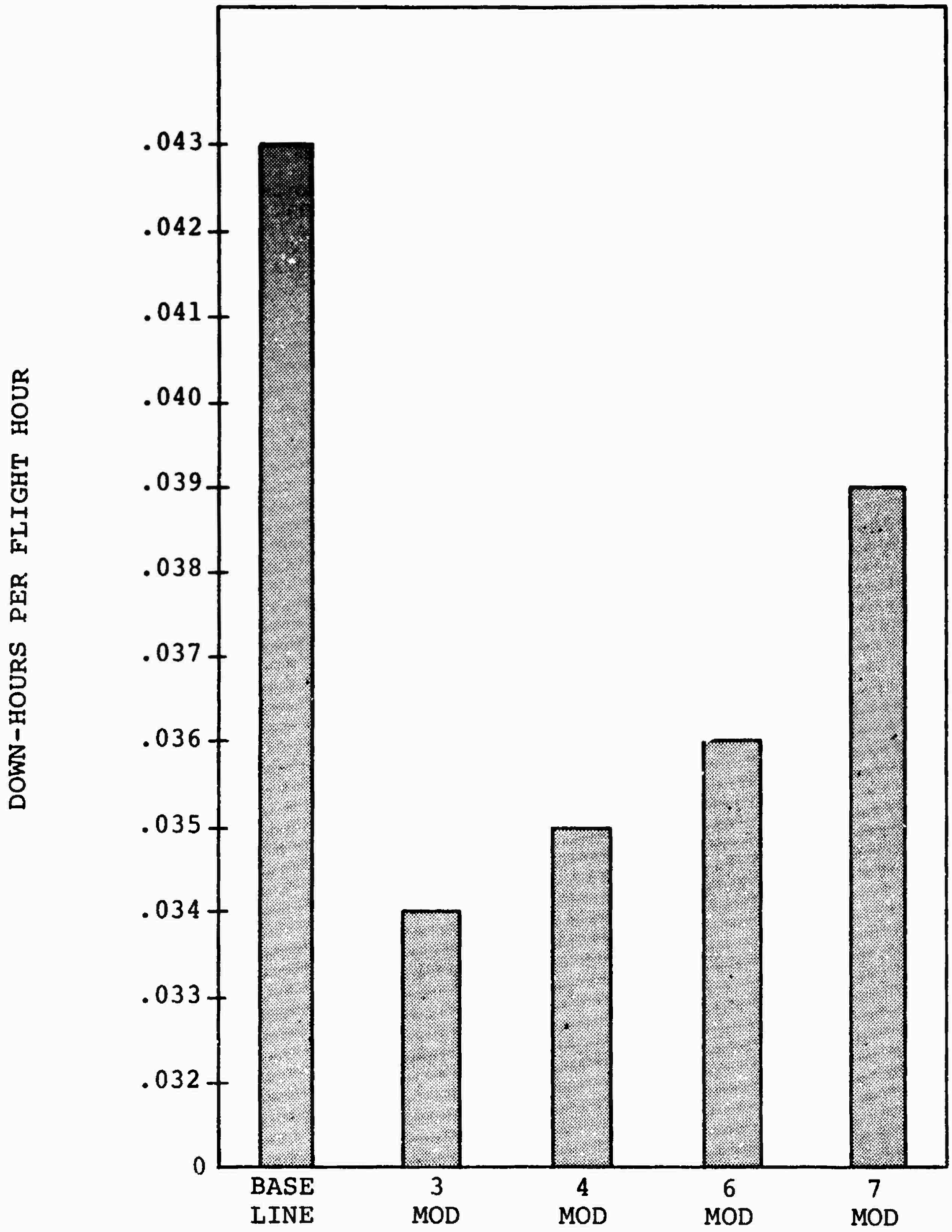

Figure 57. Down-Hours Due to Transmission Malfunction per Flight-Hour, Modularized and Baseline CH-54B Transmission.

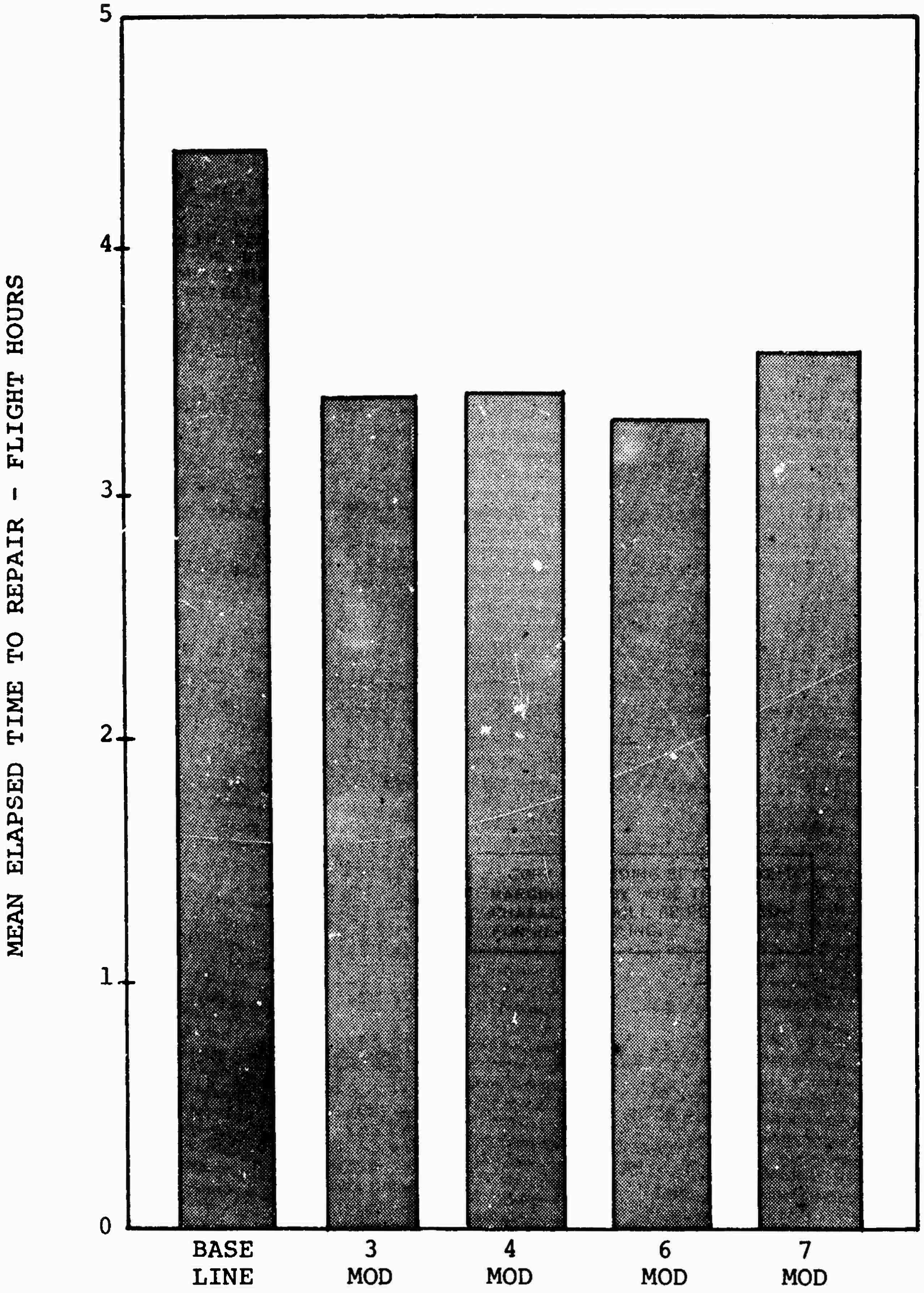

Figure 58. Mean Elapsed Time To Repair, Modularized and Baseline CH-54B Transmission.

maintenance. The maintenance duties performed at the organizational level include:

(1) Unscheduled inspection on the aircraft of transmission malfunctions.

(2) Repair of transmission components on the aircraft.

(3) Scheduled or unscheduled removal of modules.

(4) Requisition of modules.

(5) Scheduled or unscheduled installation of modules.

(6) Unscheduled inspection of removed modules.

(7) Scrap of removed modules.

(8) Scheduled daily transmission inspection.

(9) Scheduled 25-hour intermediate transmission inspection.

At the organizational maintenance level, modules that have been removed are not repaired, but are shipped to direct support or depot. At the direct support maintenance level, the following maintenance duties are performed:

(1) Unscheduled inspection of removed modules.

(2) Repair of removed modules.

(3) Scrap of removed modules.

(4) Repair of transmission components on the aircraft.

(5) Scheduled 100-hour periodic transmission inspection.

The assumption is that the direct support maintenance level does not remove or install modules, does not requisition modules, and does not perform scheduled daily or intermediate inspections. The direct support level repairs removed modules, aids in repair of transmission components on the aircraft, and performs scheduled 100-hour transmission inspections. At the depot, the following maintenance actions are performed:

(1) Inspection of modules received.

(2) Scrap of modules received.

(3) Repair of modules received.

Most helicopter transmission maintenance is performed at the depot level, since this level performs the more difficult maintenance tasks. Calculation of the MMH per flight hour at each maintenance level is accomplished with transmission module disposition, frequency of maintenance action data, and computation using equations 16, 18, and 20 of Appendix II. For the various modular designs, MMH per flight hour are relatively constant at organization and direct support. There is, however, a marked decrease in MMH per flight hour at depot with increased degrees of modularization. The results are shown in Figure 59, where it can be seen that transmission depot MMH for the seven-module transmission have been reduced to approximately one-third of the baseline CH-54B value.

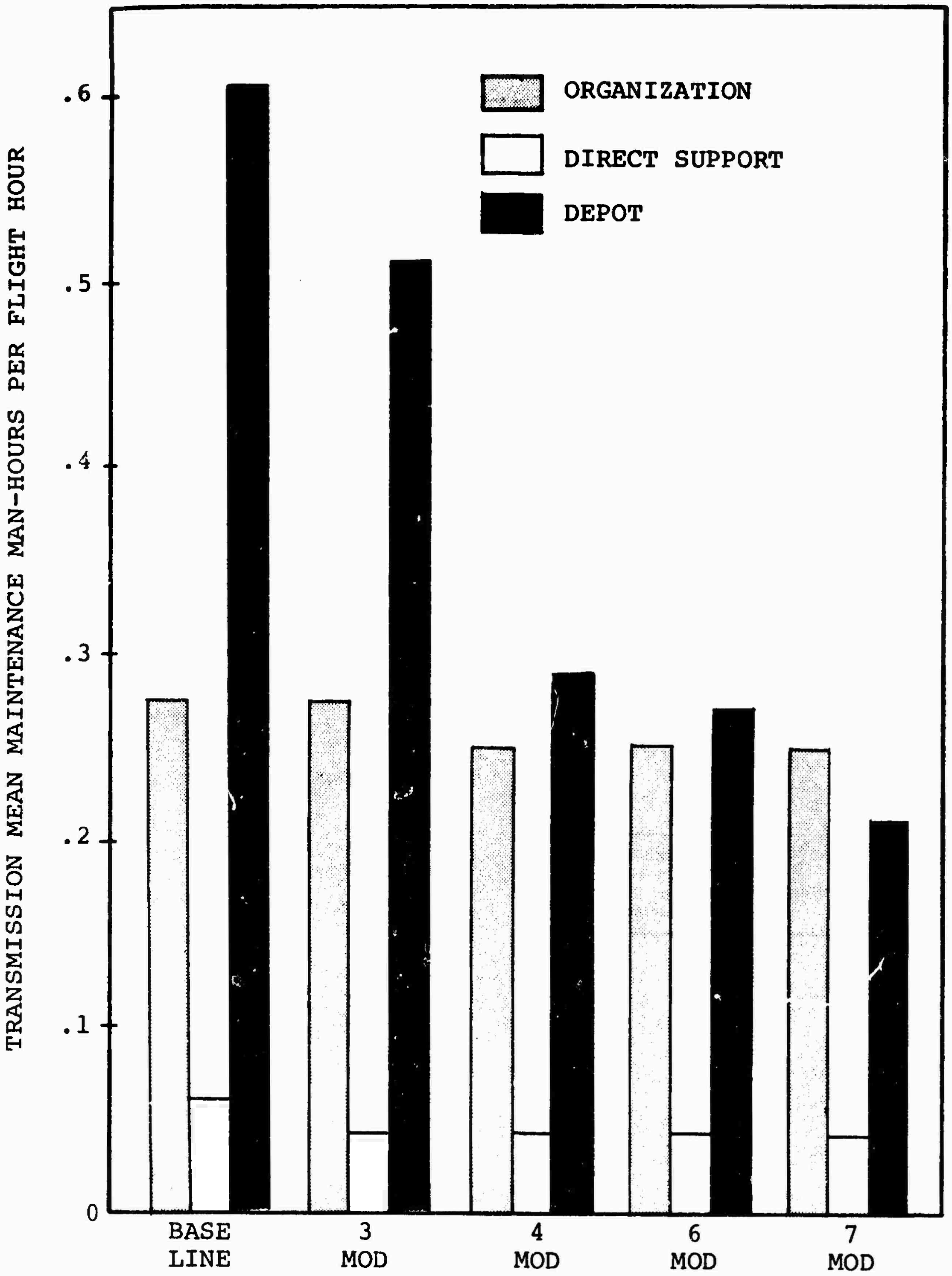

Figure 59. Transmission Maintenance Man-Hours per Flight Hour, Modularized and Baseline CH-54B Transmission.

TRANSMISSION MAINTENANCE COSTS

Total transmission maintenance cost is the chief indicator of the cost effectiveness of helicopter transmission modularization. For helicopter transmission modularization to be economical, savings in transmission maintenance costs must be large enough to offset increased acquisition costs. In this and the following sections it will be shown that helicopter transmission modularization is indeed economically effective and can lead to dramatic savings not only in transmission maintenance costs, but also in overall life cycle helicopter costs.

Total transmission maintenance cost consists of three components: labor, materials, and shipping. The percentage of labor, materials, and shipping is essentailly constant for the baseline or modularized designs for total maintenance and also at each maintenance level. Figure 60 illustrates the makeup of transmission maintenance cost with respect to these components.

Using equation 26 of Appendix II, the total transmission maintenance cost is calculated for the modular designs. Although percentages of labor, materials, and shipping are essentially constant, the total transmission maintenance costs in dollars per life cycle are remarkably reduced as shown in Figure 61. Note the dramatic reduction of maintenance cost with modularization, which completely overshadows any increases in recurring and nonrecurring acquisition.

Breakdown of maintenance costs by maintenance levels, shown in Figures 62 and 63, indicates that the cost reductions occur mainly at the depot maintenance level. In contrast with Figure 62 of the baseline transmission, the chart of Figure 63 shows the breakdown of transmission maintenance costs for the four-module configuration. Notice that depot maintenance accounts for much less of the total maintenance costs. This change is due almost entirely to reductions in depot labor and material costs as revealed by examination of Tables XXXIX to XLI, which show labor, materials, and shipping costs at the three maintenance levels.

Whereas in the baseline version a failure means shipment of the entire transmission to depot for overhaul, in the modularized version only the module in which the failure occurred is sent to depot for overhaul. This decreases considerably the amount of man-hours and material needed to repair the failure.

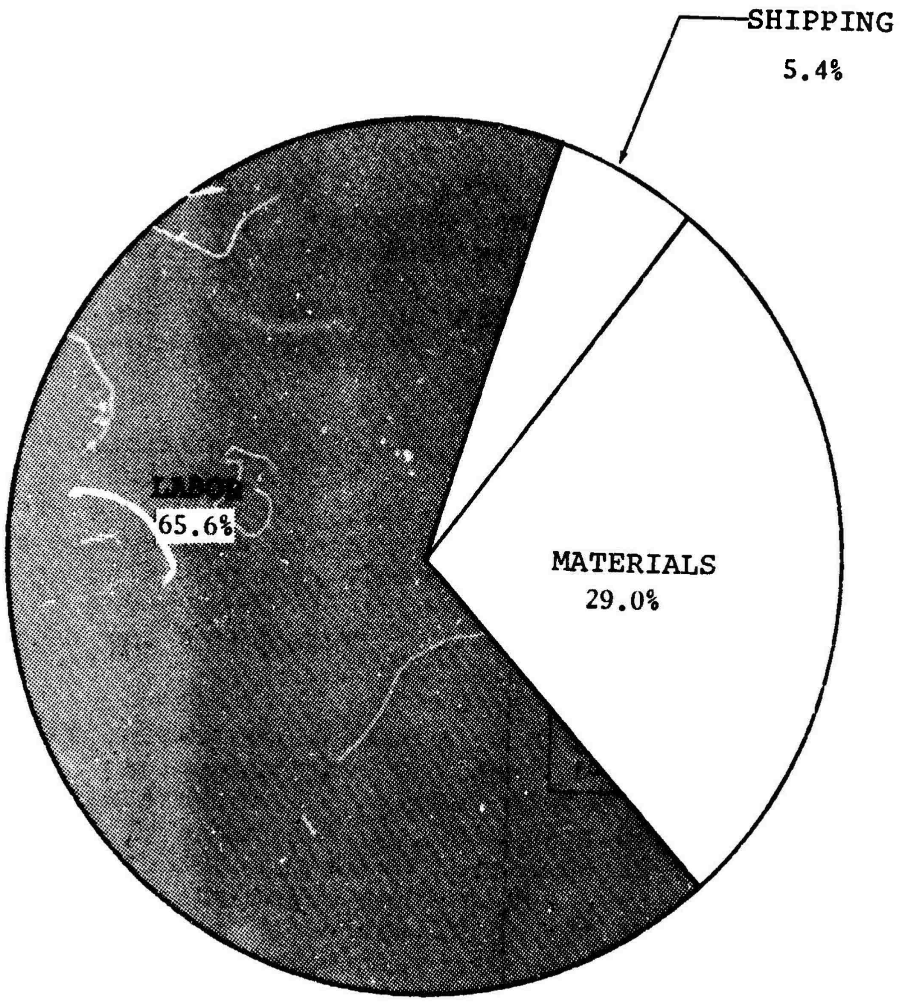

Figure 60. Typical Labor, Material, and Shipping Contributions to Total Maintenance Cost.

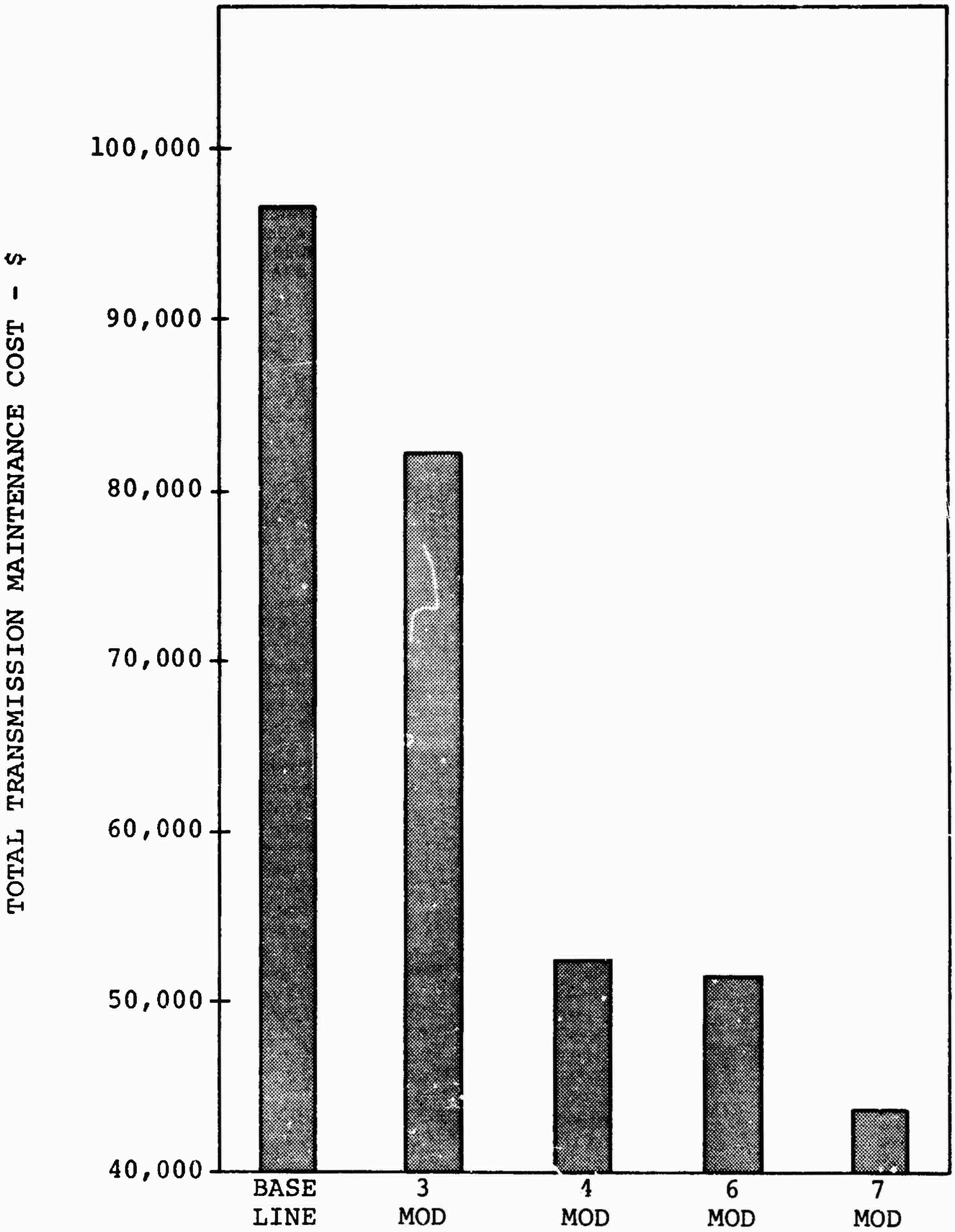

Figure 61. Total Transmission Maintenance Cost, Modularized and Baseline CH-54B Transmission.

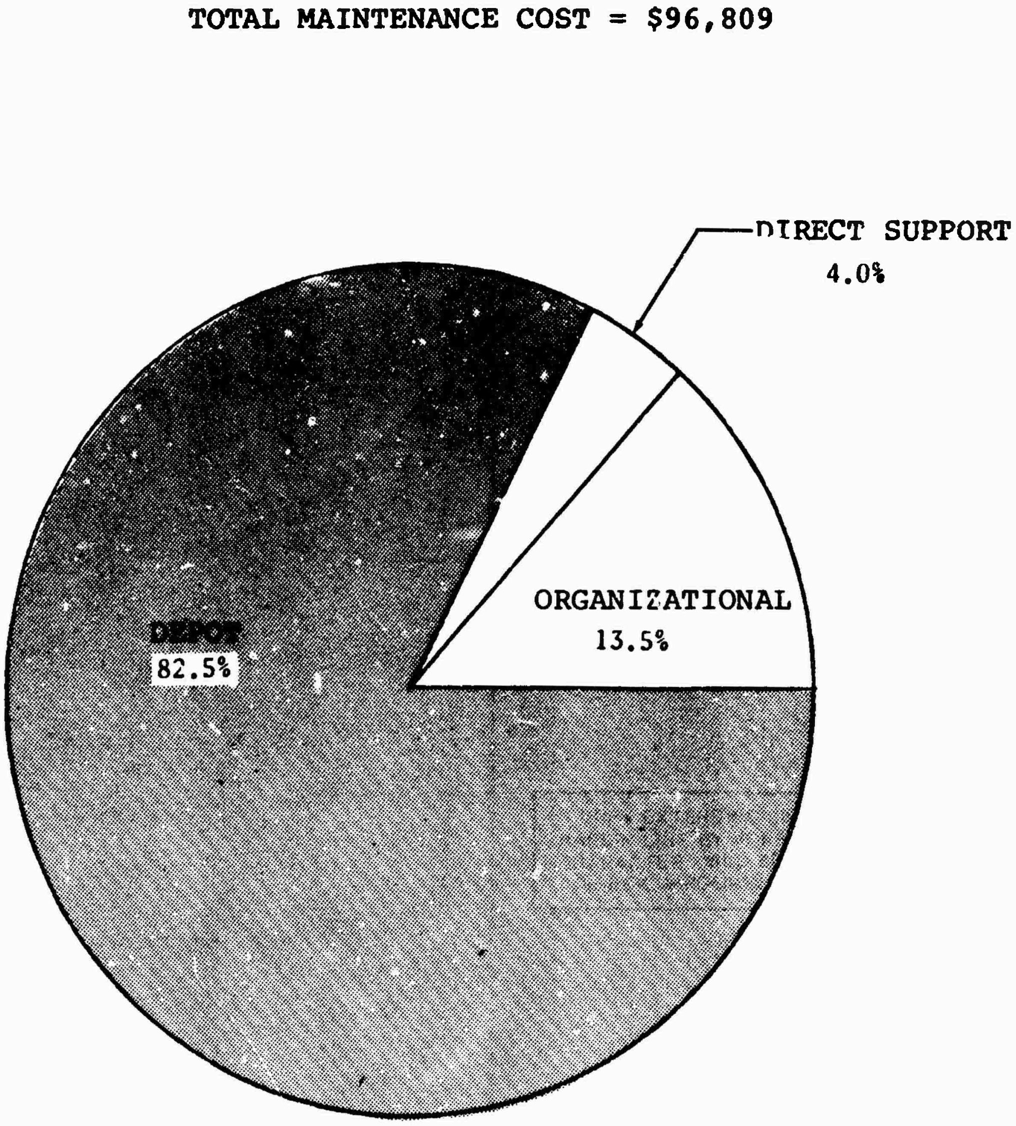

Figure 62. Maintenance Level Cost Distribution, Baseline CH-54B Transmission.

TOTAL MAINTENANCE COST = $52,397

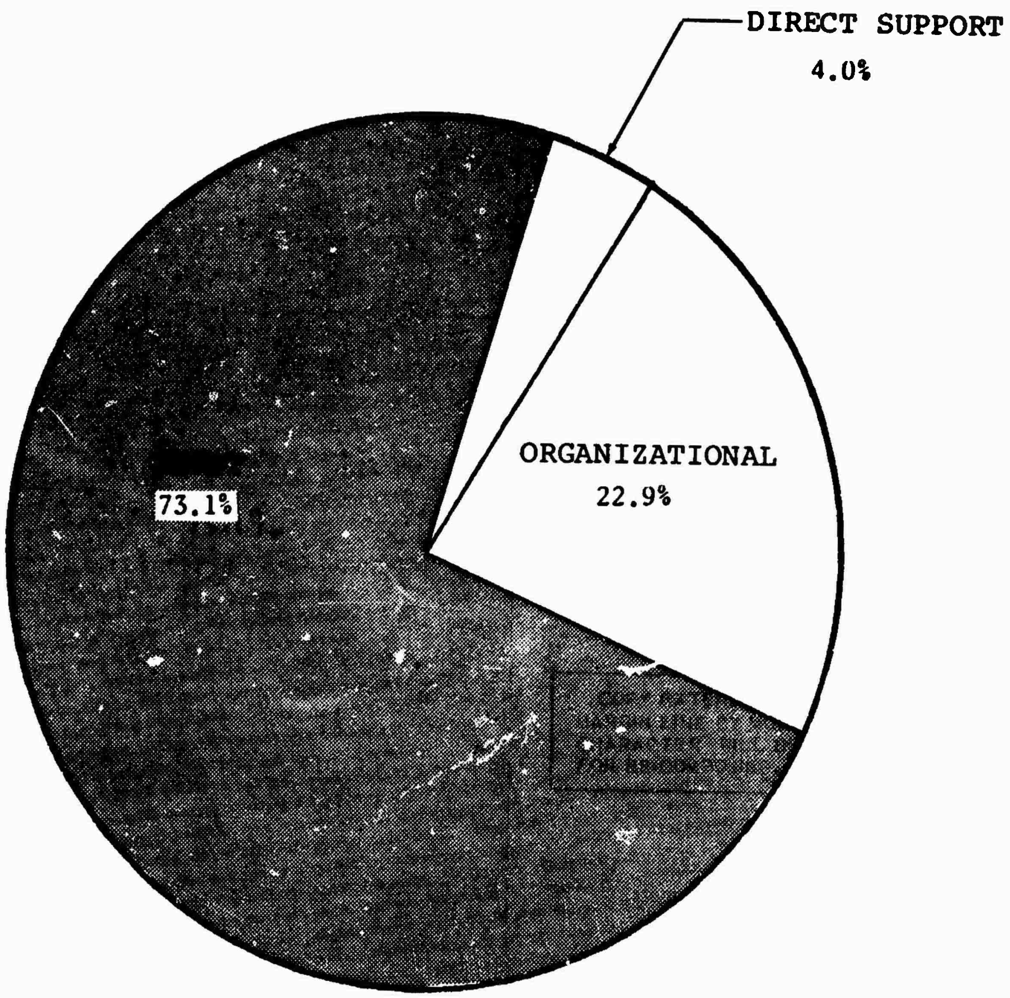

Figure 63. Maintenance Level Cost Distribution, Four-Module CH-54B Transmission.

TABLE XXXIX. SUMMARY OF LABOR COST COMPONENTS, MODULARIZED AND BASELINE CH-54B TRANSMISSION

Design	Cost of Transmission Labor ($)		
	Organizational	Direct Support	Depot
Baseline	11,004	2,422	50,065
3 Module	10,905	1,572	41,760
4 Module	10,167	1,580	23,800
6 Module	10,258	1,644	22,874
7 Module	10,737	1,647	17,166

TABLE XL. SUMMARY OF MATERIAL COST COMPONENTS, MODULARIZED AND BASELINE CH-54B TRANSMISSION

Design	Cost of Transmission Material ($)		
	Organizational	Direct Support	Depot
Baseline	376	223	27,491
3 Module	378	143	23,076
4 Module	445	278	13,378
6 Module	446	297	13,259
7 Module	471	303	10,983

For example, assume there is a failure in the input pinion stack bearings of the baseline transmission. The entire transmission would be sent to depot for a complete overhaul. Not only would the failed stack bearings be replaced, but most of the other bearings within the entire transmission would also be replaced. This is done because of the possibility of contamination with metal particles from the primary failure and also as a matter of course if the slightest signs of wear are present. In addition the entire transmission would be completely disassembled and each part would be magnetic particle inspected for cracks and visually inspected for indications of wear or damage. Many self-locking nuts and other small hardware within the transmission are replaced because they are damaged during removal or installation. This entire process requires an average of 377 man-hours at depot.

On the other hand assume these same input pinion stack bearings failed on the seven-module configuration. Instead of removing the entire transmission, field maintenance personnel would remove only the input module for overhaul at depot. Only the bearings within that module would have to be replaced, since contaminating metal particles would be isolated within the input module. Magnetic particle inspection would be performed only on that module, and small hardware would be replaced only on that module.

This entire procedure would require only 36.3 man-hours at depot, less than one-tenth the man-hours required for the baseline transmission. Similar labor and material savings can be shown with any other failure within the transmission.

These total transmission maintenance savings with modularization far outweigh all cost increases incurred as a result of modularization. The following sections discuss in detail the effect of modularization with respect to both cost and performance over the life of the aircraft.

TABLE XLI. SUMMARY OF SHIPPING COST COMPONENTS, MODULARIZED AND BASELINE CH-54B TRANSMISSION

Design	Cost of Transmission Shipping - $		
	Organizational	Direct Support	Depot
Baseline	1637	1269	2321
3 Module	2273	266	1834
4 Module	1393	215	1140
6 Module	1390	216	1134
7 Module	1276	205	976

AIRCRAFT COST EFFECTIVENESS

This chapter explains the quantitative data calculated from the mathematical model which are used to compare modularized transmissions. The effects of transmission modularization on aircraft mission capability, aircraft mission effectiveness, aircraft life cycle cost, aircraft cost effectiveness, and fleet cost are discussed and presented.

Aircraft Mission Capability

Aircraft mission capability, which is a measure of the performance of the aircraft, affects transmission modularization only by changes in weight and efficiency of the transmission. For cargo transport aircraft, such as the CH-54B, performance is measured by the aircraft's mission productivity in ton knots expressed as the product of mission payload and mission block speed. Multiplying the partial derivatives of mission capability with respect to weight and efficiency by the changes in weight and efficiency and adding them to the mission capability of the baseline gives the mission capability for the modularized transmission configurations. The equation below is used for this calculation (see Appendix II).

$$AMCAP = AMCAPB + DCAPWT\ (\Delta WT) + DCAPEFF\ (\Delta EFF)$$

where: AMCAP = Aircraft mission capability of modularized configuration

AMCAPB = Aircraft mission capability of baseline configuration

DCAPWT = Partial derivative of aircraft mission capability with respect to weight $\frac{\partial AMCAP}{\partial WT}$

ΔWT = change in weight of modularized transmission ($WT_{mod} - WT_{baseline}$)

DCAPEFF = Partial derivative of aircraft mission capability with respect to efficiency $\frac{\partial AMCAP}{\partial EFF}$

ΔEFF = Change in efficiency of modularized transmission from baseline transmission ($EFF_{mod} - EFF_{baseline}$)

The derivatives used in the above equation are calculated by simulation of the CH-54B helicopter in a probabalistic environment.

A summary of aircraft mission capability for baseline and modularized configurations appears in Table XLII below.

Although aircraft mission capability decreases with modularization, the effect is minor. In the worst case, of the seven-module configuration, for example, aircraft mission capability decreases by less than one-fourth of one percent from the baseline value.

TABLE XLII. SUMMARY OF AIRCRAFT MISSION CAPABILITY

Design	Trans. WT (lb)	Trans. EFF. (%)	Δ WT (lb)	Δ EFF (%)	Mission Capability (ton-kt)
Baseline	3096.00	98.170	0	0	503.39
3 Module	3103.00	98.160	7.00	-.010	503.23
4 Module	3113.66	98.136	17.66	-.034	502.99
6 Module	3139.82	98.098	43.83	-.072	502.41
7 Module	3151.66	98.085	55.66	-.085	502.15

Aircraft Mission Effectiveness

Aircraft mission effectiveness is defined as aircraft mission capability degraded by the aircraft's unavailability to fly a mission on demand, and by system failure aborting a mission after it is initiated. Aircraft mission effectiveness then is found by:

AMEFF = CAP X RELIA X AVAIL

Although transmission modularization affects reliability and availability, the change in these numbers is negligible. For aircraft mission availability which is primarily determined by aircraft down-hours per flight-hour, the transmission contributes approximately .04 down-hour per flight-hour out of the aircraft total of 2.30. For aircraft mission reliability, which is primarily determined by aborts per flight-hour, the transmission contributes approximately .0004 aborts per flight-hour out of the aircraft total of .0125. Hence, these factors remain essentailly constant with transmission modularization, availability at .892 and reliability at .9957. Although these effects are small, they account for the fact that the three-module version has the highest mission effectiveness. This is due mainly to the increased aircraft availability which is maximized with the three module design. Table XLIII below lists availability, reliability, aircraft mission capability and aircraft mission effectiveness for the modularized and baseline CH-54B designs.

TABLE XLIII. SUMMARY OF AIRCRAFT MISSION EFFECTIVENESS

Design	Aircraft Availability	Aircraft Reliability	Aircraft Mission Capability (ton-kt)	Aircraft Mission Effectiveness (ton-kt)
Baseline	.8917	.9957	503.39	446.95
3 Module	.8921	.9957	503.23	447.00
4 Module	.8921	.9957	502.99	446.77
6 Module	.8920	.9957	502.41	446.23
7 Module	.8919	.9957	502.15	445.92

Life-Cycle Cost

Life-cycle cost consists of all costs associated with purchase and operation of an aircraft for its life of 15 years. Here life-cycle cost is divided into acquisition costs and operating costs, and the effects of modularization on each are discussed separately.

Acquisition cost factors affected by transmission modularization include transmission flyaway cost, cost of initial transmission spares, cost of initial transmission GSE tooling and cost of additional training for Army maintenance personnel. The main transmission impacts the flyaway, initial spares and initial tooling. These contributions are given in Table XLIV below.

The changes between the baseline and modularized designs in the above factors which influence aircraft acquisition are summarized in Table XLV. From Table XLV it is seen that the greatest cost increase is incurred in the seven-module design and also that as the degree of modularization increases, aircraft acquisition cost increases.

The change in initial training cost shown in Table XLV consists of a life-cycle training dollars per maintenance man-hour factor which is multiplied by the change in Army maintenance man-hours for the modularized transmission. Modularization actually leads to a training cost savings because of the decrease in man-hours required for maintenance.

TABLE XLIV. SUMMARY OF TRANSMISSION CONTRIBUTION TO AIRCRAFT ACQUISITION COST

Design	Transmission Acquisition Cost ($)	Transmission Initial Spares Cost ($)	Transmission Initial GSE Cost ($)
Baseline	181,501	78,508	7,958
3 Module	182,867	79,345	1,967
4 Module	183,351	80,168	1,975
6 Module	184,223	81,149	1,992
7 Module	184,860	82,413	2,000

TABLE XLV. SUMMARY OF AIRCRAFT ACQUISITION COST

Cost Item	Acquisition Cost ($)				
	Baseline	3 Module	4 Module	6 Module	7 Module
Flyaway Cost	0	1366	1850	2722	3359
Init. Spares	0	837	1660	2641	3905
Init. GSE	0	9	17	34	42
Init. Tr.	0	-100	-175	-159	-109
Amort. Acq.	0	0	-14	-39	-52
A/C Acq.	2,826,000	2,828,112	2,829,338	2,831,199	2,833,145

Operating cost contribution to the aircraft's life-cycle cost are based on a 15-year service life and 280 flight hours per year utilization. The operating cost for fuel, maintenance, replenishment spares, flight crew, replacement GSE and personnel training is estimated at $491,200 annually and $7,368,000 over the 15-year service life of the baseline.

Table XLVI shows the contributions of the transmission to CH-54B operating costs.

TABLE XLVI. TRANSMISSION CONTRIBUTIONS TO AIRCRAFT OPERATING COST

Design	Maintenance Cost ($)	Replenishment Spares Cost ($)	Replacement GSE Tooling Cost ($)	Fuel Cost ($)
Baseline	96,809	65,852	2,726	253,623
3 Module	82,207	66,387	2,738	253,644
4 Module	52,397	66,698	2,749	253,693
6 Module	51,519	67,319	2,772	253,777
7 Module	43,757	67,568	2,784	253,807

Table XLVII summarizes aircraft operating costs with respect to the changes resulting from transmission modularization.

TABLE XLVII. SUMMARY OF AIRCRAFT OPERATING COST

Cost Item	Changes In Operating Cost ($) With Respect To Baseline				
	Baseline	3 Module	4 Module	6 Module	7 Module
Maintenance	0	-14,602	-44,412	-45,290	-53,052
Replen. Sp.	0	535	846	1467	1716
Repl. GSE	0	12	23	46	58
Fuel Cost	0	21	70	154	184
Rep. Train.	0	-391	-695	-630	-430
Life Cyc Op	7,363,000	7,353,575	7,323,832	7,323,747	7,316,476

Replacement training cost is based on an annual turn-over rate of .265 corresponding to an average maintenance enlisted personnel service tour of three years, nine months.

The total life-cycle cost of the aircraft, which consists of the sum of the aircraft acquisition cost and the life-cycle operating cost, is shown in Figure 64 for both modularized and baseline configurations.

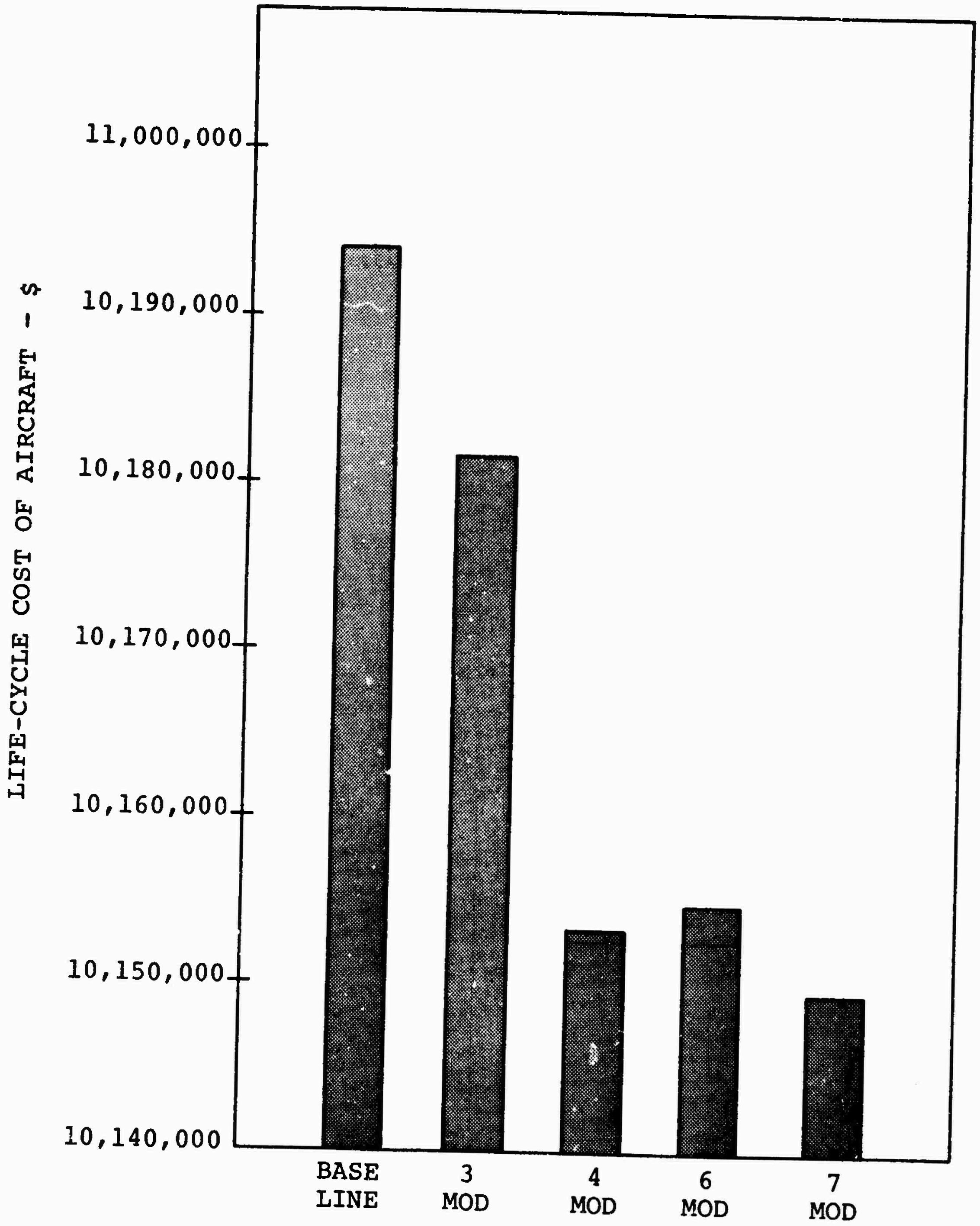

Figure 64. Life-Cycle Cost of Aircraft, Modularized and Baseline CH-54B.

Aircraft Cost Effectiveness

Aircraft cost effectiveness is defined as aircraft mission effectiveness per life cycle megadollar, and is found by dividing aircraft mission effectiveness by the life cycle cost of the aircraft in megadollars. Aircraft cost effectiveness combines performance and cost and is a useful means in evaluating the overall effect of transmission modularization on the CH-54B.

The results illustrated in Figure 65 show that the four-module configuration is the most cost effective with an aircraft cost effectiveness of 44.004 ton-knots/megadollar. It is also worth noting that every modularized configuration has a better cost effectiveness than the baseline configuration.

Fleet Effective Cost

Fleet effective cost is an equivalent measure of aircraft cost effectiveness on the fleet level. It is defined as the cost in megadollars to operate a fleet of aircraft for the life-cycle of 15 years. Ordinarily, fleet effective cost is found by simply multiplying the life-cycle cost of the aircraft by the size of the fleet, as for the baseline design. However, when comparing fleet effective costs, aircraft of equal performance capabilities must be compared. Since transmission modularization does affect aircraft performance capability, the fleet size has been adjusted for the same mission effectiveness. When comparing fleet effective costs then, aircraft of exactly the same performance capabilities are compared. The fleet effective costs for both modularized and baseline configurations are summarized in Figure 66.

Again, the four-module configuration is the best, leading to a savings of over $2.2 million over the baseline configuration. In addition, all modular configurations again are superior to the baseline.

FLEET SIZE

The variation of output parameters with fleet size was investigated. The major effect of fleet size is on recurring and nonrecurring acquisition costs. Recurring manufacturing costs are reduced as fleet size increases because manufacturing tooling is amortized over a larger number of parts, machine set-up time is less per part, cost of raw materials decreases with large lots, and the manufacturing techniques become more familiar to the factory worker. Nonrecurring costs are amortized over the baseline fleet and include all spares as well as the initial transmissions.

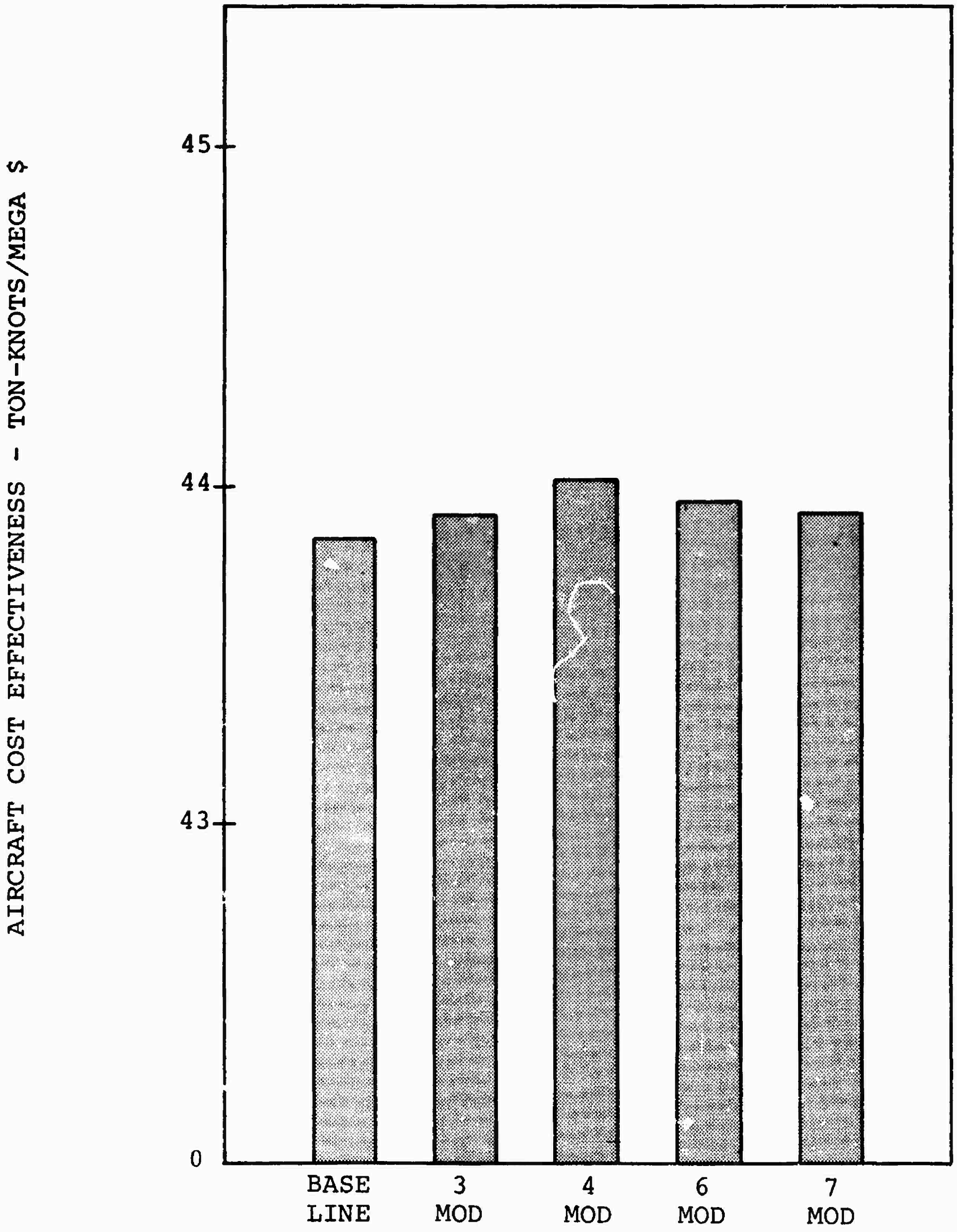

Figure 65. Aircraft Cost Effectiveness, Modularized and Baseline CH-54B.

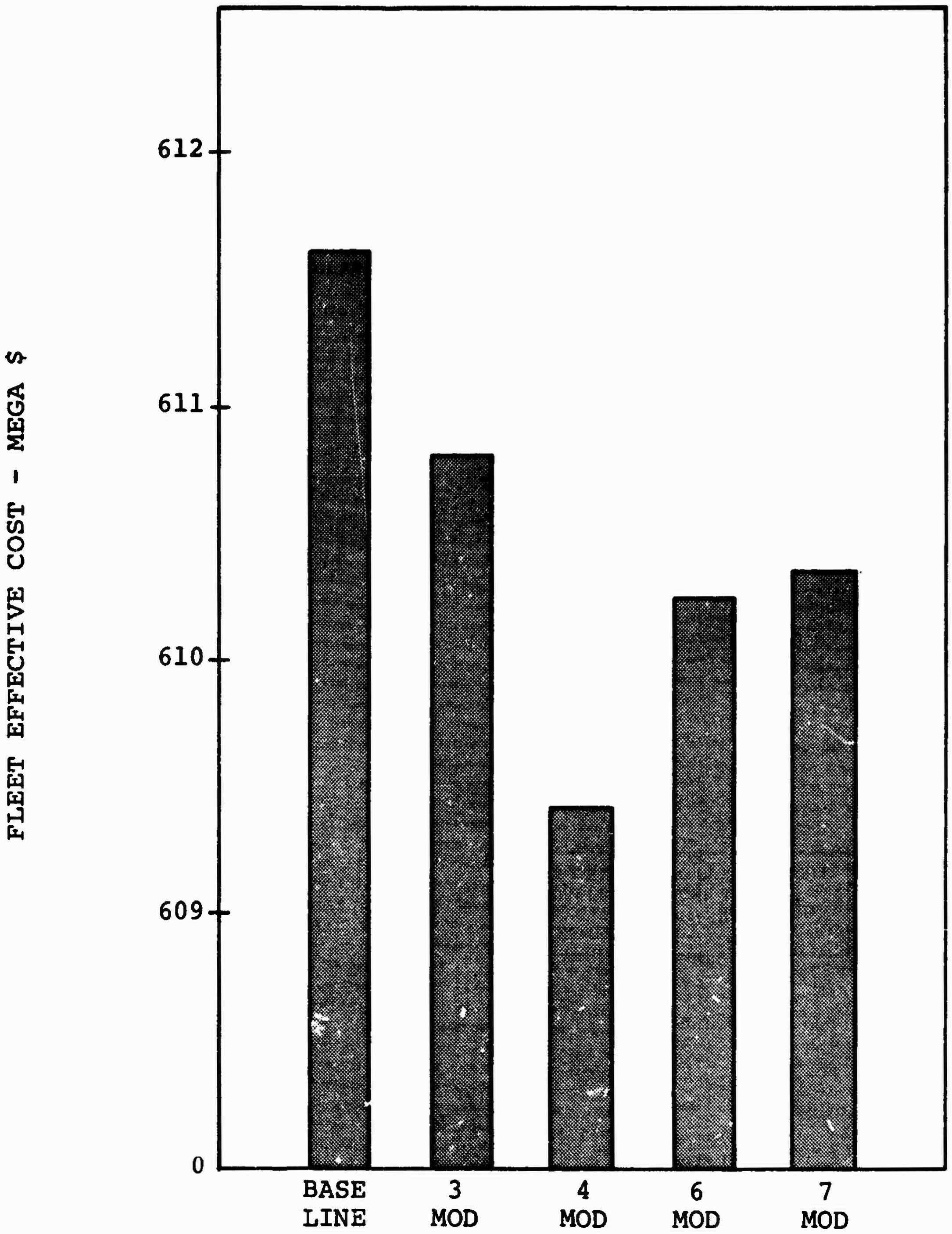

Figure 66. Fleet Effective Cost, Modularized and Baseline CH-54B.

By neglecting the recurring manufacturing cost savings, the size of fleet can be easily varied in the mathematical model and the results studied. Since recurring costs are neglected, the only changes in results are the difference in nonrecurring costs associated with acquisition. Thus transmission acquisition cost, initial spares cost, and replenishment spares cost are all reduced with increased fleet size. These data in turn influence life-cycle cost, aircraft cost effectiveness, and fleet effective cost (performance data do not change). For the fleet size of 60, which has been used in this study, the contribution of nonrecurring costs to aircraft life-cycle cost is $18,483 for the baseline configuration. The contribution of nonrecurring costs to total spares cost is $14,600. These two contributions, which total $33,083, are reduced to zero with infinite fleet size. Therefore the maximum additional cost savings due to fleet size is approximately $33,000 per aircraft per life cycle. For a fleet size of 1000 aircraft, for example, life-cycle costs are reduced by $31,100 over the fleet of 60.

CONCLUSIONS

1. Modularization leads to substantial savings in transmission maintenance costs. These savings occur primarily from depot maintenance level reductions in material and labor.

2. As the transmission degree of modularization is increased, the transmission weight increases and the drive system efficiency decreases by a small amount. For the four module configuration, transmission weight increases by less than seven-tenths of one percent while the efficiency decreases by less than one-tenth of one percent.

3. Modularization leads to small increases in container costs, recurring and non-recurring cost, logistics spares cost and GSE tooling costs. These increases are far outweighed by savings in maintenance. This is illustrated by the fact that aircraft life-cycle costs are lower with transmission modularization than without.

4. Overall aircraft performance is improved by transmission modularization. Fleet effective cost is lower and aircraft cost effectiveness is higher. According to these criteria, the four-module design is superior to both the baseline and the other modularized versions.

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APPENDIX I

CH-54B DIMENSIONS AND PERFORMANCE DATA

The aircraft chosen for study in this program is the U. S. Army CH-54B Tarhe Helicopter. Overall dimensions are contained in Table XLVIII.

TABLE XLVIII. GENERAL DIMENSIONS, CH-54B

Overall Length	88 ft 6.0 in.
Overall Width	21 ft 10.0 in.
Overall Height	25 ft 4.0 in.
Weight (Empty)	19,700 lb

The CH-54B is powered by twin JFTD 12A-5A Pratt & Whitney engines with a takeoff rating of 4800 hp. These engines feature isochronous steady-state governing, transient rotor droop of less than 4%, and rapid recovery to low-power/high-rate descents (see Figure 67). Engine output power is monitored within 2% accuracy by phase displacement torquemeters. With their low vibration environment, these engines have a TBO of approximately 1000 hours. The main transmission of the CH-54B is rated at 7900 hp for 30 minutes.

The main and tail rotors (see Table XLIX) of the CH-54B incorporate several design features which add considerably to the overall performance of the aircraft.

The main rotor, for instance, employs the following innovations:

(1) A new damper positioner to prevent ground roll and reduce rotor head stresses during engagement.

(2) High twist blades to improve hover performance.

(3) A BIM indicator to insure fail-safe blades.

(4) A leading-edge abrasion strip to prolong blade spar life.

(5) A blade pre-track provision which allows blades to be tracked singly before installation on aircraft.

The tail rotor incorporates a viscous damped tail drive shaft support which reduces high-frequency vibrations, increases misalignment allowances and reduces stress on contingent support structures. It also uses self-centering pitch control

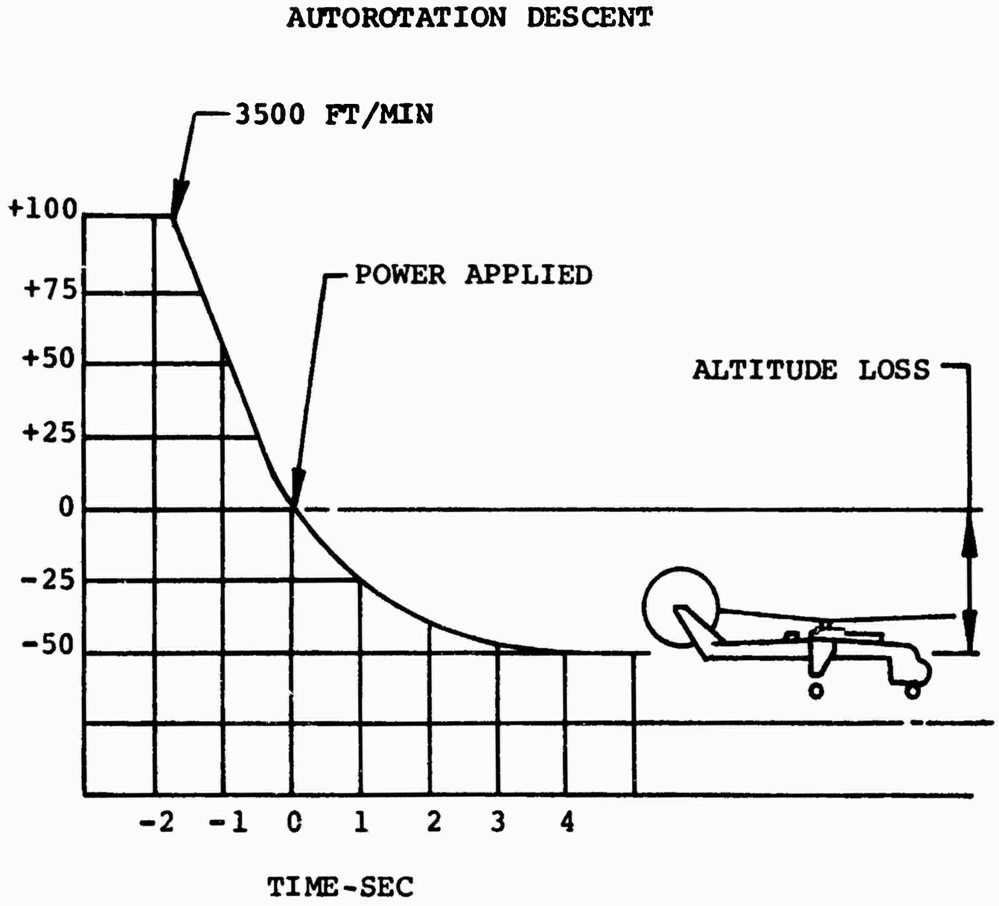

Figure 67. Altitude Loss During Recovery From Autorotation Descent of 3500 ft/min; 38,000 lb G. W.

TABLE XLIX. ROTOR DIMENSIONS, CH-54B

Main Rotor Disc Area	4072.0	sq ft
Main Rotor Blade Area (6 at 62.87 sq ft)	377.22	sq ft
Antitorque (Tail) Rotor Disc Area	201.1	sq ft
Antitorque (Tail) Rotor Blade Area (4 at 8.15 sq ft)	32.6	sq ft
Tail Area (Horizontal)	40.00	sq ft
Main Rotor (Blades) True Diameter	72.236	ft
Main Rotor Blade Chord:		
At Root	26.0	in.
At Tip	26.0	in.
Antitorque (Tail) Rotor Diameter	16.0	ft
Antitorque (Tail) Rotor Blade Chord:		
At Root	15.4	in.
At Tip	15.4	in.
Main Rotor Blade Thickness (% Chord)	11	%
Airfoil Section	NACA 0011	(MOD.)
Antitorque (Tail Rotor Blade Thickness (% Chord)	12	%
At Root	1.850	in.
At Tip	1.850	in.
Airfoil Section	NACA 0012	
Main Rotor Solidity Ratio Effective	0.115	
Main Rotor Blade Twist (non-linear)	10.65	deg
Distance Between Rotors	44 ft. 5	in.
Static Ground Clearance of Main Rotor Blades (Static Droop)	13 ft. 6	in.
Span, Maximum - Main Rotor Blades Positioned	62 ft. 4	in.
Horizontal Tail (Stabilizer):		
Span (Right Hand)	8 ft. 7	in.
Chord (Construction): At root and tip	56.00	in.
Section: At root and tip	NACA 0012	
Thickness (% chord): At root and tip	12	%
Aspect Ratio	1.75	

links which contain low friction Teflon bearings. In addition, both tail and main rotors have completely independent, self-contained, continuous lubrication systems.

The fuselage and landing gear (see Table L) have been specifically designed for the CH-54B's cargo handling duties.

Minimum fuselage bulk provides maximum visibility of cargo and cargo handling plus a large open space for the cargo itself. The wide-stance gantry-type landing gear enables the aircraft to straddle close in loads. The cargo handling system in single- and four-point configurations features a 25,000-pound-powered winch with 100 feet of useable cable, a 25,000-pound four-point suspension system for pods or pallets, normal operation control from all pilot stations, and multiple hard points with universal attachments for any type of load. Added precision and safety in cargo handling are insured by the rear-facing operator position which has full authority in all control axes and positive control priority over the forward-facing operator position.

These design features all contribute to the overall performance of the aircraft. With a large useful load to gross weight ratio, the CH-54B has the ability to pick up, transport, and place heavy external loads with precision. Although the empty weight of this aircraft is 19,700 lb, it is certified to operate at sea level with a gross weight of 47,000 lb to a temperature of 118°F. On a standard day (temperature 58.7°F), this gross weight is attainable to an altitude of 2600 ft. At an altitude of 4,000 ft and a temperature of 95°F, the allowable gross weight drops only slightly to 43,000 lb (see Figures 68 and 69). Mission productivities, up to 480 ton-knots at 40 nautical miles radius (see Figure 70), are calculated assuming:

(1) Warm-up and takeoff - 5 min at transmission rating

(2) Cruise outbound with max payload at 80 knots

(3) Hover out of ground effect and drop payload - 2 min

(4) Cruise inbound at 130 knots

(5) Land with 10% reserve fuel

For missions that include a ferry leg, climb capability exceeds 3500 ft/min. at sea level standard (see Figure 71).

The CH-54B currently holds nine world records as summarized in Table LI.

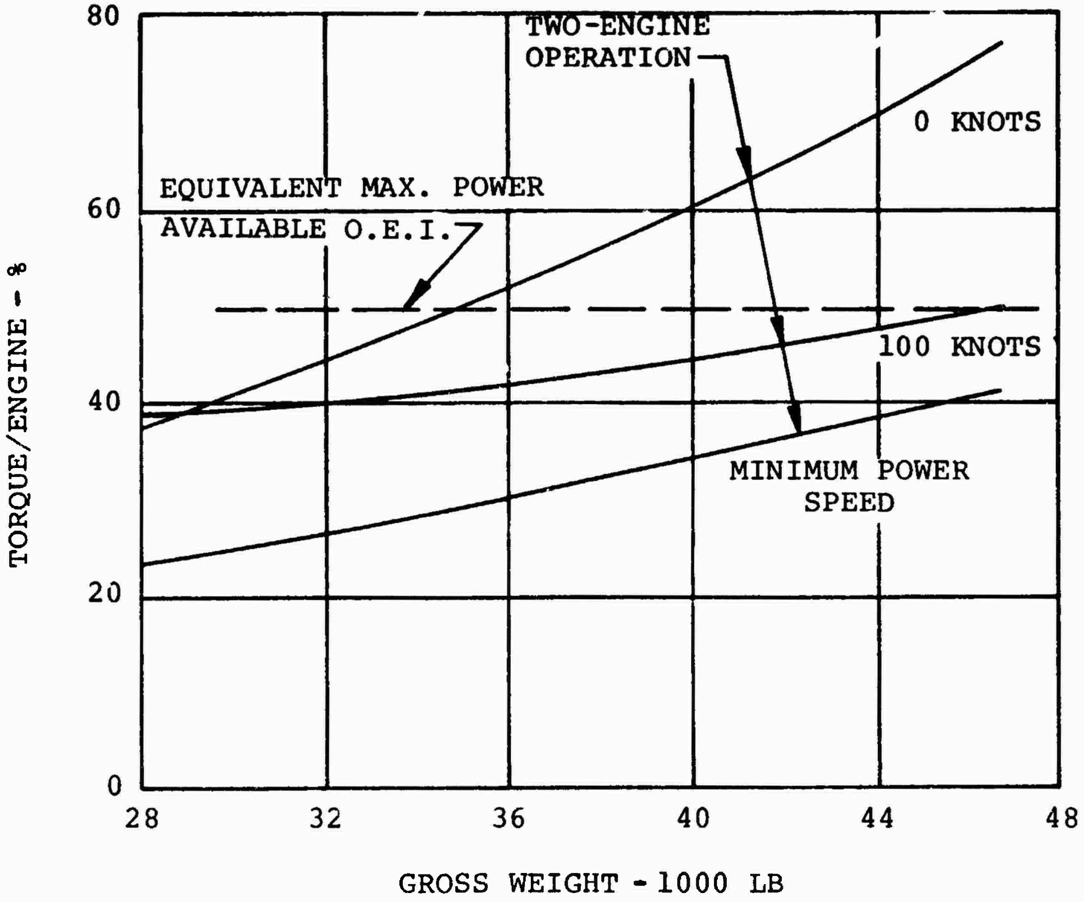

Figure 68. Forward Flight Performance, Sea Level Standard.

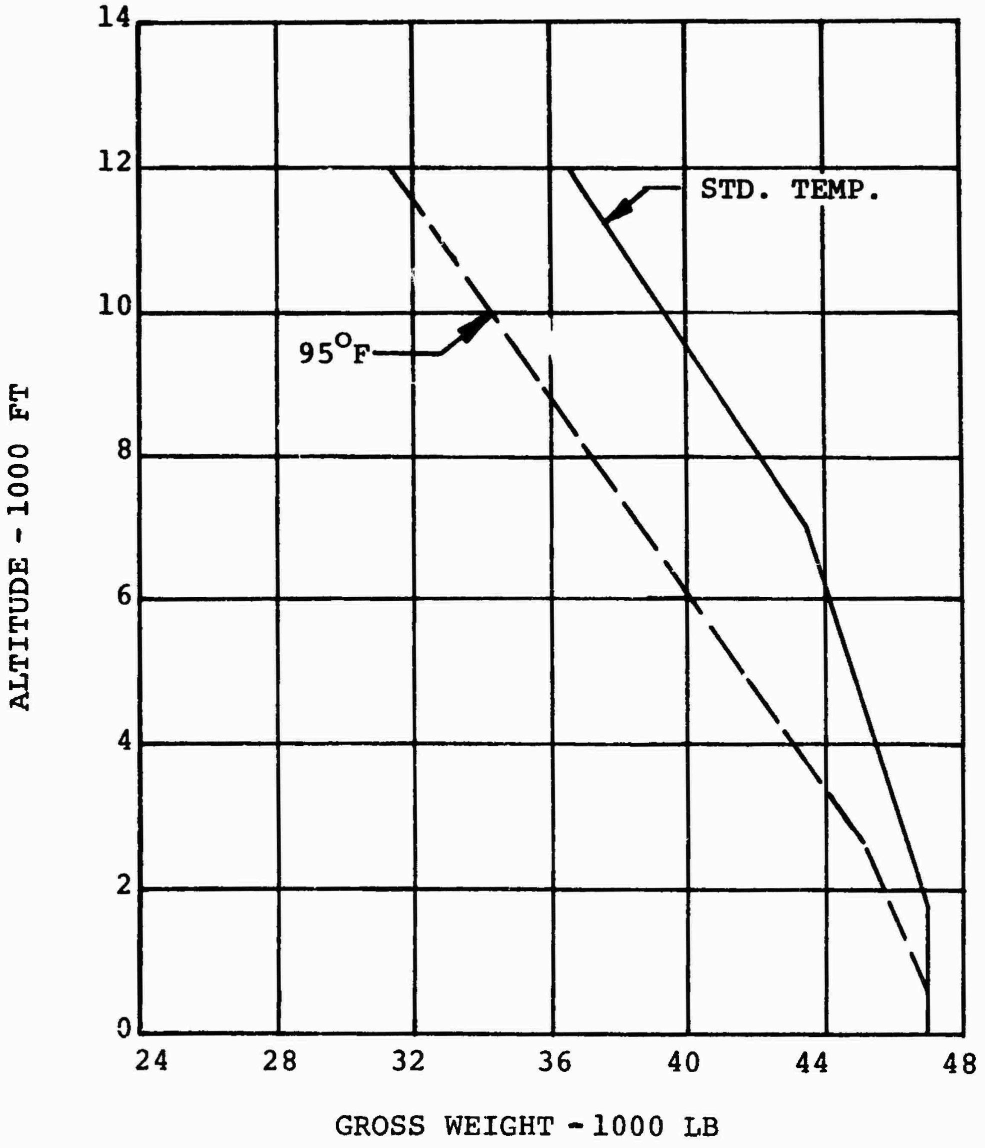

Figure 69. Hover Ceiling, Two-Engine CH-54B.

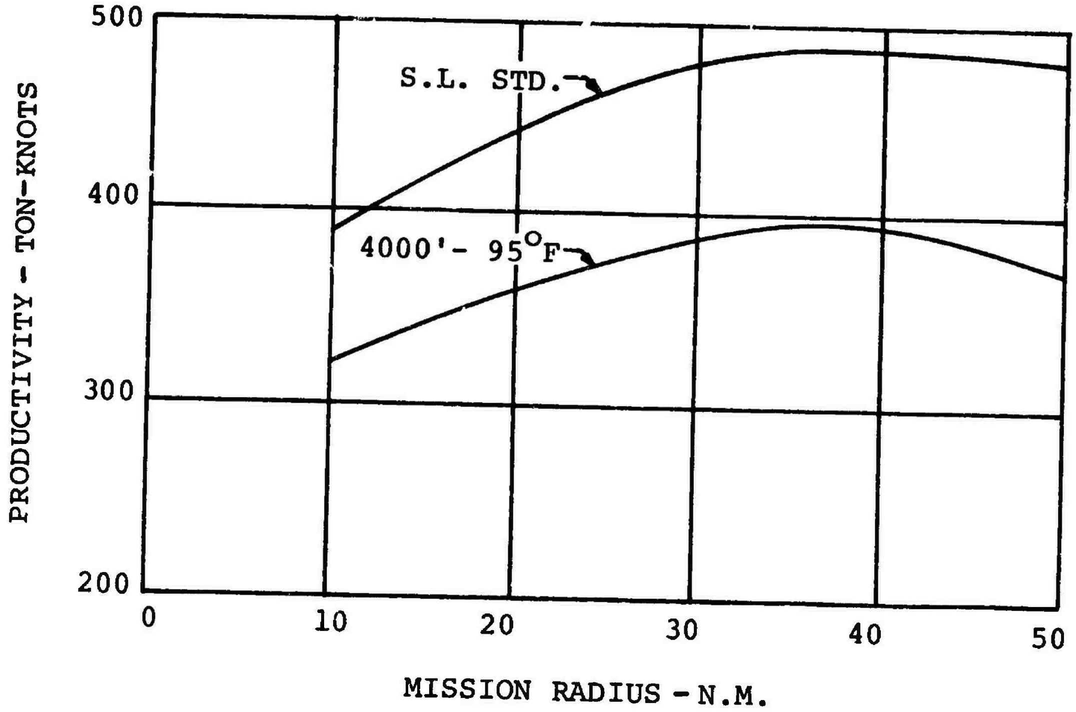

Figure 70. Productivity vs. Mission Radius, CH-54B.

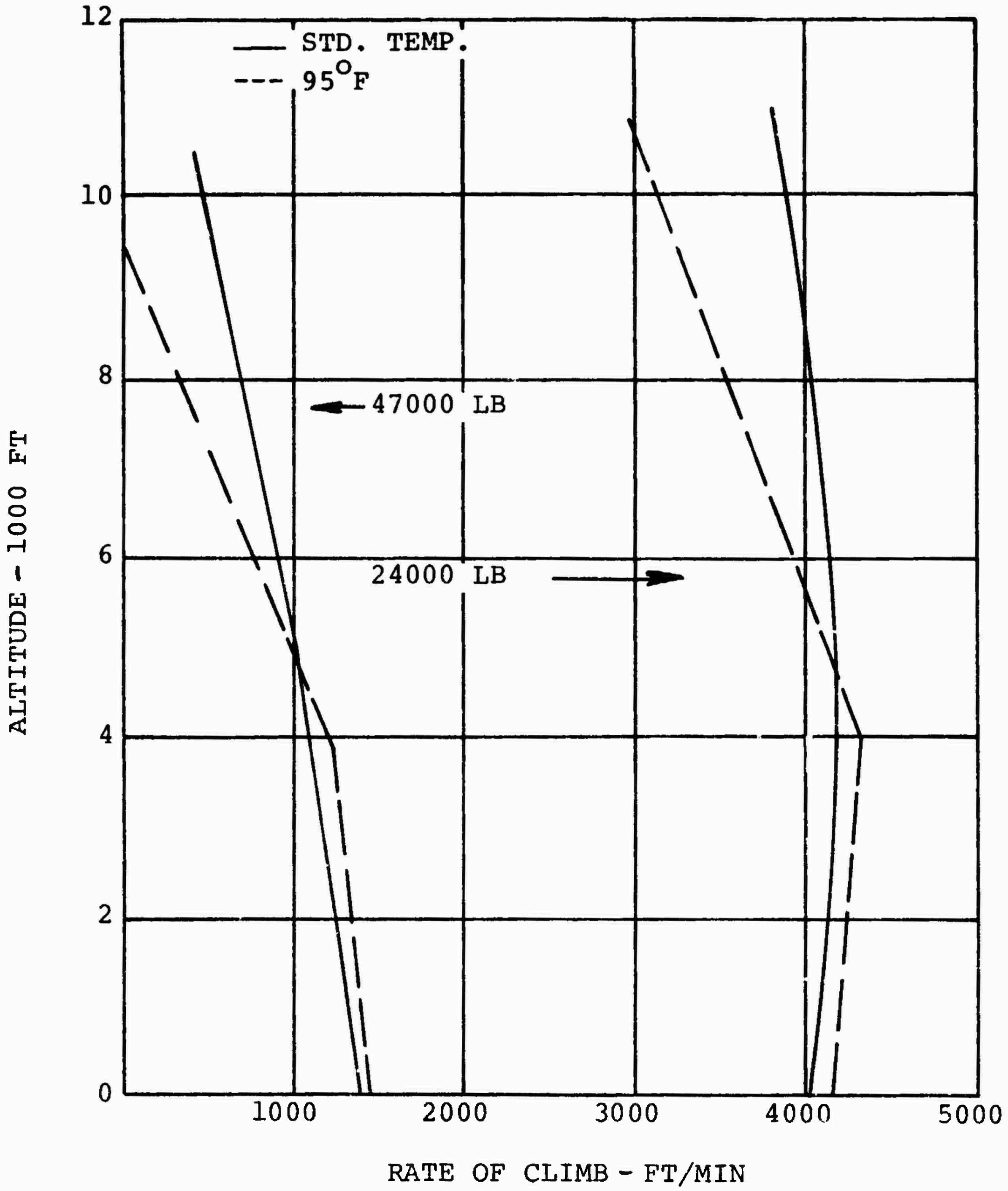

Figure 71. Forward Climb Performance, CH-54B.

TABLE L. FUSELAGE/LANDING GEAR DATA, CH-54B

Wheel Base	24 ft	5 in.
Vertical Travel of Axles:		
Main Wheels		20 in.
Nose Wheel		12 in.
Areas of Vision (minimum):		
Pilot and Copilot with eye position fixed (Reference Station 96, W.L. 164.5, B.L. ±21)		
	Pilot	Copilot
Vision downward (Pilot C.L.)	21°	21°
Vision upward (Pilot C.L.)	35°	35°
Vision horizontal - left	80°	125°
Vision horizontal - right	125°	80°
Angle between lines joining center of gravity with points of ground contact of main wheel tires, static deflection of 1W (front elevation) degrees	75°	36 ft
Angle of line through center of gravity and ground contact point of main wheel tire to vertical line, reference line level, static deflection of 1W (side elevation) degrees	21°	6 ft
Maximum slope helicopter can be parked upon without overturning, nose up-hill	21°	6 ft
Critical turnover angle about line between main and nose wheel	30°	6 ft

NOTE: (1) Rearward vision is available to pilot through aft-facing position enclosure.

(2) The above angles based on weight of aircraft without payload.

TABLE LI. CH-54B WORLD RECORDS			
RECORD TITLE	PREVIOUS RECORD	HELD BY	CH-54B
Maximum altitude; horizontal flt.	31,484 ft	CH-54A	36,122 ft
Maximum altitude; 1,000 Kg Payload	29,342 ft	CH-54A	31,165 ft
Maximum altitude; 2,000 Kg Payload	28,756 ft	CH-54A	31,480 ft
Maximum altitude; 5,000 Kg Payload	23,462 ft	Mi-10K (USSR)	25,578 ft
Maximum altitude; 10,000 Kg Payload	16,028 ft	Mi-6 (USSR)	17,211 ft
Maximum altitude; 15,000 Kg Payload	9,682 ft	V-12 (USSR)	10,850 ft
Time to climb 3,000 meters	1 min 38.32 sec	CH-54A	1 min 21.9 sec
Time to climb 6,000 meters	3 min 14.7 sec	CH-54A	2 min 58.8 sec
Time to climb 9,000 meters	7 min 57.44 sec	CH-54A	5 min 57.7 sec

APPENDIX II

MATHEMATICAL MODEL OF HELICOPTER WITH MODULARIZED MAIN TRANSMISSION

The mathematical model evaluates the cost effectiveness, relative to the baseline design, of any number of hardware alternatives to the baseline aircraft. The model is general such that the number of admissible hardware changes is unlimited mathematically, but is limited to twenty in the computer program of Appendix III. This limit can be expanded if required. The model develops the cost and technical factors of the design alternatives to provide the life-cycle cost and mission effectiveness required to evaluate their cost effectiveness.

The major parameters considered are scheduled and unscheduled maintenance at the organization level and distribution of the maintenance activities between maintenance levels: i.e., organization, direct support and depot; shipping between maintenance levels; GSE tooling required to support the design alternatives in the field; logistic spares requirements; hardware acquisition cost, design efficiency, reliability, and weight; and aircraft operating costs, availability and mission capability.

The model can be used to:

(1) determine the optimum transmission design

(2) determine the quantitative effectiveness of the design alternatives

(3) assess any additional quantitative effect of design alternatives such as maintenance burden at the Army maintenance levels, maintenance cost, container cost, shipping cost, life-cycle cost, etc.

(4) examination of the effect of TBO changes (including on-condition) on maintenance burden and cost.

There are more uses to which the model can be applied, which will be discovered by familiarity with and use of the program.

It should be noted that the model is applicable to the Navy and Air Force maintenance organization where the Army's direct support level is replaced by the Navy's intermediate level or by the Air Force's field level. Provision is made in the model for adjusting the integration of the organization level fault isolation and replacement with support from these middle maintenance levels.

Appendix III is a computer program of the mathematical model. In the computer program the symbols used are identical to the symbols used in the mathematical model for the sake of clarity. The definition of symbols is therefore the same for the mathematical model and computer program and is listed in Appendix III.

Transmission unscheduled maintenance frequency is found by summing the unscheduled maintenance frequency of the individual modules.

$$UMFX = \sum_{i=1}^{n} UMF_i \qquad (1)$$

Transmission mean time between unscheduled removal (for removals requiring overhaul) is found by summing the reciprocals of the MTBUR's for each module.

$$MTBURX = 1 / \sum_{i=1}^{n} (1/MTBUR_i) \qquad (2)$$

i^{th} module mean time between removal is found by multiplying the mean time between unscheduled removal by the reliability function for the scheduled removals.

$$MTBR_i = MTBUR_i \left[1 - e^{-TBO_i/MTBUR_i} \right] \qquad (3)$$

Life-cycle flight hours is the product of annual utilization and aircraft service life.

$$LCFH = UA\ (SERLIF) \qquad (4)$$

i^{th} module spares production run is the sum of the number of transmissions scrapped at the different levels (org., d.s., and depot) added to the number lost as a result of attrition.

$$NMOD_i = LCFH/MTBUR_i\left[(PORS_i/100) + (PORDS_i/100)(PDSS_i/100) + (PORDE_i/100)(PDES_i/100) + (PORDS_i/100)(PDSDE_i/100)(PDES_i/100) - (PDES_i/100)\right] + LCFH/MTBR_i (PDES_i/100) + LCFH\ (ATTRI_i) \qquad (5)$$

Quantity of shipping containers is determined from the product of the number of modularized spare parts times the ratio of initial to total spares produced.

$$QCONT = KIVEN \sum_{i=1}^{n} NMOD_i \qquad (6)$$

Cost of shipping containers is found from:

$$COCONT = KIVEN \sum_{i=1}^{n} CCONT_i\ (NMOD_i) \qquad (7)$$

Transmission nonrecurring cost is found by dividing the total nonrecurring cost by the number of modules produced and multiplying this by an overhead factor.

$$CNRX = KGAP \sum_{i=1}^{n} CNR_i \,/\, \left[(NMOD_i + 1)\ NBA\right] \qquad (8)$$

Transmission recurring cost is found by adding the recurring costs per module and multiplying by the overhead factor.

$$CRX = KGAP \sum_{i=1}^{n} CR_i \qquad (9)$$

Transmission acquisition cost is the sum of recurring and nonrecurring costs per transmission.

$$\text{CACQX} = \text{CRX} + \text{CNRX} \tag{10}$$

i^{th} module acquisition cost is the sum of each module's recurring and nonrecurring cost.

$$\text{CACQ}_i = \text{KGAP}\left[\text{CNR}_i \;/\; \left[(\text{NMOD}_i + 1)\ \text{NBA}\right] + \text{CR}_i\right] \tag{11}$$

Transmission initial spares cost is found by summing the acquisition, container and shipping costs for all the initial spares produced.

$$\text{CISX} = \text{KIVEN} \sum_{i=1}^{n} \text{NMOD}_i \left[\text{CACQ}_i + \text{CCONT}_i + \text{CSCF}_i\right] \tag{12}$$

Transmission replenishment spares cost is found by summing the acquisition and shipping cost of replenishment spares assuming no additional shipping containers are needed.

$$\text{CRSX} = \sum_{i=1}^{n} \left[\begin{array}{l}\text{CACQ}_i\ (\text{NMOD}_i)\ (1 - \text{KIVEN}) \\ + \text{NMOD}_i \quad \text{CSCF}_i\ (1 - \text{KIVEN})\end{array}\right] \tag{13}$$

Transmission GSE initial tooling cost is the sum of the module GSE cost divided by the number of baseline aircraft.

$$\text{CITX} = \sum_{i=1}^{n} \text{CGSE}_i/\text{NBA} \tag{14}$$

Transmission GSE replenishment tooling cost is the product of initial tooling cost and ratio of replenishment to initial tooling.

$$\mathrm{CRTX} = \mathrm{KGSE}\ (\mathrm{CITX}) \tag{15}$$

Transmission MMH/FH at organization is determined by summing the MMH/FH of inspection, removal, requisition, installation and scrappage.

$$\mathrm{MHFHOR} = \sum_{i=1}^{n} \left[\begin{array}{l} \mathrm{MION}_i\ (\mathrm{UMF}_i) + \mathrm{MRON}_i\ (\mathrm{UMF}_i - 1/\mathrm{MTBUR}_i) \\ (\mathrm{PORON}_i/100) + 1/\mathrm{MTBR}_i\ (\mathrm{MREM}_i + \mathrm{MREQ}_i + \\ \mathrm{MINST}_i) + \mathrm{MORI}_i/\mathrm{MTBUR}_i + \mathrm{MORS}_i/\mathrm{MTBUR}_i \\ (\mathrm{PORS}_i/100) \end{array} \right] + \mathrm{MDAY}/\mathrm{UD} + \mathrm{MINTER}/25 \tag{16}$$

Transmission organization maintenance cost is the sum of labor and material cost at organization.

$$\mathrm{CMORX} = \mathrm{LRMIL}\ (\mathrm{LCFH})\ (\mathrm{MHFHOR}) + \mathrm{LCFH} \sum_{i=1}^{n} \left[(\mathrm{PORON}_i/100)\ \mathrm{CMRON}_i\ (\mathrm{UMF}_i - 1/\mathrm{MTBUR}_i) \right] \tag{17}$$

Transmission MMH/FH at direct support is found in a similar manner as equation (16).

$$\mathrm{MHFHDS} = \sum_{i=1}^{n} \left[\begin{array}{l} (\mathrm{MDSI}_i/\mathrm{MTBUR}_i)\ (\mathrm{PORDS}_i/100) + (\mathrm{MDSR}_i/\mathrm{MTBUR}_i) \\ (\mathrm{PORDS}_i/100)\ (\mathrm{PDSR}_i/100) + (\mathrm{MDSS}_i/\mathrm{MTBUR}_i) \\ (\mathrm{PORDS}_i/100)\ (\mathrm{PDSS}_i/100) + (\mathrm{PDSON}_i/100)\ \mathrm{MRON}_i \\ (\mathrm{UMF}_i - 1/\mathrm{MTBUR}_i) \end{array} \right] + \mathrm{MPER}/100 \tag{18}$$

Transmission direct support maintenance cost is found in a manner similar to that of equation (17).

$$\mathrm{CMDSX} = \mathrm{LRMIL}\ (\mathrm{LCFH})\ (\mathrm{MHFHDS}) + \mathrm{LCFH} \sum_{i=1}^{n} \Big[(\mathrm{CMRDS}_i/\mathrm{MTBUR}_i)\ (\mathrm{PORDS}_i/100)\ (\mathrm{PDSR}_i/100) + \mathrm{CMRON}_i\ (\mathrm{UMF}_i - 1/\mathrm{MTBUR}_i)\ (\mathrm{PDSON}_i/100) \Big] \qquad (19)$$

Transmission MMH/FH at depot is found in a similar manner as equations (16) and (18).

$$\mathrm{MHFHDE} = \sum_{i=1}^{n} \left\{ \begin{bmatrix} (1/\mathrm{MTBUR}_i)\ \big[(\mathrm{PORDS}_i/100)\ (\mathrm{PDSDE}_i/100) \\ + (\mathrm{PORDE}_i/100) - 1 \big] + 1/\mathrm{MTBR}_i \end{bmatrix} \begin{bmatrix} \mathrm{MDEI}_i + \mathrm{MDER}_i\ (\mathrm{PDER}_i/100) + \mathrm{MDES}_i \\ (\mathrm{PDES}_i/100) \end{bmatrix} \right\} \qquad (20)$$

Transmission depot maintenance cost is similar to equations (17) and (19).

$$\mathrm{CMDEX} = \mathrm{LRCIV}\ (\mathrm{LCFH})\ (\mathrm{MHFHDE}) + \mathrm{LCFH} \sum_{i=1}^{n} \left\{ \mathrm{CMRDE}_i\ (\mathrm{PDER}_i/100) \begin{bmatrix} (1/\mathrm{MTBUR}_i)\ \big[(\mathrm{PORDE}_i/100) + (\mathrm{PORDS}_i/100) \\ (\mathrm{PDSDE}_i/100) - 1 \big] + 1/\mathrm{MTBR}_i \end{bmatrix} \right\} \qquad (21)$$

Transmission shipping cost from organization to depot is found as the product of preparation plus shipping cost times the number shipped.

$$\mathrm{CSORDE} = \mathrm{LCFH} \sum_{i=1}^{n} \left\{ (\mathrm{CPORDE}_i + \mathrm{CSFDE}_i) \Big[(1/\mathrm{MTBUR}_i)\ \big[(\mathrm{PORDE}_i/100) - 1 \big] + 1/\mathrm{MTBR}_i \Big] \right\} \qquad (22)$$

Transmission shipping cost from direct support to depot is found in a manner similar to that of equation (22).

$$CSDSE = LCFH \sum_{i=1}^{n} \Big[(CPDSDE_i + CSFDE_i) \; (1/MTBUR_i) \; (PORDS_i/100) \; (PDSDE_i/100) \Big] \qquad (23)$$

Transmission shipping cost from depot to field is similar to equations (22) and (23).

$$CSHDEF = LCFH \sum_{i=1}^{n} \Big\{ CSDEF_i \; (PDER_i/100) \Big[(1/MTBUR_i) \big[(PORDE_i100) + (PORDS_i/100) \; (PDSDE_i/100) - 1 \big] + 1/MTBR_i \Big] \Big\} \qquad (24)$$

Transmission shipping total cost between maintenance levels is the sum of the shipping costs at each level.

$$CSMX = CSORDE + CSDSDE + CSHDEF \qquad (25)$$

Transmission maintenance total cost is the sum of the maintenance and shipping costs at each level.

$$CMX = CMORX + CMDSX + CMDEX + CSMX \qquad (26)$$

Transmission maintenance down-hours/flight-hours is the sum of the product of maintenance of each module times the mean elapsed time to repair each module.

$$DHFHX = \sum_{i=1}^{n} UMF_i \; (METTR_i) \qquad (27)$$

Mean elapsed time to repair transmission is the down-hours/ flight hours divided by the sum of the maintenance frequency of each module.

$$METTRX = DHFHX \Big/ \sum_{i=1}^{n} UMF_i \qquad (28)$$

Aircraft down-hours/flight-hours is the total down-hours/flight-hours of the baseline aircraft plus the sum of the down-hours/flight-hours of the individual modules less the down-hours/flight-hours of the baseline transmission.

$$DHFHA = DHFHBA - METRBX\ (UMFBX) + \sum_{i=1}^{n} METTR_i\ (UMF_i) \qquad (29)$$

Aircraft mission availability is the percentage of the total time the aircraft is available for missions.

$$AVAIL = (24 - DHFHA\ UD) / 24 \qquad (30)$$

Aircraft mission abort failures/1000 flight hours is the total aborts of the baseline aircraft plus the differential between the candidate and baseline transmissions.

$$ABORT = (ABTBA - ABTBX + ABTX)\ \ 1000 \qquad (31)$$

Aircraft Mission Reliability is the exponential function of reliability defining the probability of completing a mission.

$$RELIA = e^{-TIMIS\ (ABORT/1000)} \qquad (32)$$

Aircraft mission capability is found by adding the differentials due to weight and efficiency changes to the baseline capability.

$$AMCAP = AMCAPB +^{*}DCAPWT\,(WTX - WTBX) +^{*}DCAPEF\ (EFFX - EFFBX) \qquad (33)$$

Aircraft mission effectiveness is found as a product of availability, reliability, and capability.

$$AMEFF = AVAIL\ (RELIA)\ (AMCAP) \qquad (34)$$

Aircraft mission fuel flow is found by adding differentials due to weight and efficiency changes to the baseline fuel flow.

$$\mathrm{FF} = \mathrm{FFBA} + {}^{*}\mathrm{DFFWT}\ (\mathrm{WTX} - \mathrm{WTBX}) + {}^{*}\mathrm{DFFEFF}\ (\mathrm{EFFX} - \mathrm{EFFBX}) \qquad (35)$$

* DCAPWT = - .02163
DCAPEF = .404
DFFWT = .0109
DFFEFF = -21.39

These derivatives are determined using a mission simulation program for the CH-54B helicopter and represent the rate of change of mission capability and mission fuel flow with respect to weight and drive system efficiency. These rates of change are constant within the expected variation of weight and efficiency. The mission simulation program determines the average mission capability and fuel flow by a probabalistic distribution of the mission environment, and by flying 1000 missions within that environment.

Cost of fuel is found as a product of unit fuel cost, lifetime flight hours, and fuel flow.

$$\mathrm{CPOL} = \mathrm{CFUEL}\ (\mathrm{LCFH})\ (\mathrm{FF}) \qquad (36)$$

Aircraft life-cycle cost is found by taking the life-cycle cost of the baseline aircraft, subtracting acquisition, tooling, spares maintenance, and fuel costs of the baseline transmission and adding the same values for the modularized transmission.

$$\begin{aligned}\mathrm{LCCA} = {} & \mathrm{LCCBA} - \mathrm{B}\ (\mathrm{CAQBX} + \mathrm{CISBX} + \mathrm{CRSBX} + \mathrm{CITBX} + \mathrm{CRTBX} + \\ & \mathrm{CMBX}) + \mathrm{B}\ (\mathrm{CACQX} + \mathrm{CISX} + \mathrm{CRSX} + \mathrm{CITX} + \mathrm{CRTX} + \mathrm{CMX}) \\ & - \mathrm{FFBA}\ (\mathrm{CFUEL})\ (\mathrm{LCFH}) + \mathrm{CPOL} + (4170 + 1100\ \mathrm{SERLIF}) \\ & (\mathrm{MHFHOR} + \mathrm{MHFHDS} - \mathrm{MHFHBX}) + \\ & \left[(\mathrm{AMEFF}/\mathrm{AMEFFB}) - 1\right]\ \mathrm{KGAP}/\mathrm{NBA} \sum_{i=1}^{n} \Big[\mathrm{CNR}_i\ / \\ & (\mathrm{NMOD}_i + 1)\ + \mathrm{CGSE}_i/\mathrm{KGAP}\Big] \end{aligned} \qquad (37)$$

In equation (37), 4170 represents the rate of change of maintenance personnel initial training cost, in dollars, with respect to the change in MMH/FH from the baseline aircraft. Also in equation (37), 1100 represents the rate of change of the annual replacement training cost, in dollars, with respect to the change in MMH/FH from the baseline aircraft.

Aircraft cost effectiveness is found by dividing the mission effectiveness by the life-cycle cost.

$$ACE = AMEFF/LCCA \tag{38}$$

Fleet effective cost is the product of number of fleet aircraft and life-cycle cost. The fleet size is adjusted so that aircraft of the same performance can be compared.

$$FEC = NBA\ (AMEFFB/AMEFF)\ LCCA \tag{39}$$

APPENDIX III

COMPUTER PROGRAM OF HELICOPTER WITH MODULARIZED MAIN TRANSMISSION

This appendix presents a computer program of the mathematical model of Appendix II. The program is written in FORTRAN IV programming language and is compatable with the IBM 360/65 computer system. The computer program documentation consists of seven sections as follows:

(1) Definitions of input symbols in program.

(2) Definitions of generated symbols in program.

(3) Definitions of output symbols in program.

(4) Listing of program source deck.

(5) Listing of sample input.

(6) Listing of sample output.

(7) Running instructions for program, and estimate of running time.

Definitions of Input Symbols in Program

Note: A subscript "j" appears after all program vector symbols for clarity.

ABTBA	baseline aircraft mission abort rate, abort/1000 fh
ABTBX	baseline transmission mission abort rate, abort/1000 fh
ABTX	candidate transmission mission abort rate, abort/fh
AMCAPB	baseline aircraft mission capability, ton-kt
AMEFFB	baseline aircraft mission effectiveness, ton-kt
ATTRIj	Jth module attrition rate, modules lost/fh
B	number of large transmissions per aircraft
CAQBX	cost of acquisition of baseline transmission, $
CCONTj	Jth module container cost, $
CFUEL	cost of fuel, $/lb
CGSEj	Jth module initial GSE tooling cost, $
CISBX	baseline transmission cost of initial spares, $
CITBX	baseline transmission cost of initial tooling, $
CMBX	baseline transmission cost of maintenance, $
CMRDEj	Jth module mean material cost to repair at depot, $
CMRDSj	Jth module mean material cost to repair at direct support, $
CMRONj	Jth module mean material cost to repair on aircraft, $
CNRj	Jth module nonrecurring cost, $
CPDEFj	cost to prepare Jth module at depot for shipment to field, $
CPDSDEj	cost to prepare Jth module at direct support for shipment to depot, $

CPORDEj	cost to prepare Jth module at organizational for shipment to depot, $
CRj	Jth module recurring cost, $
CRSBX	baseline transmission cost of replenishment spares, $
CRTBX	baseline transmission cost of replenishment tooling, $
CSCFj	cost to ship Jth module from continental U.S. to field, $
CSDEFj	cost to ship Jth module from depot to field, $
CSFDEj	cost to ship Jth module from field to depot, $
DHFHBA	down hours per flight hr for baseline aircraft, down hours/fh
EFFBX	efficiency of baseline transmission
EFFX	efficiency of candidate transmission
FFBA	average mission fuel flow of baseline aircraft, lb/hr
KGAP	nominal factor for general and administrative overhead plus profit
KGSE	ratio of CSE tooling replenishment requirements to initial GSE tooling requirements for transmission
KIVEN	ratio of initial spares required to total replenishment spares required
LCCBA	life-cycle cost of baseline aircraft, $
LRCIV	civilian maintenance personnel labor rate, $/hr
LRMIL	military maintenance personnel labor rate, $/hr
MDAY	mean maintenance man-hours to perform scheduled transmission daily inspection, mmh
MDEIj	mean maintenance man-hours to inspect Jth module for disposition at depot, mmh
MDERj	mean maintenance man-hours to repair Jth module at depot, mmh

$MDES_j$	mean maintenance man-hours to scrap J^{th} module at depot, mmh
$MDSI_j$	mean maintenance man-hours to inspect J^{th} module for disposition at direct support, mmh
$MDSR_j$	mean maintenance man-hours to repair J^{th} module at direct support, mmh
$MDSS_j$	mean maintenance man-hours to scrap J^{th} module at direct support, mmh
METRBX	mean elapsed time to repair baseline transmission, down-hours
$METTR_j$	mean elapsed time to repair J^{th} module, down-hours
MHFHBX	total maintenance man-hours per flight hour at organizational and direct support for baseline transmission, mmh/fh
$MINST_j$	mean maintenance man-hours to install J^{th} module on aircraft, mmh
MINTER	mean maintenance man-hours to perform scheduled intermediate transmission inspection, mmh
$MION_j$	mean maintenance man-hours to inspect J^{th} module on aircraft, mmh
$MORI_j$	mean maintenance man-hours to inspect J^{th} module for disposition at organizational, mmh
$MORS_j$	mean maintenance man-hours to scrap J^{th} module at organizational, mmh
MPER	mean maintenance man-hours to perform scheduled transmission periodic inspection, mmh
$MREM_j$	mean maintenance man-hours to remove J^{th} module from aircraft, mmh
$MREQ_j$	mean maintenance man-hours to requisition J^{th} module, mmh
$MRON_j$	mean maintenance man-hours to repair J^{th} module on aircraft, mmh
$MTBUR_j$	mean time between unschedule removal of J^{th} module fh
N	number of modules per transmission

NBA	number of baseline aircraft
PDER_j	percent of depot received J^{th} modules repaired
PDES_j	percent of depot received J^{th} modules scrapped
PDSDE_j	percent of direct support received J^{th} modules sent to depot
PDSON_j	percent of on aircraft repiar on J^{th} module done at direct support
PDSR_j	percent of direct support received J^{th} modules repaired
PDSS_j	percent of direct support received J^{th} modules scrapped
PORDE_j	percent of unscheduled removal J^{th} modules sent from organizational to depot
PORDS_j	percent of unscheduled removal J^{th} modules sent from organizational to direct support
PORON_j	percent of on aircraft repair of J^{th} module done at organizational
PORS_j	percent of unscheduled removed J^{th} module scrapped at organizational
SERLIF	service life, years
TBO_j	J^{th} module time between overhaul, fh
TIMIS	average mission time, hours
UA	annual utilization of aircraft, fh
UD	daily utilization of aircraft, fh
UMF_j	J^{th} module unscheduled maintenance frequency, 1/fh
UMFBX	unscheduled maintenance frequency of baseline transmission, 1/fh
WTBX	weight of baseline transmission, lb
WTX	weight of candidate transmission, lb

Definitions of Generated Symbols in Program

Note: A subscript "j" appears after all program vector symbols for clarity. Actual program used "(J)" for vectors.

DCAPEF	rate of change of capability with respect to efficiency
DCAPWT	rate of change of capability with respect to weight
DFFEFF	rate of change of fuel flow with respect to efficiency
DFFWT	rate of change of fuel flow with respect to weight
END	signal to computer that it has reached the end of the data
I	vector subscript for "REMARK"
J	vector subscript for denoting modules
LCFH	life cycle flight hours
M	twice the number of modules per transmission - used in reserving space for module names in program
$MTBR_j$	mean time between removals scheduled and unscheduled for J^th^ module, fh
NAME	vector symbol for module names
PERCEN	symbol for "percent" used in data check for totals of 100 percent
SUM 1	factor used in calculation of MTBURX
SUM 3	factor used in calculation of MHFHOR
SUM 4	factor used in calculation of CMORX
SUM 5	factor used in calculation of MHFHDS
SUM 6	factor used in calculation of CMDSX
SUM 7	factor used in calculation of MHFHDE
SUM 8	factor used in calculation of METTRX
SUM 9	factor used in calculation of DHFHA
SUM 10	factor used in calculation of LCCA

Definitions of Output Symbols in Program

Note: A subscript "j" appears after all program vector symbols for clarity. Actual program used "(J)" for vectors.

ABORT	aircraft mission abort failures per 1000 flight hours, aborts/1000 fh
ACE	aircraft cost effectiveness, ton-kt/$
AMCAP	aircraft mission capability, ton-kt
AMEFF	aircraft mission effectiveness, ton-kt
AVAIL	aircraft mission availability
CACQX	transmission acquisition cost contribution to aircraft flyaway cost, $
CISX	transmission initial spares cost, $
CITX	transmission initial tooling cost, $
CMDEX	transmission depot maintenance cost, $
CMDSX	transmission direct support maintenance cost, $
CMORX	transmission organizational maintenance cost, $
CMX	transmission total maintenance cost,$
CNRX	transmission nonrecurring cost, $
COCONT	container shipping cost, $
CPOL	total cost of fuel, $
CRSX	transmission replenishment spares cost, $
CRTX	cost of replenishment tooling, candidate transmission, $
CRX	transmission recurring cost, $
CSDSDE	transmission shipping cost between direct support and depot, $
CSHDEF	transmission cost to ship from depot to field, $
CSMX	total cost of shipping between maintenance levels, $

CSORDE	transmission shipping cost from organizational to depot, $
DHFHA	aircraft down-hours per flight-hour, down-hr/flight-hr
DHFHX	transmission maintenance down-hours per flight-hour, down-hr/flight hr
FEC	fleet effective cost, $
FF	average mission fuel flow, lb/hr
LCCA	aircraft life-cycle cost, $
METTRX	transmission mean elapsed time to reapir, down-hr
MHFHDE	transmission mean maintenance man-hours per flight hour at depot, mmh/fh
MHFHDS	transmission mean maintenance man-hours per flight hour at direct support, mmh/fh
MHFHOR	transmission mean maintenance man-hours per flight hour at organizational, mmh/fh
MTBURX	mean time between unscheduled removals requiring overhaul of transmission, fh
$NMOD_j$	J^{th} module spares production run
QCONT	quantity of shipping containers
RELIA	aircraft mission reliability
UMFX	transmission unscheduled maintenance frequency, 1/fh

LISTING OF PROGRAM SOURCE DECK

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C HELICOPTER TRANSMISSION MODULARIZATION AND MAINTAINABILITY ANALYSIS
C CONTRACT DAAJ02-72-C-0106
C
C  DEFINITION OF SYMBOLS - INPUT
C
C  ABTBA  = MISSION ABORT RATE, BASELINE AIRCRAFT
C  ABTBX  = MISSION ABORT RATE, BASELINE TRANSMISSION
C  ABTX   = MISSION ABORT RATE, CANDIDATE TRANSMISSION
C  AMCAPB = AIRCRAFT MISSION CAPABILITY, BASELINE
C  AMEFFB = AIRCRAFT MISSION EFFECTIVENESS, BASELINE
C  ATTRI  = ATTRITION RATE OF ANY MODULE
C  B      = NUMBER OF MAIN TRANSMISSIONS PER AIRCRAFT
C  CCONT  = COST OF ANY MODULE CONTAINER
C  CGSE   = COST OF ANY MODULE INITIAL GSE TOOLING
C  CFUEL  = COST OF FUEL
C  CMRON  = COST OF ANY MODULE MEAN MATERIAL REPAIR ON AIRCRAFT
C  CMRDS  = COST OF ANY MODULE MEAN MATERIAL REPAIR AT DIR.SUPPORT
C  CMRDE  = COST OF ANY MODULE MEAN MATERIAL REPAIR AT DEPOT
C  CNR    = COST OF ANY MODULE NON-RECURRING
C  CR     = COST OF ANY MODULE RECURRING
C  CSCF   = COST OF ANY MODULE TO SHIP FROM CONT.U.S. TO FIELD
C  CSDEF  = COST OF ANY MODULE TO SHIP FROM DEPOT TO FIELD
C  CSFDE  = COST OF ANY MODULE TO SHIP FROM FIELD TO DEPOT
C  CPORDE = COST OF ANY MODULE TO PREPARE TO SHIP, FIELD TO DEPOT
C  CPDSDE = COST OF ANY MODULE TO PREPARE TO SHIP, DIR.SUP. TO DEPOT
C  CPDEF  = COST OF ANY MODULE TO PREPARE TO SHIP, DEPOT TO FIELD
C  CAQBX  = COST OF ACQUISITION, BASELINE TRANSMISSION
C  CISBX  = COST OF INITIAL SPARES, BASELINE TRANSMISSION
C  CRSBX  = COST OF REPLENISHMENT SPARES, BASELINE TRANSMISSION
C  CMBX   = COST OF MAINTENANCE, BASELINE TRANSMISSION
C  CITBX  = COST OF INITIAL TOOLING, BASELINE TRANSMISSION
C  CRTBX  = COST OF REPLENISHMENT TOOLING, BASELINE TRANSMISSION
C  DHFHBA = DOWN HOURS PER FLIGHT HOUR, BASELINE AIRCRAFT
C  EFFBX  = EFFICIENCY OF BASELINE TRANSMISSION
C  EFFX   = EFFICIENCY OF CANDIDATE TRANSMISSION
C  FFBA   = FUEL FLOW OF AVERAGE MISSION, BASELINE AIRCRAFT
C  KGAP   = FACTOR FOR GENERAL AND ADMINISTRATIVE OVERHEAD PLUS PROFIT
C  KGSE   = RATIO OF TRANSMISSION GSE TOOLING REPLENESHMENT TO INITIAL
C  KIVEN  = RATIO OF TRANSMISSION INITIAL SPARES TO TOTAL REPL. SPARES
C  LCCBA  = LIFE CYCLE COST OF BASELINE AIRCRAFT
C  LRCIV  = LABOR RATE, CIVILIAN MAINTENANCE PERSONNEL
C  LRMIL  = LABOR RATE, MILITARY MAINTENANCE PERSONNEL
C  METTR  = MEAN ELAPSED TIME TO REPAIR ANY MODULE
C  METRBX = MEAN ELAPSED TIME TO REPAIR BASELINE TRANSMISSION
C  MTBUR  = MEAN TIME BETWEEN SCHEDULED REMOVAL OF ANY MODULE
C  MION   = MEAN MMH TO INSPECT ANY MODULE ON THE AIRCRAFT
C  MRON   = MEAN MMH TO REPAIR ANY MODULE ON THE AIRCRAFT
C  MREM   = MEAN MMH TO REMOVE ANY MODULE ON THE AIRCRAFT
C  MREQ   = MEAN MMH FOR REQUISITION OF ANY MODULE
C  MINST  = MEAN MMH TO INSTALL ANY MODULE ON THE AIRCRAFT
C  MDAY   = MEAN MMH TO PERFORM SCHEDULED TRANSMISSION DAILY INSPECTION
C  MINTER = MEAN MMH TO PERFORM SCHEDULED TRANSMISSION INTER INSPECTION
C  MPER   = MEAN MMH TO PERFORM SCHEDULED TRANSMISSION PERIODIC INSP
C  MORI   = MEAN MMH TO INSPECT ANY MODULE FOR DISPOSITION AT ORG
C  MORS   = MEAN MMH TO SCRAP ANY MODULE AT ORGANIZATION
C  MDSI   = MEAN MMH TO INSPECT ANY MODULE FOR DISPOSITION AT DIR SUP
C  MDSR   = MEAN MMH TO REPAIR  ANY MODULE AT DIRECT SUPPORT
C  MDSS   = MEAN MMH TO SCRAP ANY MODULE AT DIRECT SUPPORT
C  MDEI   = MEAN MMH TO INSPECT ANY MODULE FOR DISPOSITION AT DEPOT
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C   MDER   = MEAN MMH TO REPAIR ANY MODULE AT DEPOT
C   MDES   = MEAN MMH TO SCRAP ANY MODULE AT DEPOT
C   N      = NUMBER OF MODULES
C   NBA    = NUMBER OF BASELINE AIRCRAFT
C   PORS   = PERCENT OF ANY MODULE REMOVED UNSCH AND SCRAPPED AT ORG
C   PORDS  = PERCENT OF UNSCH REMOVALS OF ANY MODULES SENT TO DS FROM ORG
C   PORDE  = PERCENT OF UNSCH REMOVAL OF ANY MOD SENT TO DEPOT FROM ORG
C   PORON  = PERCENT OF ON AIRCRAFT REPAIRS PERFORMED AT ORG.
C   PDSON  = PERCENT OF ON AIRCRAFT REPAIRS PERFORMED AT DIRECT SUPPORT
C   PDSS   = PERCENT OF DIRECT SUPPORT RECEIVED FOR ANY MODULES SCRAPPED
C   PDSR   = PERCENT OF DIRECT SUPPORT RECEIVED FOR ANY MODULES REPAIRED
C   PDSDE  = PERCENT OF DIRECT SUPPORT RECEIVED FOR ANY MOD SENT TO DEPOT
C   PDER   = PERCENT OF DEPOT RECEIVED FOR ANY MODULE REPAIRED
C   PDES   = PERCENT OF DEPOT RECEIVED FOR ANY MODULE SCRAPPED
C   SERLIF = SERVICE LIFE
C   TBO    = TIME BETWEEN OVERHAUL OF ANY MODULE
C   TIMIS  = AVERAGE MISSION TIME
C   UA     = ANNUAL UTILIZATION OF AIRCRAFT
C   UD     = DAILY UTILIZATION OF AIRCRAFT
C   UMF    = UNSCHEDULED MAINTAINENCE FREQUENCY OF ANY MODULE
C   WTBX   = WEIGHT OF BASELINE TRANSMISSION
C   WTX    = WEIGHT OF CANDIDATE TRANSMISSION
C   UMFB   = UNSCHEDULED MAINTAINENCE FREQUENCY OF BASELINE TRANSMISSION
C
C
C
C   DEFINITION OF SYMBOLS - OUTPUT
C
C   ABORT  = AIRCRAFT MISSION ABORTS PER 1000 FLIGHT HOURS
C   ACE    = AIRCRAFT COST EFFECTIVENESS
C   AMCAP  = AIRCRAFT MISSION CAPABILITY
C   AMEFF  = AIRCRAFT MISSION EFFECTIVENESS
C   AVAIL  = AIRCRAFT MISSION AVAILABILITY
C   COCONT = COST OF SHIPPING CONTAINERS
C   CNRX   = COST OF TRANSMISSION, NON-RECURRING
C   CRX    = COST OF TRANSMISSION, RECURRING
C   CACQX  = COST OF TRANS.ACQUISITION,CONTRIBUTION TO AIRCRAFT FLYAWAY
C   CISX   = COST OF TRANSMISSION INITIAL SPARES
C   CRSX   = COST OF TRANSMISSION REPLENSHMENT SPARES
C   CITX   = COST OF TRANSMISSION GSE INITIAL TOOLING
C   CRTX   = COST OF TRANSMISSION GSE REPLENSHMENT TOOLING
C   CMORX  = COST OF TRANSMISSION ORGANIZATIONAL MAINTENANCE
C   CMDSX  = COST OF TRANSMISSION DIRECT SUPPORT MAINTENANCE
C   CMDEX  = COST OF TRANSMISSION DEPOT MAINTENANCE
C   CSORDE = COST OF TRANSMISSION SHIPPING, ORGANIZATION/DEPOT
C   CSDSDE = COST OF TRANSMISSION SHIPPING, DIRECT SUPPORT/DEPOT
C   CSHDEF = COST OF TRANSMISSION SHIPPING, DEPOT/FIELD
C   CSMX   = COST OF TRANSMISSION SHIPPING, TOTAL BETWEEN MAINT. LEVELS
C   CMX    = COST OF TRANSMISSION TOTAL MAINTENANCE
C   CPOL   = COST OF FUEL, OIL, AND LUBE
C   DHFHA  = AIRCRAFT DOWN-HOURS PER FLIGHT HOUR
C   DHFHX  = TRANSMISSION MAINTENANCE DOWN-HOURS PER FLIGHT HOUR
C   FEC    = FLEET EFFECTIVE COST
C   FF     = AVERAGE MISSION FUEL FLOW
C   LCCA   = AIRCRAFT LIFE CYCLE COST
C   MTBURX = TRANSMISSION MEAN TIME BETWEEN UNSCHEDULED REMOVAL
C   METTRX = TRANSMISSION MEAN ELAPSED TIME TO REPAIR
C   MHFHOR = TRANSMISSION MEAN MAINT.MAN HR.PER FLIGHT HR.AT ORGANIZATION
C   MHFHDS = TRANSMISSION MEAN MAINT.MAN HR.PER FLIGHT HR.AT DIRECT SUP.
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C  MHFHDE = TRANSMISSION MEAN MAINT.MAN HR.PER FLIGHT HR.AT DEPOT
C  NMOD   = ANY MODULE SPARES PRODUCTION RUN
C  QCONT  = QUANTITY OF SHIPPING CONTAINERS
C  RELIA  = AIRCRAFT MISSION RELIABILITY
C  UMFX   = TRANSMISSION UNSCHEDULED MAINTENANCE FREQUENCY
C
C  PRINT INPUT DATA
C
      DIMENSION ATTRI (20),CCONT (20),CGSE  (20),CMRON (20),CMRDS (20),
     1          CMRDE (20),CNR   (20),CR    (20),CSCF  (20),
     2          CSDEF (20),CSFDE (20),CPORDE(20),CPDSDE(20),CPDEF (20),
     3          PORS  (20),PORDS (20),PORDE (20),PDSS  (20),PDSR  (20),
     4          PDSDE (20),PDER  (20),PDES  (20),TBO   (20),UMF   (20),
     5          CACQ  (20),PORON (20),PDSON (20),NAME  (40
      REAL LCCBA,LRCIV,LRMIL,METTR(20),METRBX,MTBUR(20),MION(20),
     1     MRON(20),MREM(20),MREQ(20),MINST(20),MDAY,MINTFR,MPER,
     2     MORI(20),MORS(20),MDSI(20),MDSR(20),MDSS(20),MDEI(20),
     3     MDER(20),MDES(20),MTBR(20),NMOD(20),KGAP,KGSE,KIVEN,
     4     LCCA,MTBURX,MTBRX,METTRX,MHFHOR,MHFHDS,MHFHDE,LCFH,MHFHBX
  100 FORMAT(8F10.4)
  200 FORMAT(20A4)
  300 FORMAT(1H1,20A4)
  400 FORMAT(2I10)
  500 FORMAT(1H0,8X,24HAIRCRAFT COST INPUT DATA)
  600 FORMAT(1H0,3X,62HLIFE CYCLE COST OF BASELINE AIRCRAFT . . . . . .
     1. . . . . . =,F11.0,3H $ )
  700 FORMAT(1H ,3X,62HCOST OF FUEL . . . . . . . . . . . . . . . . . . .
     1. . . . . . =,F10.4,2X,10H$ PER LB. )
  800 FORMAT(1H ,3X,62HNUMBER OF MAIN TRANSMISSIONS PER AIRCRAFT. . . .
     1. . . . . . =,F6.0)
  900 FORMAT(1H ,3X,62HFACTOR FOR GENERAL AND ADMINISTRATIVE OVERHEAD PL
     1US PROFIT . =,F8.2)
 1000 FORMAT(1H0,8X,47HAIRCRAFT RELIABILITY/MAINTAINABILITY INPUT DATA)
 1100 FORMAT(1H0,3X,62HMISSION ABORT RATE OF BASELINE AIRCRAFT. . . . .
     1. . . . . . =,F10.4,1X,23H ABORTS PER FLIGHT HOUR)
 1200 FORMAT(1H ,3X,62HDOWN HOURS PER FLIGHT HOUR OF BASELINE AIRCRAFT.
     1. . . . . . =,F10.4)
 1300 FORMAT(1H0,8X,27HAIRCRAFT MISSION INPUT DATA)
 1400 FORMAT(1H0,3X,62HAIRCRAFT MISSION CAPABILITY, BASELINE AIRCRAFT .
     1. . . . . . =,F 9.3,3X,10H TON-KNOTS)
 1500 FORMAT(1H ,3X,62HAIRCRAFT MISSION EFFECTIVENESS, BASELINE AIRCRAFT
     1. . . . . . =,F 9.3,3X,10H TON-KNOTS)
 2000 FORMAT(1H ,3X,62HEFFICIENCY OF BASELINE TRANSMISSION. . . . . . .
     1. . . . . . =,F9.3,2X,8H PERCENT)
 2100 FORMAT(1H ,3X,62HEFFICIENCY OF CANDIDATE TRANSMISSION . . . . . .
     1. . . . . . =,F9.3,2X,8H PERCENT)
 2200 FORMAT(1H ,3X,62HAVERAGE MISSION FUEL FLOW OF BASELINE AIRCRAFT .
     1. . . . . . =,F9.3,4X,12HLBS.PER HOUR)
 2300 FORMAT(1H ,3X,62HSERVICE LIFE . . . . . . . . . . . . . . . . . .
     1. . . . . . =,F9.3,3X,6H YEARS)
 2400 FORMAT(1H ,3X,62HAVERAGE MISSION TIME . . . . . . . . . . . . . . .
     1. . . . . . =,F9.3,3X,6H HOURS)
 2500 FORMAT(1H ,3X,62HANNUAL UTILIZATION OF AIRCRAFT . . . . . . . . .
     1. . . . . . =,F9.3,3X,13H FLIGHT HOURS)
 2600 FORMAT(1H ,3X,62HDAILY UTILIZATION OF AIRCRAFT. . . . . . . . . .
     1. . . . . . =,F9.3,3X,13H FLIGHT HOURS)
 2700 FORMAT(1H ,3X,62HWEIGHT OF BASELINE TRANSMISSION. . . . . . . . .
     1. . . . . . =,F9.3,3X,7H POUNDS)
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2800 FORMAT(1H ,3X,62HWEIGHT OF CANDIDATE TRANSMISSION . . . . .     . .
    1. . . . . . =,F9.3,3X,7H POUNDS)
2850 FORMAT(1H ,3X,62HNUMBER OF BASELINE AIRCRAFT. . . . . . . . . . .
    1. . . . . . =,I5)
2900 FORMAT(1H0,8X,28HTRANSMISSION COST INPUT DATA,//,27X,22HINDIVIDUAL
    1      TOTAL,8X,3(15HMATERIAL       ),2X,5HTOTAL,/,28X,5(15HCOST OF
    2          ),2X,4HCOST,11X,4HCOST,/,27X,8HSHIPPING,8X,7HINITIAL,5X,
    33(15HMODULE REPAIR  ),26HNON-RECURRING    RECURRING,/,27X,9HCONTAI
    4NER,5X,11HGSE TOOLING,4X,11HON AIRCRAFT,3X,13HAT DIRECT SUP,4X,
    5 8HAT DEPOT,/)
3000 FORMAT(1H ,3X,2A4,5H  NO.,     I3,4X,7(2H $,F8.0,5X))
3010 FORMAT(1H ,3X,2A4,5H  NO.,     I3,4X,6(2H $,F8.0,5X))
3100 FORMAT(1H0,23X,6(15H    COST TO    ),/,26X,3(15HSHIP MODULE    ),3
    1(15HPREP. SHIP     ),/,25X,30HU.S. TO FIELD  DEPOT TO FIELD ,2(15H
    2FIELD TO DEPOT ),29HDIR.SUP./DEPOT DEPOT TO FIELD,/)
3200 FORMAT(1H0,3X,62HCOST OF ACQUISITION, BASELINE TRANSMISSION . . .
    1. . . . . . =,F11.0,2H $)
3300 FORMAT(1H ,3X,62HCOST OF INITIAL SPARES, BASELINE TRANSMISSION. .
    1. . . . . . =,F11.0,2H $)
3400 FORMAT(1H ,3X,62HCOST OF REPLENISHMENT SPARES, BASELINE TRANSMISSI
    1ON. . . . . =,F11.0,2H $)
3500 FORMAT(1H ,3X,62HCOST OF MAINTENANCE, BASELINE TRANSMISSION . . .
    1. . . . . . =,F11.0,2H $)
3600 FORMAT(1H ,3X,62HCOST OF INITIAL TOOLING, BASELINE TRANSMISSION .
    1. . . . . . =,F11.0,2H $)
3700 FORMAT(1H ,3X,62HCOST OF REPLENISHMENT TOOLING BASELINE TRANSMISSI
    1ON. . . . . =,F11.0,2H $)
3800 FORMAT(1H ,3X,62HRATIO OF GSE TOOLING REPLENISHMENT REQT/ GSE TOOL
    1ING,XMISSION=,F11.3)
3900 FORMAT(1H ,3X,62HRATIO OF INITIAL SPARES REQD TO REPLENISHMENT SPA
    1RES REQD. . =,F11.3)
4000 FORMAT(1H ,3X,62HLABOR RATE, CIVILIAN MAINTENANCE PERSONNEL,DIRECT
    1 + INDIRECT =,F10.2,2X,6H$/HOUR)
4100 FORMAT(1H ,3X,62HLABOR RATE, MILITARY MAINTENANCE PERSONNEL, DIREC
    1T + INDIRECT=,F10.2,2X,6H$/HOUR)
4200 FORMAT(1H0,8X,51HTRANSMISSION RELIABILITY/MAINTAINABILITY INPUT DA
    1TA,//,27X,9HATTRITION,4X,12HMEAN ELAPSED,2X,14HMEAN TIME BET.,
    24(15H   MEAN MMH    ),
    3   /,27X,10HRATE, MOD.,3X,14HTIME REP. MOD.,2X,14HUNSCH.MOD.REM.,
    42X,
    512HINSPECT MOD.,3X,11HREPAIR MOD.,4X,11HREMOVE MOD.,4X,11HREQUISIT
    6ION,/,25X,13HLOST/FLGT HR.,3X,10HDOWN HOURS,3X,12HFLIGHT HOURS,2X,
    7 2(15H  ON AIRCRAFT  ),14H FROM AIRCRAFT,5X,6HMODULE,/)
4300 FORMAT(1H ,3X,2A4,5H  NO.,     I3,F15.6,F13.2,5F15.2)
4400 FORMAT(1H0,23X,7(15H   MEAN MMH    ),/,25X,11HINSTALL MOD,5X,12HIN
    1SPECT MOD.,3X,10HSCRAP MOD.,5X,12HINSPECT MOD.,3X,11HREPAIR MOD.,
    2 4X,10HSCRAP MOD.,5X,12HINSPECT MOD.,/,25X,14HON AIRCRAFT   ,
    3 2(15H   AT ORG.      ),3(15H  AT DIR.SUP.  ),11H   AT DEPOT,/)
4500 FORMAT(1H ,3X,2A4,5H  NO.,     I3,7F15.2)
4600 FORMAT(1H0,23X,2(15H   MEAN MMH    ),5(15H   PERCENT     ),/,26X,
    111HREPAIR MOD.,4X,10HSCRAP MOD.,4X,14HUNSCH.MOD.REM.,2(15H MOD.REM
    2.SHIP. ),12H  MOD. SCRAP,4X,13HREPAIRED MOD.,/,24X,2(15H   AT DEPO
    3T    ),45H SCRAPPED ORG.   ORG./DIR.SUP.  ORG./DEPOT   ,2(15H  AT
    4DIR.SUP.  ),/)
4700 FORMAT(1H ,3X,2A4,5H  NO.,     I3,2F15.2,F14.2,4F15.2)
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4800 FORMAT(1H0,23X,3(15H   PERCENT     ),2X,10HPERCENT ON,6X,10HPERCEN
    1T ON,7X,4HTIME,8X,11HUNSCHEDULED,/,25X,13HMOD.REC.SHIP.,3X,11HREPA
    2IR MOD.,4X,10HSCRAP MOD.,3X,13HAIRCRAFT REP.,4X,13HAIRCRAFT REP.,3
    3X,7HBETWEEN,7X,12HMAINTAINENCE,/,25X,14HDIR.SUP/DEPOT ,2(15H   AT
    4DEPOT     ),4X,7HAT ORG.,7X,12HAT DIR. SUP.,2X,10H  OVERHAUL,6X,9HF
    5REQUENCY,/)
4900 FORMAT(1H ,3X,2A4,5H  NO.,      I3,F14.2,4F15.2,F15.0,F15.4)
5000 FORMAT(1H0,3X,62HMISSION ABORT RATE, BASELINE TRANSMISSION. . . .
    1. . . . . . =,F11.5,23H ABORTS PER FLIGHT HOUR)
5100 FORMAT(1H ,3X,62HMISSION ABORT RATE, CANDIDATE TRANSMISSION . . .
    1. . . . . . =,F11.5,23H ABORTS PER FLIGHT HOUR)
5200 FORMAT(1H ,3X,62HMEAN ELAPSED TIME TO REPAIR BASELINE TRANSMISSION
    1. . . . . . =,F8.2,3X,11H DOWN HOURS)
5250 FORMAT(1H ,3X,62HTOTAL MMH/FH AT ORG. AND DIR. SUP.,BASELINE TRANS
    1MISSION . . =,F8.2,4X,6HMMH/FH)
5300 FORMAT(1H ,3X,62HMEAN MMH TO PERFORM SCHEDULED TRANSMISSION DAILY
    1INSPECTION. =,F8.2,3X,6H HOURS)
5400 FORMAT(1H ,3X,62HMEAN MMH TO PERFORM SCHEDULED TRANSMISSION INTERM
    1EDIATE INSP =,F8.2,3X,6H HOURS)
5500 FORMAT(1H ,3X,62HMEAN MMH TO PERFORM SCHEDULED TRANSMISSION PERIOD
    1IC INSP . . =,F8.2,3X,6H HOURS)
5600 FORMAT(1H ,3X,62HUNSCHEDULED MAINTENANCE FREQUENCY, BASELINE TRANS
    1MISSION . . =,F10.4)
5700 FORMAT(1H0,8X,25HAIRCRAFT COST OUTPUT DATA)
5800 FORMAT(1H0,3X,62HAIRCRAFT COST EFFECTIVENESS. . . . . . . . . . .
    1. . . . . . =,F11.3,16H TON-KNOTS/MEGA$)
5900 FORMAT(1H ,3X,62HFLEET EFFECTIVE COST . . . . . . . . . . . . . .
    1. . . . . . =,F11.3,7H MEGA $)
6000 FORMAT(1H ,3X,62HAIRCRAFT LIFE CYCLE COST . . . . . . . . . . . .
    1. . . . . . =,F11.3,7H MEGA $)
6100 FORMAT(1H0,8X,48HAIRCRAFT RELIABILITY/MAINTAINABILITY OUTPUT DATA)
6200 FORMAT(1H0,3X,62HAIRCRAFT MISSION ABORT FAILURES PER 1000 FLIGHT H
    1OURS. . . . =,F11.2,21H  ABORTS/1000 FLT.HR.)
6300 FORMAT(1H ,3X,62HAIRCRAFT MISSION AVAILABILITY. . . . . . . . . .
    1. . . . . . =,F11.3)
6400 FORMAT(1H ,3X,62HAIRCRAFT DOWN HOURS PER FLIGHT HOUR. . . . . . .
    1. . . . . . =,F10.2)
6500 FORMAT(1H ,3X,62HAIRCRAFT MISSION RELIABILITY . . . . . . . . . .
    1. . . . . . =,F12.4)
6600 FORMAT(1H0,8X,41HAIRCRAFT MISSION OUTPUT DATA PER AIRCRAFT)
6700 FORMAT(1H0,3X,62HAIRCRAFT MISSION CAPABILITY. . . . . . . . . . .
    1. . . . . . =,F 10.2,2X,9HTON KNOTS)
6800 FORMAT(1H ,3X,62HAIRCRAFT MISSION EFFECTIVENESS . . . . . . . . .
    1. . . . . . =,F 10.2,2X,9HTON KNOTS)
6900 FORMAT(1H ,3X,62HTOTAL COST OF FUEL . . . . . . . . . . . . . . .
    1. . . . . . =,F11.0,2H $)
7000 FORMAT(1H ,3X,62HAVERAGE MISSION FUEL FLOW. . . . . . . . . . . .
    1. . . . . . =,F10.2,2X,8HLBS/HOUR)
7100 FORMAT(1H0,8X,42HTRANSMISSION COST OUTPUT DATA PER AIRCRAFT)
7200 FORMAT(1H0,3X,62HTOTAL COST OF SHIPPING CONTAINERS. . . . . . . .
    1. . . . . . =,F11.0,2H $)
7300 FORMAT(1H ,3X,62HTRANSMISSION NON-RECURRING COST. . . . . . . . .
    1. . . . . . =,F11.0,2H $)
7400 FORMAT(1H ,3X,62HTRANSMISSION RECURRING COST. . . . . . . . . . .
    1. . . . . . =,F11.0,2H $)
7500 FORMAT(1H ,3X,62HTRANSMISSION ACQUISITION COST CONTRIBUTION TO LCC
    1A . . . . . =,F11.0,2H $)
7600 FORMAT(1H ,3X,62HTRANSMISSION INITIAL SPARES COST CONTRIBUTION TO
    1LCCA. . . . =,F11.0,2H $)
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7700 FORMAT(1H ,3X,62HTRANSMISSION REPLENESHMENT SPARES COST CONTRIBUTI
     1ON TO LCCA. =,F11.0,2H $)
8000 FORMAT(1H ,3X,62HTRANSMISSION ORGANIZATION MAINTENANCE COST . . .
     1. . . . . . =,F11.0,2H $)
8100 FORMAT(1H ,3X,62HTRANSMISSION DIRECT SUPPORT MAINTENANCE COST . .
     1. . . . . . =,F11.0,2H $)
8200 FORMAT(1H ,3X,62HTRANSMISSION DEPOT MAINTENANCE COST. . . . . . .
     1. . . . . . =,F11.0,2H $)
8300 FORMAT(1H ,3X,62HTRANSMISSION SHIPPING COST BETWEEN ORG.  AND DEPO
     1T . . . . . =,F11.0,2H $)
8400 FORMAT(1H ,3X,62HTRANSMISSION SHIPPING COST BETWEEN DIRECT SUPPORT
     1 AND DEPOT. =,F11.0,2H $)
8500 FORMAT(1H ,3X,62HTRANSMISSION SHIPPING COST BETWEEN DEPOT AND FIEL
     1D . . . . . =,F11.0,2H $)
8600 FORMAT(1H ,3X,62HTRANSMISSION TOTAL SHIPPING COST BETWEEN MAINTENA
     1NCE LEVELS. =,F11.0,2H $)
8700 FORMAT(1H ,3X,62HTRANSMISSION TOTAL MAINTENANCE COST. . . . . . .
     1. . . . . . =,F11.0,2H $)
8800 FORMAT(1H ,3X,62HQUANTITY OF SHIPPING CONTAINERS. . . . . . . . .
     1. . . . . . =,F11.2)
8900 FORMAT(1H ,3X,22HSPARES PRODUCTION RUN,,2X,2A4,4H NO.,I3,23H. . .
     1. . . . . . . . =,F8.2)
9000 FORMAT(1H0,8X,52HTRANSMISSION RELIABILITY/MAINTAINABILITY OUTPUT D
     1ATA)
9100 FORMAT(1H0,3X,62HTRANSMISSION MAINTENANCE DOWN-HOURS PER FLIGHT HO
     1UR. . . . . =,F9.3)
9200 FORMAT(1H ,3X,62HTRANSMISSION MEAN TIME BETWEEN UNSCHEDULED REMOVA
     1L REQ.O.HAUL=,F8.0,3X,13H FLIGHT HOURS)
9400 FORMAT(1H ,3X,62HMEAN ELAPSED TIME TO REPAIR TRANSMISSION . . . .
     1. . . . . . =,F8.2,3X,11H DOWN HOURS)
9500 FORMAT(1H ,3X,62HTRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT
     1ORG.  . . . =,F8.2,3X,16H MMH/FLIGHT HOUR)
7800 FORMAT(1H ,3X,62HTRANSMISSION GSE INITIAL TOOLING COST CONTRIBUTIO
     1N TO LCCA . =,F11.0,2H $)
7900 FORMAT(1H ,3X,62HTRANSMISSION GSE REPLENESHMENT TOOLING COST CONTR
     1. TO LCCA . =,F11.0,2H $)
9600 FORMAT(1H ,3X,62HTRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT
     1DIRECT SUP. =,F8.2,3X,16H MMH/FLIGHT HOUR)
9700 FORMAT(1H ,3X,62HTRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT
     1DEPOT . . . =,F8.2,3X,16H MMH/FLIGHT HOUR)
9800 FORMAT(1H ,3X,62HTRANSMISSION UNSCHEDULED MAINTENANCE FREQUENCY .
     1. . . . . . =,F8.4)
9900 FORMAT(1H1,112H****WARNING- PERCENT OF ORGANIZATIONAL REMOVED TRAN
     1SMISSIONS REMOVED: SHIPPED TO DIR. SUP.,REPAIRED AND SCRAPPED,/,
     234H DOES NOT TOTAL 100 FOR MODULE NO.,I3)
9901 FORMAT(1H1,113H****WARNING- PERCENT OF DIRECT SUPPORT TRANSMISSION
     1S REMOVED AND RECEIVED: SHIPPED TO DEPOT,REPAIRED AND SCRAPPED,/,
     234H DOES NOT TOTAL 100 FOR MODULE NO.,I3)
9902 FORMAT(1H1,75H****WARNING- PERCENT OF DEPOT RECEIVED TRANSMISSIONS
     1: REPAIRED AND SCRAPPED,/,34H DOES NOT TOTAL 100 FOR MODULE NO.,I3
     22)
9903 FORMAT(1H1,114H****WARNING- PERCENT OF ON AIRCRAFT REPAIRS AT ORGA
     1NIZATIONAL AND DIRECT SUPPORT DOES NOT TOTAL 100 FOR MODULE NO.,I3
     22)
      INTEGER REMARK(20),END
      DATA END/3HEND/
1     READ(5,200) (REMARK(I),I=1,20)
      IF(REMARK(1).EQ.END) STOP
C
```

```
C  READ INPUT DATA
C
      READ(5,400) N,NBA
      M=2*N
      READ(5,200)(NAME(J),J=1,M)
C
C  READ AIRCRAFT COST DATA
C
      READ(5,100) LCCBA,CFUEL,B,KGAP
C
C  READ AIRCRAFT RELIABILITY/MAINTAINABILITY DATA
C
      READ(5,100) ABTBA,DHFHBA
C
C  READ AIRCRAFT MISSION DATA
C
      READ(5,100) AMCAPB,AMEFFB,EFFBX,EFFX
      READ(5,100) FFBA,SERLIF,TIMIS,UA,UD,WTBX,WTX
C
C  READ TRANSMISSION COST DATA
C
      READ(5,100) (CCONT (J),J=1,N)
      READ(5,100) (CGSE  (J),J=1,N)
      READ(5,100) (CMRON (J),J=1,N)
      READ(5,100) (CMRDS (J),J=1,N)
      READ(5,100) (CMRDE (J),J=1,N)
      READ(5,100) (CNR   (J),J=1,N)
      READ(5,100) (CR    (J),J=1,N)
      READ(5,100) (CSCF  (J),J=1,N)
      READ(5,100) (CSDEF (J),J=1,N)
      READ(5,100) (CSFDE (J),J=1,N)
      READ(5,100) (CPORDE(J),J=1,N)
      READ(5,100) (CPDSDE(J),J=1,N)
      READ(5,100) (CPDEF (J),J=1,N)
      READ(5,100) CAQBX,CISBX,CRSBX,CMBX,CITBX,CRTBX
      READ(5,100) KGSE,KIVEN,LRCIV,LRMIL
C
C  READ TRANSMISSION RELIABILITY/MAINTAINABILITY DATA
C
      READ(5,100) ABTBX,ABTX,METRBX,MHFHBX,MDAY,MINTER,MPER,UMFBX
      READ(5,100) (ATTRI (J),J=1,N)
      READ(5,100) (METTR (J),J=1,N)
      READ(5,100) (MTBUR (J),J=1,N)
      READ(5,100) (MION  (J),J=1,N)
      READ(5,100) (MRON  (J),J=1,N)
      READ(5,100) (MREM  (J),J=1,N)
      READ(5,100) (MREQ  (J),J=1,N)
      READ(5,100) (MINST (J),J=1,N)
      READ(5,100) (MORI  (J),J=1,N)
      READ(5,100) (MORS  (J),J=1,N)
      READ(5,100) (MDSI  (J),J=1,N)
      READ(5,100) (MDSR  (J),J=1,N)
      READ(5,100) (MDSS  (J),J=1,N)
      READ(5,100) (MDEI  (J),J=1,N)
      READ(5,100) (MDER  (J),J=1,N)
      READ(5,100) (MDES  (J),J=1,N)
      READ(5,100) (PORS  (J),J=1,N)
      READ(5,100) (PORDS (J),J=1,N)
      READ(5,100) (PORDE (J),J=1,N)
```

```
      READ(5,100) (PDSS  (J),J=1,N)
      READ(5,100) (PDSR  (J),J=1,N)
      READ(5,100) (PDSDE (J),J=1,N)
      READ(5,100) (PDER  (J),J=1,N)
      READ(5,100) (PDES  (J),J=1,N)
      READ(5,100) (PORON (J),J=1,N)
      READ(5,100) (PDSON (J),J=1,N)
      READ(5,100) (TBO   (J),J=1,N)
      READ(5,100) (UMF   (J),J=1,N)
C
C   INPUT DATA CHECK
C
      DO 18 J=1,N
      PERCEN = PORS(J)+PORDS(J)+PORDE(J)
   18 IF((PERCEN .LT.99.9).OR.(PERCEN .GT.100.1)) WRITE(6,9900) J
      DO 19 J=1,N
      PERCEN = PDSS(J)+PDSR(J)+PDSDE(J)
   19 IF((PERCEN .LT.99.9).OR.(PERCEN .GT.100.1)) WRITE(6,9901) J
      DO 20 J=1,N
      PERCEN = PDES(J)+PDER(J)
   20 IF((PERCEN .LT.99.9).OR.(PERCEN .GT.100.1)) WRITE(6,9902) J
      DO 21 J=1,N
      PERCEN = PORON(J)+PDSON(J)
   21 IF((PERCEN .LT.99.9).OR.(PERCEN .GT.100.1)) WRITE(6,9903) J
C
C   SET INITIAL VALUES EQUAL TO ZERO
C
      UMFX   = 0.
      SUM1   = 0.
      QCONT  = 0.
      COCONT = 0.
      CNRX   = 0.
      CRX    = 0.
      CISX   = 0.
      CRSX   = 0.
      CITX   = 0.
      SUM3   = 0.
      SUM4   = 0.
      SUM5   = 0.
      SUM6   = 0.
      MHFHDE = 0.
      SUM7   = 0.
      CSORDE = 0.
      CSHDEF = 0.
      CSDSDE = 0.
      DHFHX  = 0.
      SUM8   = 0.
      SUM9   = 0.
      SUM10  = 0.
      DO 2  J=1,N
      UMFX   = UMFX + UMF(J)
      SUM1   = SUM1 + 1./MTBUR(J)
      IF((TBO(J)/MTBUR(J)).GT.20.) GO TO 22
      MTBR(J)= MTBUR(J)*(1.-EXP(-TBO(J)/MTBUR(J)))
      GO TO 2
   22 MTBR(J)=MTBUR(J)
    2 CONTINUE
      MTBURX = 1./SUM1
      LCFH   = UA*SERLIF
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      DO 3  J=1,N
      NMOD(J)=(LCFH/MTBUR(J))*(PORS(J)/100. + PORDS(J)*PDSS(J)/10000. +
     1 PORDE(J)*PDES(J)/10000. + PORDS(J)*PDSDE(J)*PDES(J)/1000000.   -
     2 PDES(J)/100.) + (LCFH/MTBR(J))*(PDES(J)/100.) + (LCFH*ATTRI(J))
      QCONT  = QCONT + KIVEN*NMOD(J)
      COCONT = COCONT+ KIVEN*CCONT(J)*NMOD(J)
      CNRX   = CNRX  + KGAP*CNR(J)/((NMOD(J)+1.)*NBA)
    3 CRX    = CRX   + KGAP*CR(J)
      CACQX  = CRX + CNRX
      DO 4  J=1,N
      CACQ(J)= KGAP*(CNR(J)/((NMOD(J)+1.)*NBA)  + CR(J))
      CISX   = CISX  + KIVEN*NMOD(J)*(CACQ(J)+CCONT(J)+CSCF(J))
      CRSX   = CRSX  + CACQ(J)*NMOD(J)*(1.-KIVEN) + NMOD(J)*(CSCF(J)*
     1 (1.-KIVEN))
    4 CITX   = CITX  + CGSE(J)/NBA
      CRTX   = KGSE * CITX
      DO 5  J=1,N
    5 SUM3   = SUM3 +  MION(J)*UMF(J) + MRON(J)*(UMF(J)-1./MTBUR(J))*
     1 PORON(J)/100. + (1./MTBR(J))*(MREM(J)+MREQ(J)+MINST(J)) +
     2 MORI(J)/MTBUR(J) + MORS(J)*PORS(J)/(MTBUR(J)*100.)
      MHFHOR = SUM3 + MDAY/UD + MINTER/25.
      DO 6  J=1,N
      SUM4   = SUM4 + LCFH*CMRON(J)*(UMF(J)-(1./MTBUR(J)))*(PORON(J)
     1 /100.)
      SUM5   = SUM5 + MDSI(J)*PORDS(J)/(MTBUR(J)*100.) + MDSR(J) *
     1 PORDS(J)*PDSR(J)/(MTBUR(J)*10000.) + MDSS(J)*PORDS(J)*PDSS(J)/
     2 (MTBUR(J)*10000.) + (PDSON(J)/100.)*(MRON(J))*((UMF(J))-1./
     3 MTBUR(J))
      SUM6   = SUM6 + LCFH*(CMRDS(J)*PORDS(J)*PDSR(J)/(MTBUR(J)*10000.)+
     1 (CMRON(J))*(UMF(J)-(1./MTBUR(J)))*PDSON(J)/100.)
    6 MHFHDE = MHFHDE+ ((PORDS(J)*PDSDE(J)/10000.+PORDE(J)/100.-1.)/
     1 MTBUR(J)+1./MTBR(J))*(MDEI(J)+MDER(J)*PDER(J)/100.+MDES(J) *
     2 PDES(J)/100.)
      CMORX  = SUM4 + LRMIL*LCFH*MHFHOR
      MHFHDS = SUM5 + MPER/100.
      CMDSX  = SUM6 + LRMIL*LCFH*MHFHDS
      DO 7  J=1,N
      SUM7   = SUM7 + (CMRDE(J)*PDER(J)/100.)*((PORDE(J)/100. + PORDS(J)
     1 *PDSDE(J)/10000. -1.)/MTBUR(J) + 1./MTBR(J))
      CSORDE = CSORDE+ LCFH*((CPORDE(J)+CSFDE(J))*((PORDE(J)/100.-1.)/
     1 MTBUR(J) + 1./MTBR(J)))
      CSDSDE = CSDSDE+ LCFH*((PORDS(J)*PDSDE(J)/(MTBUR(J)*10000.))*(
     1 CPDSDE(J)+CSFDE(J)))*LCFH
    7 CSHDEF = CSHDEF+LCFH*((CSDEF(J)*PDER(J)/100 )*((PORDE(J)/100.+
     1 PORDS(J)*PDSDE(J)/10000.-1.)/MTBUR(J)+1./MTBR(J)))
      CMDEX  = LRCIV*LCFH*MHFHDE+SUM7
      CSMX   = CSORDE + CSDSDE + CSHDEF
      CMX    = CMORX  + CMDSX  + CMDEX  + CSMX
      DO 8  J=1,N
      DHFHX  = DHFHX + UMF(J)*METTR(J)
    8 SUM8   = SUM8  + UMF(J)
      METTRX = DHFHX/SUM8
      DO 9  J=1,N
    9 SUM9   = SUM9  + METTR(J)*UMF(J)
      DHFHA  = DHFHBA- METRBX*UMFBX + SUM9
      AVAIL  = (24.-DHFHA*UD)/24.
      ABORT  = (ABTBA-ABTBX+ABTX)*1000.
      RELIA  = EXP(-TIMIS*(ABORT/1000))
      DCAPWT =-.02163
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      DCAPEF =  .404
      DFFWT  =  .0109
      DFFEFF = -21.39
      AMCAP  = AMCAPB- .02163*(WTX-WTBX)+.404*(EFFX-EFFBX)
      AMEFF  = AVAIL*RELIA*AMCAP
      FF     = FFBA + .0109*(WTX-WTBX)- 21.39*(EFFX-EFFBX)
      CPOL   = CFUEL*LCFH*FF
      DO 10 J=1,N
   10 SUM10  = SUM10 + (KGAP/NBA)*(CNR(J)/(NMOD(J)+1.)) + CGSE(J)/NBA
      LCCA   =(LCCBA - B*(CAQBX+CISBX+CRSBX+CITBX+CRTBX+CMBX) - FFBA*
     1 CFUEL*LCFH + B*(CACQX+CISX+CRSX+CITX+CRTX+CMX) + CPOL + (AMEFF/
     2 AMEFFB - 1.)*SUM10 + (4170.+1100.*SERLIF)*(MHFHOR+MHFHDS-MHFHBX))
     3/1000000.
      ACE    =(AMEFF/LCCA)
      FEC    =(NBA*AMEFFB/ACE)
      WRITE(6,300)(REMARK(I),I=1,20)
      WRITE(6, 500)
      WRITE(6, 600) LCCBA
      WRITE(6, 700) CFUEL
      WRITE(6, 800) B
      WRITE(6, 900) KGAP
      WRITE(6,1000)
      WRITE(6,1100) ABTBA
      WRITE(6,1200) DHFHBA
      WRITE(6,1300)
      WRITE(6,1400) AMCAPB
      WRITE(6,1500) AMEFFB
      WRITE(6,2000) EFFBX
      WRITE(6,2100) EFFX
      WRITE(6,2200) FFBA
      WRITE(6,2300) SERLIF
      WRITE(6,2400) TIMIS
      WRITE(6,2500) UA
      WRITE(6,2600) UD
      WRITE(6,2700) WTBX
      WRITE(6,2800) WTX
      WRITE(6,2850) NBA
      WRITE(6,2900)
      DO 11 J=1,N
   11 WRITE(6,3000) NAME(2*J-1),NAME(2*J),J,CCONT(J),CGSE(J),CMRON(J),
     1              CMRDS(J),CMRDE(J),CNR(J),CR(J)
      WRITE(6,3100)
      DO 12 J=1,N
   12 WRITE(6,3010) NAME(2*J-1),NAME(2*J),J,CSCF(J),CSDEF(J),CSFDE(J),
     1              CPORDE(J),CPDSDE(J),CPLDEF(J)
      WRITE(6,3200) CAQBX
      WRITE(6,3300) CISBX
      WRITE(6,3400) CRSBX
      WRITE(6,3500) CMBX
      WRITE(6,3600) CITBX
      WRITE(6,3700) CRTBX
      WRITE(6,3800) KGSE
      WRITE(6,3900) KIVEN
      WRITE(6,4000) LRCIV
      WRITE(6,4100) LRMIL
      WRITE(6,4200)
      DO 13 J=1,N
   13 WRITE(6,4300) NAME(2*J-1),NAME(2*J),J,ATTRI(J),METTR(J),MTBUR(J),
     1              MION(J),MRON(J),MREM(J),MREQ(J)
```

```
      WRITE(6,4400)
      DO 14 J=1,N
   14 WRITE(6,4500) NAME(2*J-1),NAME(2*J),J,MINST(J),MORI(J),MORS(J),
     1              MDSI(J),MDSR(J),MDSS(J),MDEI(J)
      WRITE(6,4600)
      DO 15 J=1,N
   15 WRITE(6,4700) NAME(2*J-1),NAME(2*J),J,MDER(J),MDES(J),PORS(J),
     1              PORDS(J),PORDE(J),PDSS(J),PDSR(J)
      WRITE(6,4800)
      DO 16 J=1,N
   16 WRITE(6,4900) NAME(2*J-1),NAME(2*J),J,PDSDE(J),PDER(J),PDES(J),
     1              PORON(J),PDSON(J),TBO(J),UMF(J)
      WRITE(6,5000) ABTBX
      WRITE(6,5100) ABTX
      WRITE(6,5200) METRBX
      WRITE(6,5250) MHFHBX
      WRITE(6,5300) MDAY
      WRITE(6,5400) MINTER
      WRITE(6,5500) MPER
      WRITE(6,5600) UMFBX
C
C  PRINT OUTPUT DATA
C
      WRITE(6,300) (REMARK(I),I=1,20)
      WRITE(6,5700)
      WRITE(6,5800) ACE
      WRITE(6,5900) FEC
      WRITE(6,6000) LCCA
      WRITE(6,6100)
      WRITE(6,6200) ABORT
      WRITE(6,6300) AVAIL
      WRITE(6,6400) DHFHA
      WRITE(6,6500) RELIA
      WRITE(6,6600)
      WRITE(6,6700) AMCAP
      WRITE(6,6800) AMEFF
      WRITE(6,6900) CPOL
      WRITE(6,7000) FF
      WRITE(6,7100)
      WRITE(6,7200) COCONT
      WRITE(6,7300) CNRX
      WRITE(6,7400) CRX
      WRITE(6,7500) CACQX
      WRITE(6,7600) CISX
      WRITE(6,7700) CRSX
      WRITE(6,7800) CITX
      WRITE(6,7900) CRTX
      WRITE(6,8000) CMORX
      WRITE(6,8100) CMDSX
      WRITE(6,8200) CMDEX
      WRITE(6,8300) CSORDE
      WRITE(6,8400) CSDSDE
      WRITE(6,8500) CSHDEF
      WRITE(6,8600) CSMX
      WRITE(6,8700) CMX
      WRITE(6,8800) QCONT
      WRITE(6,9000)
      WRITE(6,9100) DHFHX
      WRITE(6,9200) MTBURX
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      WRITE(6,9400) METTRX
      WRITE(6,9500) MHFHOR
      WRITE(6,9600) MHFHDS
      WRITE(6,9700) MHFHDE
      WRITE(6,9800) UMFX
      DO 17 J=1,N
   17 WRITE(6,8900) NAME(2*J-1),NAME(2*J),J,NMOD(J)
      GO TO 1
      END
```

LISTING OF SAMPLE INPUT DECK

```
MODULARIZED TRANSMISSION - BASELINE CONFIGURATION - FLEET SIZE  60 A/C
         1        60
BASELINE
10194000.    .0181       1.       1.20
 .0125     2.3
 503.386   446.95    98.170    98.170
 3336.27   15.0      .344     280.         1.13    3096.      3096.
3575.
 117500.
 16.97
 30.36
   4464.41
 1650000.
 135848.
  377.
 377.
 377.
 95.
 95.
 156.
181500.    78508.    65852.    96809.    1958.33   2726.66
 1.392     .539      19.50       9.50
 .00040    .00040    4.37      .35        .1         1.5      2.5       .00975
  .000187
4.37
  615.0
  .48
10.04
  12.6
  2.0
  25.2
   3.0
  5.0
   5.0
   19.73
  5.0
   40.0
   377.
  5.0
   0.0
   49.2
   50.8
   0.0
   20.
   80.
   100.
   0.0
65.
35.
  99999.
 .00975

MODULARIZED TRANSMISSION - 7 MODULE DESIGN - FLEET SIZE  60 A/C
         7        60
LH INPUTRH INPUTLH FWU  RH FWU  TTO     MN. BEV.PLANET.
10194000.   .0181      1.0      1.20
 .0125     2.3
 503.386   446.95    98.170    98.085
 3336.27     15.0     .344    280.0      1.13     3096.0     3151.66
  871.     871.      252.        280.    1075.     2290.      2330.
 16600.     14800.    2000.    2000.     26000.     20500.     38100.
  19.20      11.50      1.20     1.20    7.20      66.00      29.40
31.       18.       13.        13.      248.      590.      36.
 641.      570.       74.       74.      1010.     791.       1500.
 253230.   223870.  29360.     29360.   398200.   311950.      589030.
  18890.   16440.    2300.     2300.    27340.    24760.     44940.
 38.       36.       20.        20.      33.       123.       184.
```

```
 38.        36.        20.        20.         33.       123.        184.
38.        36.        20.        20.          33.        123.       184.
29.        29.        10.        10.          33.       57.         76.
 29.        29.        10.        10.        33.        57.          76.
47.        47.        16.        15.        55.         94.         125.
181500.     78508.     65852.     96809.     1958.33    2726.66
 1.392      .539       19.50      9.50
 .00040     .00044     4.37       .35         .1         1.5        2.5        .00975
 .0001875   .0001875   .000208    .000208    0.0001875.0001875      .0001875
2.91       2.19       2.77       0.37       2.45       7.16        5.79
2400.      2824.      4800.      4800.      1091.      3429.       1297.
  .4        .4         .44        .44        .48        .6          .6
5.49       4.19       5.12       1.00       6.05       18.64       14.67
2.16       1.36       1.13        .33       2.67       14.13       15.5
2.0        2.0         2.0       2.0         2.0        2.0        2.
4.34        2.74      2.27       .67        5.33        28.27       30.0
  .4         .4         .27         .27       .53        1.06        1.06
  1.0       1.0       .5         .5         1.5         2.0         2.0
  .75       .75       .51         .51       .99         1.99        1.99
5.08       7.77       4.41       1.00       0.80       37.60        31.64
  1.0       1.0       .5         .5         1.5         2.0         2.0
  3.0        3.0       2.0       2.0        8.0         9.5          9.5
  36.3       29.0      14.5      10.9        54.5       90.7        127.1
  1.0       1.0       .5         .5         1.5         2.0         2.0
 0.0        0.0        0.0        0.0       0.0         0.0         0.0
  30.        30.       90.        90.        35.        10.         10.
  70.        70.        10.       10.       65.         90.         90.
 0.0        0.0        0.0         0.0      0.0         0.0         0.0
  20.       20.        90.        90.        40.        10.          10.
  80.        80.       10.        10.        60.        90.         90.
  100.       100.      90.       90.         100.        100.       100.
 0.0        0.0        10.         10.        0.0         0.0           0.0
 68.         39.        56.        56.       100.         91.        92.
  32.        61.        44.        44.        0.0       9.0          8.0
  99999.      99999.   99999.      99999.    99999.     99999.     99999.
 .00292      .00177    .0016      .00021     .0013      .00069      .00244

MODULARIZED TRANSMISSION - 6 MODULE DESIGN - FLEET SIZE  60 A/C
          6        60
LH INPUTRH INPUTLH FWU  RH FWU  TTO      MB + PLN
10194000. .0181     1.0         1.20
 .0125       2.30
503.386     446.950   98.170     98.098
 3336.27    15.0       .344        280.     1.13       3096.        3139.82
  871.      871.       252.      280.     1075.      2330.
 16600.     14800.     2000.      2000.      26000.   58100.
 19.20      11.50     1.20       1.20      7.20       34.10
 30.60      17.80      13.30      13.30     247.80     104.40
 641.      570.       74.        74.       1010.      2263.
253230.     223870.    29360.      29360.  398200.     874550.
18890.      16440.     2300.      2300.      27340.    69416.
 38.       36.         20.        20.       33.        255.
 38.       36.         20.        20.       33.        255.
 38.       36.         20.        20.       33.        255.
 29.       29.         10.       10.        33.        76.
 29.       29.         10.       10.        33.        76.
  47.       47.        16.        16.       55.        125.
181500.     78508.    65852.     96809.     1958.33   2726.66
1.392      .539       19.50      9.50
.00040     .00044     4.37        .35      .10        1.5        2.5         .00975
.0001875    .0001875   .000208    .000208    .0001875  .0001875
2.91       2.19       2.77       .37        2.45      5.41
2400.      2824.     4800.      4800.      1091.      1170.
 .40        .40        .44        .44      .48        .60
5.49       4.19       5.12       1.00       6.05      14.24
2.16        1.36      1.13       .33        2.67      14.83
  2.0       2.0        2.0        2.0        2.0       2.0
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```
 4.34      2.74      2.27       .67       5.33      29.66
    .4        .4     .27        .27      .53        1.98
  1.0      1.0      .5           .5        1.5       2.5
 .75       .75       .51        .51      .99       3.62
 5.08      7.77      4.41       1.00      .8       33.02
  1.0      1.0      .5           .5        1.5       2.5
 3.0        3.0       2.0       2.0       8.0      20.0
 36.3      29.0      14.5      10.9     54.5      219.8
  1.0      1.0      .5           .5        1.5       2.5
 0.0       0.0        0.0      0.0       0.0       0.0
  30.       30.         90.        90.      35.       10.
 70.        70.      10.        10.        65.       90.
 0.0        0.0         0.0       0.0      0.0       0.0
 20.       20.       90.        90.       40.       10.
80.        80.         10.        10.     60.       90.
  100.      100.       90.        90.      100.      100.
  0.0       0.0      10.        10.      0.0        0.0
 68.       39.       56.        56.      100.       91.5
 32.       61.      44.        44.        0.0        8.5
 99999.    99999.    99999.    99999.    99999.     99999.
.0029      .0018    .0016     .0002     .0013     .0029

MODULARIZED TRANSMISSION - 4 MODULE DESIGN - FLEET SIZE  60 A/C
         4         60
L IN+FWUR IN+FWUTTO     MB + PLN
10194000.  .0181     1.0       1.20
.0125      2.30
503.386   446.95     98.170     98.136
3336.27    15.0      .344      280.        1.13      3096.      3113.66
871.       871.     1075.     2330.
18100.     16300.     26000.    58100.
12.78      11.47    7.20       34.10
25.24      17.80      247.80     104.40
687.       616.      1010.     2263.
256090.    226730.   398200.   874550.
21059.     18609.   27340.     69416.
42.          40.     33.       255.
42.          40.     33.       255.
42.          40.     33.       255.
29.        29.       33.        76.
29.        29.       33.        76.
47.          47.      55.      125.
181500.     78508.   65852.     96809.     1958.33   2726.66
1.392       .539     19.50       9.50
.00040      .00042    4.37       .35         .1         1.5      2.5        .00975
.0001875  .0001875  .0001875  .0001875
2.90      2.10      2.45      5.41
2400.     2824.     1091.     1170.
  .41        .41        .48     .60
5.45      3.85      6.05      14.24
1.82        .98      2.67      14.83
 2.0       2.0       2.0        2.0
3.65      1.97      5.33      29.66
.53       .53       .53       1.98
1.25        1.25      1.5       2.5
  .9        .9       .99       3.62
4.70      7.77       .8       33.02
1.25        1.25      1.5       2.5
5.25      5.25      8.         20.
  52.8     41.9      54.5      219.8
1.25        1.25      1.5       2.5
0.0        0.0      0.0        0.0
30.        30.       35.       10.
70.       70.        65.       90.
0.0        0.0      0.0        0.0
20.         20.      40.        10.
```

```
80.         80.       60.       90.
100.        100.      100.      100.
0.0         0.0      0.0       0.0
63.        50.        100.      91.5
37.         50.       0.0        8.5
99999.     99999.    99999.    99999.
.0043      .0018     .0013     .0029

MODULARIZED TRANSMISSION - 3 MODULE DESIGN - FLEET SIZE  60 A/C
         3         60
L IN+FWUR IN+FWUMB+PL+TT
10194000.  .0181     1.0       1.20
.0125      2.30
503.386     446.95    98.170    98.161
3336.27     15.0     .344      280.       1.13      3096.     3103.
871.       871.      2330.
18100.      16300.    83600.
12.78       11.47     22.13
25.24      17.80      133.50
687.       616.       3245.
256090.      226730.  1246320.
21059.      18609.    96585.
42.         40.       263.
42.         40.       263.
42.         40.       263.
29.         29.       95.
29.         29.       95.
47.         47.      156.
181500.      78508.   65852.    96809.    1958.33   2726.66
1.392       .539     19.50     9.50
.00040      .00042    4.37      .35        .1         1.5      2.5       .00975
.0001875     .0001875  .0001875
2.90       2.10      4.51
2400.      2824.     640.
0.41       0.41      0.52
5.45       3.85       12.69
1.82        .98      13.50
2.0         2.0       2.0
3.65       1.97      27.00
  .53        .53       2.37
1.25        1.25      2.75
  .9        .9         4.25
4.70        7.77     33.02
1.25        1.25      2.75
  5.25        5.25      28.50
  52.8      41.9      276.3
1.25        1.25      2.75
0.0         0.0        0.0
30.         30.        10.
70.         70.       90.
0.0         0.0        0.0
20.         20.        10.
80.        80.         90.
100.        100.         100.
0.0         0.0        0.0
  63.      50.         93.
 37.       50,        7.
99999.      99999.    99999.
.0043      .0018     .004
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LISTING OF SAMPLE OUTPUT DECK

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MODULARIZED TRANSMISSION - BASELINE CONFIGURATION - FLEET SIZE  60 A/C

        AIRCRAFT COST INPUT DATA

   LIFE CYCLE COST OF BASELINE AIRCRAFT . . . . . . . . . . . . . . =  10194000. $
   COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . . . . . =    0.0181  $ PER LB.
   NUMBER OF MAIN TRANSMISSIONS PER AIRCRAFT. . . . . . . . . . . . =    1.
   FACTOR FOR GENERAL AND ADMINISTRATIVE OVERHEAD PLUS PROFIT . . . =    1.20

        AIRCRAFT RELIABILITY/MAINTAINABILITY INPUT DATA

   MISSION ABORT RATE OF BASELINE AIRCRAFT. . . . . . . . . . . . . =    0.0125  ABORTS PER FLIGHT HOUR
   DOWN HOURS PER FLIGHT HOUR OF BASELINE AIRCRAFT. . . . . . . . . =    2.3000

        AIRCRAFT MISSION INPUT DATA

   AIRCRAFT MISSION CAPABILITY, BASELINE AIRCRAFT . . . . . . . . . =  503.386    TON-KNOTS
   AIRCRAFT MISSION EFFECTIVENESS, BASELINE AIRCRAFT. . . . . . . . =  446.950    TON-KNOTS
   EFFICIENCY OF BASELINE TRANSMISSION. . . . . . . . . . . . . . . =   98.170   PERCENT
   EFFICIENCY OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . . =   98.170   PERCENT
   AVERAGE MISSION FUEL FLOW OF BASELINE AIRCRAFT . . . . . . . . . = 3336.270    LBS.PER HOUR
   SERVICE LIFE . . . . . . . . . . . . . . . . . . . . . . . . . . =   15.000    YEARS
   AVERAGE MISSION TIME . . . . . . . . . . . . . . . . . . . . . . =    0.344    HOURS
   ANNUAL UTILIZATION OF AIRCRAFT . . . . . . . . . . . . . . . . . =  280.000    FLIGHT HOURS
   DAILY UTILIZATION OF AIRCRAFT. . . . . . . . . . . . . . . . . . =    1.130    FLIGHT HOURS
   WEIGHT OF BASELINE TRANSMISSION. . . . . . . . . . . . . . . . . = 3096.000    POUNDS
   WEIGHT OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . . . . = 3096.000    POUNDS
   NUMBER OF BASELINE AIRCRAFT. . . . . . . . . . . . . . . . . . . =   60

        TRANSMISSION COST INPUT DATA

                      INDIVIDUAL     TOTAL,      MATERIAL      MATERIAL      MATERIAL        TOTAL
                       COST OF      COST OF       COST OF       COST OF       COST OF         COST           COST
                       SHIPPING     INITIAL    MODULE REPAIR MODULE REPAIR MODULE REPAIR  NON-RECURRING    RECURRING
                      CONTAINER   GSE TOOLING   ON AIRCRAFT  AT DIRECT SUP   AT DEPOT

   BASELINE  NO.  1   $   3575.   $ 117500.    $     17.     $     30.     $   4464.     $1650000.      $ 135848.

                       COST TO      COST TO      COST TO       COST TO       COST TO       COST TO
                     SHIP MODULE  SHIP MODULE  SHIP MODULE   PREP. SHIP    PREP. SHIP    PREP. SHIP
                     U.S. TO FIELD DEPOT TO FIELD FIELD TO DEPOT FIELD TO DEPOT DIR.SUP./DEPOT DEPOT TO FIELD

   BASELINE  NO.  1   $    377.    $    377.    $    377.     $     95.     $     95.     $    156.

   COST OF ACQUISITION, BASELINE TRANSMISSION . . . . . . . . . . =  181500. $
   COST OF INITIAL SPARES, BASELINE TRANSMISSION. . . . . . . . . =   78508. $
   COST OF REPLENISHMENT SPARES, BASELINE TRANSMISSION. . . . . . =   65852. $
   COST OF MAINTENANCE, BASELINE TRANSMISSION . . . . . . . . . . =   96809. $
   COST OF INITIAL GSE TOOLING, BASELINE TRANSMISSION . . . . . . =    1958. $
   COST OF REPLENISHMENT GSE TOOLING, BASELINE TRANSMISSION . . . =    2727. $
   RATIO OF GSE TOOLING REPLENISHMENT REQT/ GSE TOOLING,XMISSION=      1.392
   RATIO OF INITIAL SPARES REQD TO REPLENISHMENT SPARES REQD. . =      0.539
   LABOR RATE, CIVILIAN MAINTENANCE PERSONNEL,DIRECT + INDIRECT =     19.50   $/HOUR
   LABOR RATE, MILITARY MAINTENANCE PERSONNEL, DIRECT + INDIRECT=      9.50   $/HOUR

        TRANSMISSION RELIABILITY/MAINTAINABILITY INPUT DATA

                      ATTRITION   MEAN ELAPSED  MEAN TIME BET.   MEAN MMH      MEAN MMH      MEAN MMH      MEAN MMH
                      RATE, MOD.  TIME REP. MOD. UNSCH.MOD.REM. INSPECT MOD.  REPAIR MOD.   REMOVE MOD.  REQUISITION
                    LOST/FLGT HR.  DOWN HOURS   FLIGHT HOURS   ON AIRCRAFT   ON AIRCRAFT  FROM AIRCRAFT    MODULE

   BASELINE  NO.  1   0.000187        4.37         615.00          0.48         10.04         12.60          2.00
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                            MEAN MMH       MEAN MMH       MEAN MMH        MEAN MMH        MEAN MMH       MEAN MMH       MEAN MMH
                           INSTALL MOD   INSPECT MOD.    SCRAP MOD.     INSPECT MOD.    REPAIR MOD.    SCRAP MOD.    INSPECT MOD.
                           ON AIRCRAFT    AT ORG.         AT ORG.       AT DIR.SUP.     AT DIR.SUP.    AT DIR.SUP.    AT DEPOT

BASELINE  NO.  1              25.00          3.00           5.00            5.00           19.73           5.00          40.00

                            MEAN MMH       MEAN MMH       PERCENT         PERCENT         PERCENT        PERCENT        PERCENT
                           REPAIR MOD.    SCRAP MOD.   UNSCH.MOD.REM. MOD.REM.SHIP.  MOD.REM.SHIP.   MOD. SCRAP   REPAIRED MOD.
                            AT DEPOT       AT DEPOT    SCRAPPED ORG.  ORG./DIR.SUP.   ORG./DEPOT     AT DIR.SUP.   AT DIR.SUP.

BASELINE  NO.  1             377.00          5.00           0.0            49.20           50.80           0.0           20.00

                            PERCENT        PERCENT        PERCENT       PERCENT ON      PERCENT ON       TIME        UNSCHEDULED
                          MOD.REC.SHIP.  REPAIR MOD.     SCRAP MOD.    AIRCRAFT REP.   AIRCRAFT REP.   BETWEEN       MAINTAINENCE
                          DIR.SUP/DEPOT   AT DEPOT        AT DEPOT       AT ORG.        AT DIR. SUP.    OVERHAUL      FREQUENCY

BASELINE  NO.  1              80.00        100.00           0.0            65.00           35.00         99999.         0.0097

MISSION ABORT RATE, BASELINE TRANSMISSION. . . . . . . . . . =     0.00040 ABORTS PER FLIGHT HOUR
MISSION ABORT RATE, CANDIDATE TRANSMISSION . . . . . . . . . =     0.00040 ABORTS PER FLIGHT HOUR
MEAN ELAPSED TIME TO REPAIR BASELINE TRANSMISSION. . . . . . =     4.37    DOWN HOURS
TOTAL MMH/FH AT ORG. AND DIR. SUP.,BASELINE TRANSMISSION . . =     0.35    MMH/FH
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION DAILY INSPECTION. =     0.10    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION INTERMEDIATE INSP =     1.50    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION PERIODIC INSP . . =     2.50    HOURS
UNSCHEDULED MAINTENANCE FREQUENCY, BASELINE TRANSMISSION . . =     0.0097
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MODULARIZED TRANSMISSION - BASELINE CONFIGURATION - FLEET SIZE  60 A/C

         AIRCRAFT COST OUTPUT DATA

    AIRCRAFT COST EFFECTIVENESS. . . . . . . . . . . . . . . . . . =    43.845 TON-KNOTS/MEGAS
    FLEET EFFECTIVE COST . . . . . . . . . . . . . . . . . . . . . =   611.627 MEGA $
    AIRCRAFT LIFE CYCLE COST . . . . . . . . . . . . . . . . . . . =    10.194 MEGA $

         AIRCRAFT RELIABILITY/MAINTAINABILITY OUTPUT DATA

    AIRCRAFT MISSION ABORT FAILURES PER 1000 FLIGHT HOURS. . . . =      12.50  ABORTS/1000 FLT.HR.
    AIRCRAFT MISSION AVAILABILITY. . . . . . . . . . . . . . . . . =     0.892
    AIRCRAFT DOWN HOURS PER FLIGHT HOUR. . . . . . . . . . . . . . =     2.30
    AIRCRAFT MISSION RELIABILITY . . . . . . . . . . . . . . . . . =     0.9957

         AIRCRAFT MISSION OUTPUT DATA PER AIRCRAFT

    AIRCRAFT MISSION CAPABILITY. . . . . . . . . . . . . . . . . . =    503.39  TON KNOTS
    AIRCRAFT MISSION EFFECTIVENESS . . . . . . . . . . . . . . . . =    446.95  TON KNOTS
    TOTAL COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . =   253623.  $
    AVERAGE MISSION FUEL FLOW. . . . . . . . . . . . . . . . . . . =  3336.27   LBS/HOUR

         TRANSMISSION COST OUTPUT DATA PER AIRCRAFT

    TOTAL COST OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . =     1513. $
    TRANSMISSION NON-RECURRING COST. . . . . . . . . . . . . . . . =    18483. $
    TRANSMISSION RECURRING COST. . . . . . . . . . . . . . . . . . =   163018. $
    TRANSMISSION ACQUISITION COST CONTRIBUTION TO LCCA . . . . . . =   181501. $
    TRANSMISSION INITIAL SPARES COST CONTRIBUTION TO LCCA. . . . . =    78508. $
    TRANSMISSION REPLENESHMENT SPARES COST CONTRIBUTION TO LCCA. =    65852. $
    TRANSMISSION GSE INITIAL TOOLING COST CONTRIBUTION TO LCCA . =     1958. $
    TRANSMISSION GSE REPLENESHMENT TOOLING COST CONTR. TO LCCA . =     2726. $
    TRANSMISSION ORGANIZATION MAINTENANCE COST . . . . . . . . . =    11380. $
    TRANSMISSION DIRECT SUPPORT MAINTENANCE COST . . . . . . . . =     2645. $
    TRANSMISSION DEPOT MAINTENANCE COST. . . . . . . . . . . . . =    77556. $
    TRANSMISSION SHIPPING COST BETWEEN ORG.  AND DEPOT . . . . . =     1637. $
    TRANSMISSION SHIPPING COST BETWEEN DIRECT SUPPORT AND DEPOT. =     1269. $
    TRANSMISSION SHIPPING COST BETWEEN DEPOT AND FIELD . . . . . =     2321. $
    TRANSMISSION TOTAL SHIPPING COST BETWEEN MAINTENANCE LEVELS. =     5228. $
    TRANSMISSION TOTAL MAINTENANCE COST. . . . . . . . . . . . . =    96809. $
    QUANTITY OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . =     0.42

         TRANSMISSION RELIABILITY/MAINTAINABILITY OUTPUT DATA

    TRANSMISSION MAINTENANCE DOWN-HOURS PER FLIGHT HOUR. . . . . =   0.043
    TRANSMISSION MEAN TIME BETWEEN UNSCHEDULED REMOVAL REQ.O.HAUL=   615.     FLIGHT HOURS
    MEAN ELAPSED TIME TO REPAIR TRANSMISSION . . . . . . . . . . =   4.37     DOWN HOURS
    TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT ORG.  . . . =   0.2758   MMH/FLIGHT HOUR
    TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DIRECT SUP. =   0.0607   MMH/FLIGHT HOUR
    TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DEPOT . . . =   0.6113   MMH/FLIGHT HOUR
    TRANSMISSION UNSCHEDULED MAINTENANCE FREQUENCY . . . . . . . = 0.0097
    SPARES PRODUCTION RUN.  BASELINE NO.  1. . . . . . . . . . . =   0.79
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MODULARIZED TRANSMISSION - 7 MODULE DESIGN - FLEET SIZE  60 A/C

      AIRCRAFT COST INPUT DATA

   LIFE CYCLE COST OF BASELINE AIRCRAFT . . . . . . . . . . . . . =  10194000. $
   COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . . . . =    0.0181  $ PER LB.
   NUMBER OF MAIN TRANSMISSIONS PER AIRCRAFT. . . . . . . . . . . =    1.
   FACTOR FOR GENERAL AND ADMINISTRATIVE OVERHEAD PLUS PROFIT . =    1.20

      AIRCRAFT RELIABILITY/MAINTAINABILITY INPUT DATA

   MISSION ABORT RATE OF BASELINE AIRCRAFT. . . . . . . . . . . . =    0.0125  ABORTS PER FLIGHT HOUR
   DOWN HOURS PER FLIGHT HOUR OF BASELINE AIRCRAFT. . . . . . . . =    2.3000

      AIRCRAFT MISSION INPUT DATA

   AIRCRAFT MISSION CAPABILITY, BASELINE AIRCRAFT . . . . . . . . =  503.386    TON-KNOTS
   AIRCRAFT MISSION EFFECTIVENESS, BASELINE AIRCRAFT. . . . . . . =  446.950    TON-KNOTS
   EFFICIENCY OF BASELINE TRANSMISSION. . . . . . . . . . . . . . =   98.170   PERCENT
   EFFICIENCY OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . =   98.085   PERCENT
   AVERAGE MISSION FUEL FLOW OF BASELINE AIRCRAFT . . . . . . . . = 3336.270    LBS.PER HOUR
   SERVICE LIFE . . . . . . . . . . . . . . . . . . . . . . . . . =   15.000    YEARS
   AVERAGE MISSION TIME . . . . . . . . . . . . . . . . . . . . . =    0.344    HOURS
   ANNUAL UTILIZATION OF AIRCRAFT . . . . . . . . . . . . . . . . =  280.000    FLIGHT HOURS
   DAILY UTILIZATION OF AIRCRAFT. . . . . . . . . . . . . . . . . =    1.130    FLIGHT HOURS
   WEIGHT OF BASELINE TRANSMISSION. . . . . . . . . . . . . . . . = 3096.000    POUNDS
   WEIGHT OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . . . = 3151.660    POUNDS
   NUMBER OF BASELINE AIRCRAFT. . . . . . . . . . . . . . . . . . =   60

      TRANSMISSION COST INPUT DATA

                              INDIVIDUAL      TOTAL,      MATERIAL      MATERIAL      MATERIAL       TOTAL
                               COST OF       COST OF       COST OF       COST OF       COST OF        COST           COST
                               SHIPPING      INITIAL    MODULE REPAIR MODULE REPAIR MODULE REPAIR NON-RECURRING    RECURRING
                              CONTAINER    GSE TOOLING  ON AIRCRAFT   AT DIRECT SUP   AT DEPOT

   LH INPUT   NO.  1     $     871.     $  16600.     $     19.     $     31.     $    641.     $ 253230.     $  18890.
   RH INPUT   NO.  2     $     871.     $  14800.     $     12.     $     18.     $    570.     $ 223870.     $  16440.
   LH FWU     NO.  3     $     252.     $   2000.     $      1.     $     13.     $     74.     $  29360.     $   2300.
   RH FWU     NO.  4     $     280.     $   2000.     $      1.     $     13.     $     74.     $  29360.     $   2300.
   TTO        NO.  5     $    1075.     $  26000.     $      7.     $    248.     $   1010.     $ 398200.     $  27340.
   MN. BEV.   NO.  6     $    2290.     $  20500.     $     66.     $    590.     $    791.     $ 311950.     $  24760.
   PLANET.    NO.  7     $    2330.     $  38100.     $     29.     $     36.     $   1500.     $ 589030.     $  44940.

                               COST TO       COST TO       COST TO       COST TO       COST TO       COST TO
                             SHIP MODULE   SHIP MODULE   SHIP MODULE   PREP. SHIP    PREP. SHIP    PREP. SHIP
                            U.S. TO FIELD DEPOT TO FIELD FIELD TO DEPOT FIELD TO DEPOT DIR.SUP./DEPOT DEPOT TO FIELD

   LH INPUT   NO.  1     $      38.     $     38.     $     38.     $     29.     $     29.     $     47.
   RH INPUT   NO.  2     $      36.     $     36.     $     36.     $     29.     $     29.     $     47.
   LH FWU     NO.  3     $      20.     $     20.     $     20.     $     10.     $     10.     $     16.
   RH FWU     NO.  4     $      20.     $     20.     $     20.     $     10.     $     10.     $     16.
   TTO        NO.  5     $      33.     $     33.     $     33.     $     33.     $     33.     $     55.
   MN. BEV.   NO.  6     $     123.     $    123.     $    123.     $     57.     $     57.     $     94.
   PLANET.    NO.  7     $     184.     $    184.     $    184.     $     76.     $     76.     $    125.

   COST OF ACQUISITION, BASELINE TRANSMISSION . . . . . . . . . =    181500. $
   COST OF INITIAL SPARES, BASELINE TRANSMISSION. . . . . . . . =     78508. $
   COST OF REPLENISHMENT SPARES, BASELINE TRANSMISSION. . . . . =     65852. $
   COST OF MAINTENANCE, BASELINE TRANSMISSION . . . . . . . . . =     96809. $
   COST OF INITIAL GSE TOOLING, BASELINE TRANSMISSION . . . . . =      1958. $
   COST OF REPLENISHMENT GSE TOOLING, BASELINE TRANSMISSION . . =      2727. $
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RATIO OF GSE TOOLING REPLENISHMENT REQT/ GSE TOOLING,XMISSION=       1.392
RATIO OF INITIAL SPARES REQD TO REPLENISHMENT SPARES REQD. . =       0.539
LABOR RATE, CIVILIAN MAINTENANCE PERSONNEL,DIRECT + INDIRECT =      19.50  $/HOUR
LABOR RATE, MILITARY MAINTENANCE PERSONNEL, DIRECT + INDIRECT=       9.50  $/HOUR

     TRANSMISSION RELIABILITY/MAINTAINABILITY INPUT DATA

                         ATTRITION    MEAN ELAPSED  MEAN TIME BET.   MEAN MMH       MEAN MMH       MEAN MMH        MEAN MMH
                         RATE, MOD.   TIME REP. MOD. UNSCH.MOD.REM.  INSPECT MOD.   REPAIR MOD.    REMOVE MOD.     REQUISITION
                        LOST/FLGT HR.  DOWN HOURS   FLIGHT HOURS    ON AIRCRAFT    ON AIRCRAFT  FROM AIRCRAFT     MODULE

LH INPUT   NO.  1        0.000187        2.91        2400.00          0.40           5.49          2.16           2.00
RH INPUT   NO.  2        0.000187        2.19        2824.00          0.40           4.19          1.36           2.00
LH FWU     NO.  3        0.000208        2.77        4800.00          0.44           5.12          1.13           2.00
RH FWU     NO.  4        0.000208        0.37        4800.00          0.44           1.00          0.33           2.00
TTO        NO.  5        0.000187        2.45        1091.00          0.48           6.05          2.67           2.00
MN. BEV.   NO.  6        0.000187        7.16        3429.00          0.60          18.64         14.13           2.00
PLANET.    NO.  7        0.000187        5.79        1297.00          0.60          14.67         15.50           2.00

                         MEAN MMH      MEAN MMH      MEAN MMH       MEAN MMH       MEAN MMH       MEAN MMH        MEAN MMH
                        INSTALL MOD   INSPECT MOD.   SCRAP MOD.    INSPECT MOD.   REPAIR MOD.    SCRAP MOD.      INSPECT MOD.
                        ON AIRCRAFT    AT ORG.        AT ORG.      AT DIR.SUP.    AT DIR.SUP.    AT DIR.SUP.      AT DEPOT

LH INPUT   NO.  1           4.34         0.40          1.00           0.75           5.08          1.00            3.00
RH INPUT   NO.  2           2.74         0.40          1.00           0.75           7.77          1.00            3.00
LH FWU     NO.  3           2.27         0.27          0.50           0.51           4.41          0.50            2.00
RH FWU     NO.  4           0.67         0.27          0.50           0.51           1.00          0.50            2.00
TTO        NO.  5           5.33         0.53          1.50           0.99           0.80          1.50            8.00
MN. BEV.   NO.  6          28.27         1.06          2.00           1.99          37.60          2.00            9.50
PLANET.    NO.  7          30.00         1.06          2.00           1.99          31.64          2.00            9.50

                         MEAN MMH      MEAN MMH      PERCENT        PERCENT        PERCENT       PERCENT         PERCENT
                        REPAIR MOD.   SCRAP MOD.   UNSCH.MOD.REM. MOD.REM.SHIP.  MOD.REM.SHIP.  MOD. SCRAP     REPAIRED MOD.
                         AT DEPOT      AT DEPOT    SCRAPPED ORG.  ORG./DIR.SUP.  ORG./DEPOT     AT DIR.SUP.     AT DIR.SUP.

LH INPUT   NO.  1          36.30         1.00          0.0           30.00          70.00          0.0            20.00
RH INPUT   NO.  2          29.00         1.00          0.0           30.00          70.00          0.0            20.00
LH FWU     NO.  3          14.50         0.50          0.0           90.00          10.00          0.0            90.00
RH FWU     NO.  4          10.90         0.50          0.0           90.00          10.00          0.0            90.00
TTO        NO.  5          54.50         1.50          0.0           35.00          65.00          0.0            40.00
MN. BEV.   NO.  6          90.70         2.00          0.0           10.00          90.00          0.0            10.00
PLANET.    NO.  7         127.10         2.00          0.0           10.00          90.00          0.0            10.00

                         PERCENT       PERCENT       PERCENT       PERCENT ON     PERCENT ON      TIME          UNSCHEDULED
                       MOD.REC.SHIP.  REPAIR MOD.   SCRAP MOD.    AIRCRAFT REP.  AIRCRAFT REP.   BETWEEN       MAINTAINENCE
                       DIR.SUP/DEPOT   AT DEPOT     AT DEPOT        AT ORG.      AT DIR. SUP.    OVERHAUL       FREQUENCY

LH INPUT   NO.  1          80.00       100.00          0.0           68.00          32.00         99999.         0.0029
RH INPUT   NO.  2          80.00       100.00          0.0           39.00          61.00         99999.         0.0018
LH FWU     NO.  3          10.00        90.00         10.00          56.00          44.00         99999.         0.0016
RH FWU     NO.  4          10.00        90.00         10.00          56.00          44.00         99999.         0.0002
TTO        NO.  5          60.00       100.00          0.0          100.00           0.0          99999.         0.0013
MN. BEV.   NO.  6          90.00       100.00          0.0           91.00           9.00         99999.         0.0007
PLANET.    NO.  7          90.00       100.00          0.0           92.00           8.00         99999.         0.0024

MISSION ABORT RATE, BASELINE TRANSMISSION. . . . . . . . . . =     0.00040 ABORTS PER FLIGHT HOUR
MISSION ABORT RATE, CANDIDATE TRANSMISSION . . . . . . . . . =     0.00044 ABORTS PER FLIGHT HOUR
MEAN ELAPSED TIME TO REPAIR BASELINE TRANSMISSION. . . . . . =     4.37    DOWN HOURS
TOTAL MMH/FH AT ORG. AND DIR. SUP.,BASELINE TRANSMISSION . . =     0.35    MMH/FH
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION DAILY INSPECTION. =     0.10    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION INTERMEDIATE INSP =     1.50    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION PERIODIC INSP . . =     2.50    HOURS
UNSCHEDULED MAINTENANCE FREQUENCY, BASELINE TRANSMISSION . . =     0.0097
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MODULARIZED TRANSMISSION - 7 MODULE DESIGN - FLEET SIZE  60 A/C

      AIRCRAFT COST OUTPUT DATA

   AIRCRAFT COST EFFECTIVENESS. . . . . . . . . . . . . . . . . . =     43.936 TON-KNOTS/MEGA$
   FLEET EFFECTIVE COST . . . . . . . . . . . . . . . . . . . . . =    610.362 MEGA $
   AIRCRAFT LIFE CYCLE COST . . . . . . . . . . . . . . . . . . . =     10.149 MEGA $

      AIRCRAFT RELIABILITY/MAINTAINABILITY OUTPUT DATA

   AIRCRAFT MISSION ABORT FAILURES PER 1000 FLIGHT HOURS. . . . =     12.54  ABORTS/1000 FLT.HP.
   AIRCRAFT MISSION AVAILABILITY. . . . . . . . . . . . . . . . . =     0.892
   AIRCRAFT DOWN HOURS PER FLIGHT HOUR. . . . . . . . . . . . . . =     2.30
   AIRCRAFT MISSION RELIABILITY . . . . . . . . . . . . . . . . . =     0.9957

      AIRCRAFT MISSION OUTPUT DATA PER AIRCRAFT

   AIRCRAFT MISSION CAPABILITY. . . . . . . . . . . . . . . . . . =    502.15  TON KNOTS
   AIRCRAFT MISSION EFFECTIVENESS . . . . . . . . . . . . . . . . =    445.92  TON KNOTS
   TOTAL COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . =    253807. $
   AVERAGE MISSION FUEL FLOW. . . . . . . . . . . . . . . . . . . =   3338.69  LBS/HOUR

      TRANSMISSION COST OUTPUT DATA PER AIRCRAFT

   TOTAL COST OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . =      3412. $
   TRANSMISSION NON-RECURRING COST. . . . . . . . . . . . . . . . =     20496. $
   TRANSMISSION RECURRING COST. . . . . . . . . . . . . . . . . . =    164364. $
   TRANSMISSION ACQUISITION COST CONTRIBUTION TO LCCA . . . . . . =    184860. $
   TRANSMISSION INITIAL SPARES COST CONTRIBUTION TO LCCA. . . . . =     82413. $
   TRANSMISSION REPLENESHMENT SPARES COST CONTRIBUTION TO LCCA. =     67568. $
   TRANSMISSION GSE INITIAL TOOLING COST CONTRIBUTION TO LCCA . =      2000. $
   TRANSMISSION GSE REPLENESHMENT TOOLING COST CONTR. TO LCCA . =      2784. $
   TRANSMISSION ORGANIZATION MAINTENANCE COST . . . . . . . . . . =     11208. $
   TRANSMISSION DIRECT SUPPORT MAINTENANCE COST . . . . . . . . . =      1950. $
   TRANSMISSION DEPOT MAINTENANCE COST. . . . . . . . . . . . . . =     28149. $
   TRANSMISSION SHIPPING COST BETWEEN ORG.  AND DEPOT . . . . . . =      1276. $
   TRANSMISSION SHIPPING COST BETWEEN DIRECT SUPPORT AND DEPOT. =       205. $
   TRANSMISSION SHIPPING COST BETWEEN DEPOT AND FIELD . . . . . . =       967. $
   TRANSMISSION TOTAL SHIPPING COST BETWEEN MAINTENANCE LEVELS. =      2448. $
   TRANSMISSION TOTAL MAINTENANCE COST. . . . . . . . . . . . . . =     43757. $
   QUANTITY OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . . =      3.08

      TRANSMISSION RELIABILITY/MAINTAINABILITY OUTPUT DATA

   TRANSMISSION MAINTENANCE DOWN-HOURS PER FLIGHT HOUR. . . . . =    0.039
   TRANSMISSION MEAN TIME BETWEEN UNSCHEDULED REMOVAL REQ.O.HAUL=    316.     FLIGHT HOURS
   MEAN ELAPSED TIME TO REPAIR TRANSMISSION . . . . . . . . . . . =    3.58     DOWN HOURS
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT ORG.  . . . =    0.2691   MMH/FLIGHT HOUR
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DIRECT SUP. =    0.0413   MMH/FLIGHT HOUR
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DEPOT . . . =    0.2096   MMH/FLIGHT HOUR
   TRANSMISSION UNSCHEDULED MAINTENANCE FREQUENCY . . . . . . . . =  0.0109
   SPARES PRODUCTION RUN,  LH INPUT NO.  1. . . . . . . . . . . . =    0.79
   SPARES PRODUCTION RUN,  RH INPUT NO.  2. . . . . . . . . . . . =    0.79
   SPARES PRODUCTION RUN,  LH FWU   NO.  3. . . . . . . . . . . . =    0.89
   SPARES PRODUCTION RUN,  RH FWU   NO.  4. . . . . . . . . . . . =    0.89
   SPARES PRODUCTION RUN,  TTO      NO.  5. . . . . . . . . . . . =    0.79
   SPARES PRODUCTION RUN,  MN. BEV. NO.  6. . . . . . . . . . . . =    0.79
   SPARES PRODUCTION RUN,  PLANET.  NO.  7. . . . . . . . . . . . =    0.79
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MODULARIZED TRANSMISSION - 5 MODULE DESIGN - FLEET SIZE  60 A/C

     AIRCRAFT COST INPUT DATA

  LIFE CYCLE COST OF BASELINE AIRCRAFT . . . . . . . . . . . . . = 10194000. $
  COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . . . . =    0.0181  $ PER LB.
  NUMBER OF MAIN TRANSMISSIONS PER AIRCRAFT. . . . . . . . . . . =    1.
  FACTOR FOR GENERAL AND ADMINISTRATIVE OVERHEAD PLUS PROFIT . =    1.20

     AIRCRAFT RELIABILITY/MAINTAINABILITY INPUT DATA

  MISSION ABORT RATE OF BASELINE AIRCRAFT. . . . . . . . . . . . =    0.0125  ABORTS PER FLIGHT HOUR
  DOWN HOURS PER FLIGHT HOUR OF BASELINE AIRCRAFT. . . . . . . . =    2.3000

     AIRCRAFT MISSION INPUT DATA

  AIRCRAFT MISSION CAPABILITY, BASELINE AIRCRAFT . . . . . . . . =  503.386    TON-KNOTS
  AIRCRAFT MISSION EFFECTIVENESS, BASELINE AIRCRAFT. . . . . . . =  446.950    TON-KNOTS
  EFFICIENCY OF BASELINE TRANSMISSION. . . . . . . . . . . . . . =   98.170   PERCENT
  EFFICIENCY OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . =   98.098   PERCENT
  AVERAGE MISSION FUEL FLOW OF BASELINE AIRCRAFT . . . . . . . . = 3336.270    LBS.PER HOUR
  SERVICE LIFE . . . . . . . . . . . . . . . . . . . . . . . . . =   15.000    YEARS
  AVERAGE MISSION TIME . . . . . . . . . . . . . . . . . . . . . =    0.344    HOURS
  ANNUAL UTILIZATION OF AIRCRAFT . . . . . . . . . . . . . . . . =  280.000    FLIGHT HOURS
  DAILY UTILIZATION OF AIRCRAFT. . . . . . . . . . . . . . . . . =    1.130    FLIGHT HOURS
  WEIGHT OF BASELINE TRANSMISSION. . . . . . . . . . . . . . . . = 3096.000    POUNDS
  WEIGHT OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . . . = 3139.820    POUNDS
  NUMBER OF BASELINE AIRCRAFT. . . . . . . . . . . . . . . . . . =   60

     TRANSMISSION COST INPUT DATA

                         INDIVIDUAL     TOTAL,      MATERIAL      MATERIAL      MATERIAL       TOTAL
                          COST OF      COST OF       COST OF       COST OF       COST OF        COST          COST
                          SHIPPING     INITIAL    MODULE REPAIR MODULE REPAIR MODULE REPAIR NON-RECURRING   RECURRING
                          CONTAINER  GSE TOOLING   ON AIRCRAFT  AT DIRECT SUP   AT DEPOT

  LH INPUT  NO.  1       $    871.    $ 16600.    $     19.     $     31.     $    641.    $ 253230.     $  18890.
  RH INPUT  NO.  2       $    871.    $ 14800.    $     12.     $     18.     $    570.    $ 223870.     $  16440.
  LH FWU    NO.  3       $    252.    $  2000.    $      1.     $     13.     $     74.    $  29360.     $   2300.
  RH FWU    NO.  4       $    280.    $  2000.    $      1.     $     13.     $     74.    $  29360.     $   2300.
  TTO       NO.  5       $   1075.    $ 26000.    $      7.     $    248.     $   1010.    $ 398200.     $  27340.
  MB & PLN  NO.  6       $   2330.    $ 58100.    $     34.     $    104.     $   2263.    $ 874550.     $  69416.

                          COST TO      COST TO      COST TO       COST TO       COST TO       COST TO
                        SHIP MODULE  SHIP MODULE  SHIP MODULE    PREP. SHIP    PREP. SHIP    PREP. SHIP
                        U.S. TO FIELD DEPOT TO FIELD FIELD TO DEPOT FIELD TO DEPOT DIR.SUP./DEPOT DEPOT TO FIELD

  LH INPUT  NO.  1       $     38.    $     38.    $     38.     $     29.     $     29.     $     47.
  RH INPUT  NO.  2       $     36.    $     36.    $     36.     $     29.     $     29.     $     47.
  LH FWU    NO.  3       $     20.    $     20.    $     20.     $     10.     $     10.     $     16.
  RH FWU    NO.  4       $     20.    $     20.    $     20.     $     10.     $     10.     $     16.
  TTO       NO.  5       $     33.    $     33.    $     33.     $     33.     $     33.     $     55.
  MB & PLN  NO.  6       $    255.    $    255.    $    255.     $     76.     $     76.     $    125.

  COST OF ACQUISITION, BASELINE TRANSMISSION . . . . . . . . . . =    181500. $
  COST OF INITIAL SPARES, BASELINE TRANSMISSION. . . . . . . . . =     78508. $
  COST OF REPLENISHMENT SPARES, BASELINE TRANSMISSION. . . . . . =     65652. $
  COST OF MAINTENANCE, BASELINE TRANSMISSION . . . . . . . . . . =     96809. $
  COST OF INITIAL GSE TOOLING, BASELINE TRANSMISSION . . . . . . =      1958. $
  COST OF REPLENISHMENT GSE TOOLING, BASELINE TRANSMISSION . . . =      2727. $
  RATIO OF GSE TOOLING REPLENISHMENT REQT/ GSE TOOLING,XMISSION=      1.392
  RATIO OF INITIAL SPARES REQD TO REPLENISHMENT SPARES REQD. . =      0.539
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LABOR RATE, CIVILIAN MAINTENANCE PERSONNEL,DIRECT + INDIRECT =     19.50  $/HOUR
LABOR RATE, MILITARY MAINTENANCE PERSONNEL, DIRECT + INDIRECT=      9.50  $/HOUR

     TRANSMISSION RELIABILITY/MAINTAINABILITY INPUT DATA

                        ATTRITION    MEAN ELAPSED  MEAN TIME BET.   MEAN MMH      MEAN MMH      MEAN MMH       MEAN MMH
                        RATE, MOD.   TIME REP. MOD. UNSCH.MOD.REM.  INSPECT MOD.  REPAIR MOD.   REMOVE MOD.    REQUISITION
                      LOST/FLGT HR.   DOWN HOURS   FLIGHT HOURS    ON AIRCRAFT   ON AIRCRAFT  FROM AIRCRAFT   MODULE

LH INPUT   NO. 1       0.000187        2.91        2400.00          0.40          5.49          2.16           2.00
RH INPUT   NO. 2       0.000187        2.19        2824.00          0.40          4.19          1.36           2.00
LH FWU     NO. 3       0.000208        2.77        4800.00          0.44          5.12          1.13           2.00
RH FWU     NO. 4       0.000208        0.37        4800.00          0.44          1.00          0.33           2.00
TTO        NO. 5       0.000187        2.45        1091.00          0.48          6.05          2.67           2.00
MB & PLN   NO. 6       0.000187        5.41        1170.00          0.60         14.24         14.83           2.00

                        MEAN MMH       MEAN MMH       MEAN MMH      MEAN MMH      MEAN MMH      MEAN MMH       MEAN MMH
                       INSTALL MOD   INSPECT MOD.    SCRAP MOD.    INSPECT MOD.  REPAIR MOD.   SCRAP MOD.     INSPECT MOD.
                       ON AIRCRAFT     AT ORG.        AT ORG.      AT DIR.SUP.   AT DIR.SUP.   AT DIR.SUP.     AT DEPOT

LH INPUT   NO. 1          4.34          0.40           1.00          0.75          5.08          1.00           3.00
RH INPUT   NO. 2          2.74          0.40           1.00          0.75          7.77          1.00           3.00
LH FWU     NO. 3          2.27          0.27           0.50          0.51          4.41          0.50           2.00
RH FWU     NO. 4          0.67          0.27           0.50          0.51          1.00          0.50           2.00
TTO        NO. 5          5.33          0.53           1.50          0.99          0.80          1.50           8.00
MB & PLN   NO. 6         29.66          1.98           2.50          3.62         33.02          2.50          20.00

                        MEAN MMH       MEAN MMH       PERCENT       PERCENT       PERCENT       PERCENT        PERCENT
                       REPAIR MOD.    SCRAP MOD.   UNSCH.MOD.REM. MOD.REM.SHIP. MOD.REM.SHIP.  MOD. SCRAP    REPAIRED MOD.
                        AT DEPOT       AT DEPOT    SCRAPPED ORG.  ORG./DIR.SUP.  ORG./DEPOT    AT DIR.SUP.    AT DIR.SUP.

LH INPUT   NO. 1         36.30          1.00           0.0          30.00         70.00          0.0           20.00
RH INPUT   NO. 2         29.00          1.00           0.0          30.00         70.00          0.0           20.00
LH FWU     NO. 3         14.50          0.50           0.0          90.00         10.00          0.0           90.00
RH FWU     NO. 4         10.90          0.50           0.0          90.00         10.00          0.0           90.00
TTO        NO. 5         54.50          1.50           0.0          35.00         65.00          0.0           40.00
MB & PLN   NO. 6        219.80          2.50           0.0          10.00         90.00          0.0           10.00

                        PERCENT        PERCENT        PERCENT     PERCENT ON     PERCENT ON      TIME        UNSCHEDULED
                      MOD.REC.SHIP.  REPAIR MOD.    SCRAP MOD.   AIRCRAFT REP.  AIRCRAFT REP.   BETWEEN      MAINTAINENCE
                      DIR.SUP/DEPOT   AT DEPOT       AT DEPOT      AT ORG.      AT DIR. SUP.   OVERHAUL       FREQUENCY

LH INPUT   NO. 1         80.00         100.00          0.0          68.00         32.00         99999.         0.0029
RH INPUT   NO. 2         80.00         100.00          0.0          39.00         61.00         99999.         0.0018
LH FWU     NO. 3         10.00          90.00         10.00         56.00         44.00         99999.         0.0016
RH FWU     NO. 4         10.00          90.00         10.00         56.00         44.00         99999.         0.0002
TTO        NO. 5         60.00         100.00          0.0         100.00          0.0          99999.         0.0013
MB & PLN   NO. 6         90.00         100.00          0.0          91.50          8.50         99999.         0.0029

MISSION ABORT RATE, BASELINE TRANSMISSION. . . . . . . . . . =    0.00040 ABORTS PER FLIGHT HOUR
MISSION ABORT RATE, CANDIDATE TRANSMISSION . . . . . . . . . =    0.00044 ABORTS PER FLIGHT HOUR
MEAN ELAPSED TIME TO REPAIR BASELINE TRANSMISSION. . . . . . =    4.37    DOWN HOURS
TOTAL MMH/FH AT ORG. AND DIR. SUP.,BASELINE TRANSMISSION . . =    0.35    MMH/FH
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION DAILY INSPECTION. =    0.10    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION INTERMEDIATE INSP =    1.50    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION PERIODIC INSP . . =    2.50    HOURS
UNSCHEDULED MAINTENANCE FREQUENCY, BASELINE TRANSMISSION . . =    0.0097
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MODULARIZED TRANSMISSION - 6 MODULE DESIGN - FLEET SIZE  60 A/C

         AIRCRAFT COST OUTPUT DATA

   AIRCRAFT COST EFFECTIVENESS. . . . . . . . . . . . . . . . . . =      43.944 TON-KNOTS/MEGA$
   FLEET EFFECTIVE COST . . . . . . . . . . . . . . . . . . . . . =     610.256 MEGA $
   AIRCRAFT LIFE CYCLE COST . . . . . . . . . . . . . . . . . . . =      10.155 MEGA $

         AIRCRAFT RELIABILITY/MAINTAINABILITY OUTPUT DATA

   AIRCRAFT MISSION ABORT FAILURES PER 1000 FLIGHT HOURS. . . . =      12.54  ABORTS/1000 FLT.HR.
   AIRCRAFT MISSION AVAILABILITY. . . . . . . . . . . . . . . . . =      0.892
   AIRCRAFT DOWN HOURS PER FLIGHT HOUR. . . . . . . . . . . . . . =      2.29
   AIRCRAFT MISSION RELIABILITY . . . . . . . . . . . . . . . . . =      0.9957

         AIRCRAFT MISSION OUTPUT DATA PER AIRCRAFT

   AIRCRAFT MISSION CAPABILITY. . . . . . . . . . . . . . . . . . =     502.41   TON KNOTS
   AIRCRAFT MISSION EFFECTIVENESS . . . . . . . . . . . . . . . . =     446.23   TON KNOTS
   TOTAL COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . =    253777.   $
   AVERAGE MISSION FUEL FLOW. . . . . . . . . . . . . . . . . . . =    3338.29   LBS/HOUR

         TRANSMISSION COST OUTPUT DATA PER AIRCRAFT

   TOTAL COST OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . =      2440. $
   TRANSMISSION NON-RECURRING COST. . . . . . . . . . . . . . . . =     20200. $
   TRANSMISSION RECURRING COST. . . . . . . . . . . . . . . . . . =    164023. $
   TRANSMISSION ACQUISITION COST CONTRIBUTION TO LCCA . . . . . . =    184223. $
   TRANSMISSION INITIAL SPARES COST CONTRIBUTION TO LCCA. . . . . =     81149. $
   TRANSMISSION REPLENESHMENT SPARES COST CONTRIBUTION TO LCCA. =     67319. $
   TRANSMISSION GSE INITIAL TOOLING COST CONTRIBUTION TO LCCA . =      1992. $
   TRANSMISSION GSE REPLENESHMENT TOOLING COST CONTR. TO LCCA . =      2772. $
   TRANSMISSION ORGANIZATION MAINTENANCE COST . . . . . . . . . . =     10704. $
   TRANSMISSION DIRECT SUPPORT MAINTENANCE COST . . . . . . . . . =      1941. $
   TRANSMISSION DEPOT MAINTENANCE COST. . . . . . . . . . . . . . =     36133. $
   TRANSMISSION SHIPPING COST BETWEEN ORG.  AND DEPOT . . . . . . =      1390. $
   TRANSMISSION SHIPPING COST BETWEEN DIRECT SUPPORT AND DEPOT. =       216. $
   TRANSMISSION SHIPPING COST BETWEEN DEPOT AND FIELD . . . . . . =      1134. $
   TRANSMISSION TOTAL SHIPPING COST BETWEEN MAINTENANCE LEVELS. =      2740. $
   TRANSMISSION TOTAL MAINTENANCE COST. . . . . . . . . . . . . . =     51519. $
   QUANTITY OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . . =      2.66

         TRANSMISSION RELIABILITY/MAINTAINABILITY OUTPUT DATA

   TRANSMISSION MAINTENANCE DOWN-HOURS PER FLIGHT HOUR. . . . . =     0.036
   TRANSMISSION MEAN TIME BETWEEN UNSCHEDULED REMOVAL REQ.O.HAUL=    338.      FLIGHT HOURS
   MEAN ELAPSED TIME TO REPAIR TRANSMISSION . . . . . . . . . . . =     3.34     DOWN HOURS
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT ORG.  . . . =     0.2571   MMH/FLIGHT HOUR
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DIRECT SUP. =     0.0412   MMH/FLIGHT HOUR
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DEPOT . . . =     0.2793   MMH/FLIGHT HOUR
   TRANSMISSION UNSCHEDULED MAINTENANCE FREQUENCY . . . . . . . = 0.0107
   SPARES PRODUCTION RUN,  LH INPUT NO.  1. . . . . . . . . . . . =     0.79
   SPARES PRODUCTION RUN,  RH INPUT NO.  2. . . . . . . . . . . . =     0.79
   SPARES PRODUCTION RUN,  LH FWU   NO.  3. . . . . . . . . . . . =     0.89
   SPARES PRODUCTION RUN,  RH FWU   NO.  4. . . . . . . . . . . . =     0.89
   SPARES PRODUCTION RUN,  TTO      NO.  5. . . . . . . . . . . . =     0.79
   SPARES PRODUCTION RUN,  MB & PLN NO.  6. . . . . . . . . . . . =     0.79
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MODULARIZED TRANSMISSION - 4 MODULE DESIGN - FLEET SIZE  60 A/C

     AIRCRAFT COST INPUT DATA

   LIFE CYCLE COST OF BASELINE AIRCRAFT . . . . . . . . . . . . . =  10194000. $
   COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . . . . =    0.0181  $ PER LB.
   NUMBER OF MAIN TRANSMISSIONS PER AIRCRAFT. . . . . . . . . . . =    1.
   FACTOR FOR GENERAL AND ADMINISTRATIVE OVERHEAD PLUS PROFIT . =    1.20

     AIRCRAFT RELIABILITY/MAINTAINABILITY INPUT DATA

   MISSION ABORT RATE OF BASELINE AIRCRAFT. . . . . . . . . . . . =    0.0125  ABORTS PER FLIGHT HOUR
   DOWN HOURS PER FLIGHT HOUR OF BASELINE AIRCRAFT. . . . . . . . =    2.3000

     AIRCRAFT MISSION INPUT DATA

   AIRCRAFT MISSION CAPABILITY, BASELINE AIRCRAFT . . . . . . . . =  503.366    TON-KNOTS
   AIRCRAFT MISSION EFFECTIVENESS, BASELINE AIRCRAFT. . . . . . . =  446.950    TON-KNOTS
   EFFICIENCY OF BASELINE TRANSMISSION. . . . . . . . . . . . . . =   98.170   PERCENT
   EFFICIENCY OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . =   98.136   PERCENT
   AVERAGE MISSION FUEL FLOW OF BASELINE AIRCRAFT . . . . . . . . = 3336.270    LBS.PER HOUR
   SERVICE LIFE . . . . . . . . . . . . . . . . . . . . . . . . . =   15.000    YEARS
   AVERAGE MISSION TIME . . . . . . . . . . . . . . . . . . . . . =    0.344    HOURS
   ANNUAL UTILIZATION OF AIRCRAFT . . . . . . . . . . . . . . . . =  280.000    FLIGHT HOURS
   DAILY UTILIZATION OF AIRCRAFT. . . . . . . . . . . . . . . . . =    1.130    FLIGHT HOURS
   WEIGHT OF BASELINE TRANSMISSION. . . . . . . . . . . . . . . . = 3096.000    POUNDS
   WEIGHT OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . . . = 3113.660    POUNDS
   NUMBER OF BASELINE AIRCRAFT. . . . . . . . . . . . . . . . . . =   60

     TRANSMISSION COST INPUT DATA

                           INDIVIDUAL      TOTAL,       MATERIAL      MATERIAL      MATERIAL       TOTAL
                            COST OF       COST OF       COST OF       COST OF       COST OF        COST           COST
                           SHIPPING       INITIAL     MODULE REPAIR MODULE REPAIR MODULE REPAIR NON-RECURRING   RECURRING
                           CONTAINER    GSE TOOLING   ON AIRCRAFT   AT DIRECT SUP   AT DEPOT

   L IN&FWU  NO. 1      $    871.     $  18100.     $     13.     $     23.     $    687.     $ 256090.     $  21059.
   R IN&FWU  NO. 2      $    871.     $  16300.     $     11.     $     18      $    616.     $ 226730.     $  18609.
   TTO       NO. 3      $   1075.     $  26000.     $      7.     $    248.     $   1010.     $ 398200.     $  27340.
   MB & PLN  NO. 4      $   2330.     $  58100.     $     34.     $    104.     $   2263.     $ 874550.     $  69416.

                            COST TO       COST TO       COST TO       COST TO       COST TO       COST TO
                          SHIP MODULE   SHIP MODULE   SHIP MODULE    PREP. SHIP    PREP. SHIP    PREP. SHIP
                          U.S. TO FIELD DEPOT TO FIELD FIELD TO DEPOT FIELD TO DEPOT DIR.SUP./DEPOT DEPOT TO FIELD

   L IN&FWU  NO. 1      $     42.     $     42.     $     42.     $     29.     $     29.     $     47.
   R IN&FWU  NO. 2      $     40.     $     40.     $     40.     $     29.     $     29.     $     47.
   TTO       NO. 3      $     33.     $     33.     $     33.     $     33.     $     33.     $     55.
   MB & PLN  NO. 4      $    255.     $    255.     $    255.     $     76.     $     76.     $    125.

   COST OF ACQUISITION, BASELINE TRANSMISSION . . . . . . . . . =    181500. $
   COST OF INITIAL SPARES, BASELINE TRANSMISSION. . . . . . . . =     78508. $
   COST OF REPLENISHMENT SPARES, BASELINE TRANSMISSION. . . . . =     65852. $
   COST OF MAINTENANCE, BASELINE TRANSMISSION . . . . . . . . . =     96609. $
   COST OF INITIAL GSE TOOLING, BASELINE TRANSMISSION . . . . . =      1958. $
   COST OF REPLENISHMENT GSE TOOLING, BASELINE TRANSMISSION . . =      2727. $
   RATIO OF GSE TOOLING REPLENISHMENT REQT/ GSE TOOLING,XMISSION=      1.392
   RATIO OF INITIAL SPARES REQD TO REPLENISHMENT SPARES REQD. . =      0.539
   LABOR RATE, CIVILIAN MAINTENANCE PERSONNEL,DIRECT + INDIRECT =     19.50   $/HOUR
   LABOR RATE, MILITARY MAINTENANCE PERSONNEL, DIRECT + INDIRECT=      9.50   $/HOUR

     TRANSMISSION RELIABILITY/MAINTAINABILITY INPUT DATA
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                         ATTRITION    MEAN ELAPSED  MEAN TIME BET.   MEAN MMH      MEAN MMH       MEAN MMH        MEAN MMH
                         RATE, MOD.   TIME REP. MOD. UNSCH.MOD.REM.  INSPECT MOD.  REPAIR MOD.    REMOVE MOD.     REQUISITION
                        LOST/FLGT HR.  DOWN HOURS    FLIGHT HOURS   ON AIRCRAFT   ON AIRCRAFT   FROM AIRCRAFT    MODULE

L IN&FWU   NO.  1         0.000187       2.90         2400.00          0.41          5.45          1.82           2.00
R IN&FWU   NO.  2         0.000187       2.10         2824.00          0.41          3.85          0.98           2.00
TTO        NO.  3         0.000187       2.45         1091.00          0.48          6.05          2.67           2.00
MB & PLN   NO.  4         0.000187       5.41         1170.00          0.60         14.24         14.83           2.00

                         MEAN MMH      MEAN MMH      MEAN MMH        MEAN MMH      MEAN MMH      MEAN MMH        MEAN MMH
                        INSTALL MOD   INSPECT MOD.   SCRAP MOD.     INSPECT MOD.   REPAIR MOD.   SCRAP MOD.     INSPECT MOD.
                        ON AIRCRAFT    AT ORG.        AT ORG.       AT DIR.SUP.    AT DIR.SUP.   AT DIR.SUP.     AT DEPOT

L IN&FWU   NO.  1            3.65         0.53          1.25           0.90          4.70          1.25            5.25
R IN&FWU   NO.  2            1.97         0.53          1.25           0.90          7.77          1.25            5.25
TTO        NO.  3            5.33         0.53          1.50           0.99          0.80          1.50            8.00
MB & PLN   NO.  4           29.66         1.98          2.50           3.62         33.02          2.50           20.00

                         MEAN MMH      MEAN MMH       PERCENT         PERCENT       PERCENT       PERCENT         PERCENT
                        REPAIR MOD.   SCRAP MOD.   UNSCH.MOD.REM.  MOD.REM.SHIP.  MOD.REM.SHIP.  MOD. SCRAP     REPAIRED MOD.
                         AT DEPOT      AT DEPOT    SCRAPPED ORG.   ORG./DIR.SUP.  ORG./DEPOT     AT DIR.SUP.     AT DIR.SUP.

L IN&FWU   NO.  1           52.80         1.25          0.0           30.00         70.00           0.0           20.00
R IN&FWU   NO.  2           41.90         1.25          0.0           30.00         70.00           0.0           20.00
TTO        NO.  3           54.50         1.50          0.0           35.00         65.00           0.0           40.00
MB & PLN   NO.  4          219.80         2.50          0.0           10.00         90.00           0.0           10.00

                         PERCENT       PERCENT        PERCENT        PERCENT ON    PERCENT ON      TIME         UNSCHEDULED
                       MOD.REC.SHIP.  REPAIR MOD.    SCRAP MOD.     AIRCRAFT REP.  AIRCRAFT REP.   BETWEEN      MAINTAINENCE
                       DIR.SUP/DEPOT   AT DEPOT       AT DEPOT        AT ORG.      AT DIR. SUP.    OVERHAUL      FREQUENCY

L IN&FWU   NO.  1           80.00       100.00          0.0           63.00         37.00         99999.         0.0043
R IN&FWU   NO.  2           80.00       100.00          0.0           50.00         50.00         99999.         0.0018
TTO        NO.  3           60.00       100.00          0.0          100.00          0.0          99999.         0.0013
MB & PLN   NO.  4           90.00       100.00          0.0           91.50          8.50         99999.         0.0029

MISSION ABORT RATE, BASELINE TRANSMISSION. . . . . . . . . . =   0.00040 ABORTS PER FLIGHT HOUR
MISSION ABORT RATE, CANDIDATE TRANSMISSION . . . . . . . . . =   0.00042 ABORTS PER FLIGHT HOUR
MEAN ELAPSED TIME TO REPAIR BASELINE TRANSMISSION. . . . . . =   4.37    DOWN HOURS
TOTAL MMH/FH AT ORG. AND DIR. SUP.,BASELINE TRANSMISSION . . =   0.35    MMH/FH
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION DAILY INSPECTION. =   0.10    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION INTERMEDIATE INSP =   1.50    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION PERIODIC INSP . . =   2.50    HOURS
UNSCHEDULED MAINTENANCE FREQUENCY, BASELINE TRANSMISSION . . =   0.0097
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MODULARIZED TRANSMISSION - 4 MODULE DESIGN - FLEET SIZE  60 A/C

      AIRCRAFT COST OUTPUT DATA

  AIRCRAFT COST EFFECTIVENESS. . . . . . . . . . . . . . . . . . . =     44.004 TON-KNOTS/MEGA$
  FLEET EFFECTIVE COST . . . . . . . . . . . . . . . . . . . . . . =    609.420 MEGA $
  AIRCRAFT LIFE CYCLE COST . . . . . . . . . . . . . . . . . . . . =     10.153 MEGA $

      AIRCRAFT RELIABILITY/MAINTAINABILITY OUTPUT DATA

  AIRCRAFT MISSION ABORT FAILURES PER 1000 FLIGHT HOURS. . . . =      12.52  ABORTS/1000 FLT.HR.
  AIRCRAFT MISSION AVAILABILITY. . . . . . . . . . . . . . . . . . =      0.892
  AIRCRAFT DOWN HOURS PER FLIGHT HOUR. . . . . . . . . . . . . . . =      2.29
  AIRCRAFT MISSION RELIABILITY . . . . . . . . . . . . . . . . . . =      0.9957

      AIRCRAFT MISSION OUTPUT DATA PER AIRCRAFT

  AIRCRAFT MISSION CAPABILITY. . . . . . . . . . . . . . . . . . . =    502.99  TON KNOTS
  AIRCRAFT MISSION EFFECTIVENESS . . . . . . . . . . . . . . . . . =    446.77  TON KNOTS
  TOTAL COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . . =    253693. $
  AVERAGE MISSION FUEL FLOW. . . . . . . . . . . . . . . . . . . . =   3337.19  LBS/HOUR

      TRANSMISSION COST OUTPUT DATA PER AIRCRAFT

  TOTAL COST OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . . =      2185. $
  TRANSMISSION NON-RECURRING COST. . . . . . . . . . . . . . . . . =     19643. $
  TRANSMISSION RECURRING COST. . . . . . . . . . . . . . . . . . . =    163709. $
  TRANSMISSION ACQUISITION COST CONTRIBUTION TO LCCA . . . . . . =    183351. $
  TRANSMISSION INITIAL SPARES COST CONTRIBUTION TO LCCA. . . . =     80168. $
  TRANSMISSION REPLENISHMENT SPARES COST CONTRIBUTION TO LCCA. =     66698. $
  TRANSMISSION GSE INITIAL TOOLING COST CONTRIBUTION TO LCCA . =      1975. $
  TRANSMISSION GSE REPLENESHMENT TOOLING COST CONTR. TO LCCA . =      2749. $
  TRANSMISSION ORGANIZATION MAINTENANCE COST . . . . . . . . . . =     10612. $
  TRANSMISSION DIRECT SUPPORT MAINTENANCE COST . . . . . . . . . =      1858. $
  TRANSMISSION DEPOT MAINTENANCE COST. . . . . . . . . . . . . . =     37178. $
  TRANSMISSION SHIPPING COST BETWEEN ORG.  AND DEPOT . . . . . =      1393. $
  TRANSMISSION SHIPPING COST BETWEEN DIRECT SUPPORT AND DEPOT. =       215. $
  TRANSMISSION SHIPPING COST BETWEEN DEPOT AND FIELD . . . . . =      1140. $
  TRANSMISSION TOTAL SHIPPING COST BETWEEN MAINTENANCE LEVELS. =      2749. $
  TRANSMISSION TOTAL MAINTENANCE COST. . . . . . . . . . . . . . =     52397. $
  QUANTITY OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . . =      1.70

      TRANSMISSION RELIABILITY/MAINTAINABILITY OUTPUT DATA

  TRANSMISSION MAINTENANCE DOWN-HOURS PER FLIGHT HOUR. . . . . =    0.035
  TRANSMISSION MEAN TIME BETWEEN UNSCHEDULED REMOVAL REQ.O.HAUL=    393.     FLIGHT HOURS
  MEAN ELAPSED TIME TO REPAIR TRANSMISSION . . . . . . . . . . . =    3.41     DOWN HOURS
  TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT ORG.  . . . =    0.2548   MMH/FLIGHT HOUR
  TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DIRECT SUP. =    0.0396   MMH/FLIGHT HOUR
  TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DEPOT . . . =    0.2906   MMH/FLIGHT HOUR
  TRANSMISSION UNSCHEDULED MAINTENANCE FREQUENCY . . . . . . . . =  0.0103
  SPARES PRODUCTION RUN.  L IN&FWU NO.  1. . . . . . . . . . . . . =    0.79
  SPARES PRODUCTION RUN.  R IN&FWU NO.  2. . . . . . . . . . . . . =    0.79
  SPARES PRODUCTION RUN.  TTO      NO.  3. . . . . . . . . . . . . =    0.79
  SPARES PRODUCTION RUN.  MB & PLN NO.  4. . . . . . . . . . . . . =    0.79
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MODULARIZED TRANSMISSION - 3 MODULE DESIGN - FLEET SIZE  60 A/C

      AIRCRAFT COST INPUT DATA

   LIFE CYCLE COST OF BASELINE AIRCRAFT . . . . . . . . . . . . . . =  10194000. $
   COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . . . . . =    0.0181  $ PER LB.
   NUMBER OF MAIN TRANSMISSIONS PER AIRCRAFT. . . . . . . . . . . . =    1.
   FACTOR FOR GENERAL AND ADMINISTRATIVE OVERHEAD PLUS PROFIT . =    1.20

      AIRCRAFT RELIABILITY/MAINTAINABILITY INPUT DATA

   MISSION ABORT RATE OF BASELINE AIRCRAFT. . . . . . . . . . . =    0.0125  ABORTS PER FLIGHT HOUR
   DOWN HOURS PER FLIGHT HOUR OF BASELINE AIRCRAFT. . . . . . . =    2.3000

      AIRCRAFT MISSION INPUT DATA

   AIRCRAFT MISSION CAPABILITY, BASELINE AIRCRAFT . . . . . . . . =  503.366    TON-KNOTS
   AIRCRAFT MISSION EFFECTIVENESS, BASELINE AIRCRAFT. . . . . . . =  446.950    TON-KNOTS
   EFFICIENCY OF BASELINE TRANSMISSION. . . . . . . . . . . . . . =   98.170   PERCENT
   EFFICIENCY OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . =   98.161   PERCENT
   AVERAGE MISSION FUEL FLOW OF BASELINE AIRCRAFT . . . . . . . . = 3336.270    LBS.PER HOUR
   SERVICE LIFE . . . . . . . . . . . . . . . . . . . . . . . . . =   15.000    YEARS
   AVERAGE MISSION TIME . . . . . . . . . . . . . . . . . . . . . =    0.344    HOURS
   ANNUAL UTILIZATION OF AIRCRAFT . . . . . . . . . . . . . . . . =  280.000    FLIGHT HOURS
   DAILY UTILIZATION OF AIRCRAFT. . . . . . . . . . . . . . . . . =    1.130    FLIGHT HOURS
   WEIGHT OF BASELINE TRANSMISSION. . . . .   . . . . . . . . . . = 3096.000    POUNDS
   WEIGHT OF CANDIDATE TRANSMISSION . . . . . . . . . . . . . . . = 3103.000    POUNDS
   NUMBER OF BASELINE AIRCRAFT. . . . . . . . . . . . . . . . . . =   60

      TRANSMISSION COST INPUT DATA

                           INDIVIDUAL      TOTAL,       MATERIAL       MATERIAL       MATERIAL         TOTAL
                            COST OF       COST OF       COST OF        COST OF        COST OF          COST           COST
                           SHIPPING       INITIAL    MODULE REPAIR  MODULE REPAIR  MODULE REPAIR  NON-RECURRING    RECURRING
                           CONTAINER    GSE TOOLING   ON AIRCRAFT   AT DIRECT SUP    AT DEPOT

   L IN&FWU  NO.  1      $    871.     $  18100.     $     13.      $     25.      $    687.     $ 256090.      $  21059.
   R IN&FWU  NO.  2      $    871.     $  16300.     $     11.      $     18.      $    616.     $ 226730.      $  18609.
   MB&PL&TT  NO.  3      $   2330.     $  83600.     $     22.      $    134.      $   3245.     $1246320.      $  96585.

                           COST TO        COST TO        COST TO        COST TO        COST TO        COST TO
                         SHIP MODULE    SHIP MODULE    SHIP MODULE     PREP. SHIP     PREP. SHIP     PREP. SHIP
                         U.S. TO FIELD DEPOT TO FIELD FIELD TO DEPOT FIELD TO DEPOT DIR.SUP./DEPOT DEPOT TO FIELD

   L IN&FWU  NO.  1      $     42.     $     42.     $     42.      $     29.      $     29.     $     47.
   R IN&FWU  NO.  2      $     40.     $     40.     $     40.      $     29.      $     29.     $     47.
   MB&PL&TT  NC.  3      $    263.     $    263.     $    263.      $     95.      $     95.     $    156.

   COST OF ACQUISITION, BASELINE TRANSMISSION . . . . . . . . . . =    181500. $
   COST OF INITIAL SPARES, BASELINE TRANSMISSION. . . . . . . . . =     78508. $
   COST OF REPLENISHMENT SPARES, BASELINE TRANSMISSION. . . . . . =     65852. $
   COST OF MAINTENANCE, BASELINE TRANSMISSION . . . . . . . . . . =     96809. $
   COST OF INITIAL GSE TOOLING, BASELINE TRANSMISSION . . . . . . =      1958. $
   COST OF REPLENISHMENT GSE TOOLING, BASELINE TRANSMISSION . . . =      2727. $
   RATIO OF GSE TOOLING REPLENISHMENT REQT/ GSE TOOLING,XMISSION=       1.392
   RATIO OF INITIAL SPARES REQD TO REPLENISHMENT SPARES REQD. . =       0.539
   LABOR RATE, CIVILIAN MAINTENANCE PERSONNEL,DIRECT + INDIRECT =     19.50  $/HOUR
   LABOR RATE, MILITARY MAINTENANCE PERSONNEL, DIRECT + INDIRECT=      9.50  $/HOUR

      TRANSMISSION RELIABILITY/MAINTAINABILITY INPUT DATA

                           ATTRITION    MEAN ELAPSED  MEAN TIME BET.  MEAN MMH       MEAN MMH       MEAN MMH       MEAN MMH
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                         RATE, MOD.     TIME REP. MOD.  UNSCH.MOD.REM.  INSPECT MOD.   REPAIR MOD.    REMOVE MOD.     REQUISITION
                        LOST/FLGT HR.   DOWN HOURS     FLIGHT HOURS    ON AIRCRAFT    ON AIRCRAFT   FROM AIRCRAFT     MODULE

L IN&FWU  NO.  1          0.000187         2.90         2400.00           0.41          5.45           1.82            2.00
R IN&FWU  NO.  2          0.000187         2.10         2824.00           0.41          3.85           0.98            2.00
MB&PL&TT  NO.  3          0.000187         4.51          640.00           0.52         12.69          13.50            2.00

                         MEAN MMH        MEAN MMH        MEAN MMH        MEAN MMH       MEAN MMH       MEAN MMH        MEAN MMH
                        INSTALL MOD     INSPECT MOD.    SCRAP MOD.     INSPECT MOD.   REPAIR MOD.    SCRAP MOD.     INSPECT MOD.
                        ON AIRCRAFT       AT ORG.         AT ORG.      AT DIR.SUP.    AT DIR.SUP.    AT DIR.SUP.      AT DEPOT

L IN&FWU  NO.  1              3.65         0.53            1.25           0.90          4.70           1.25            5.25
R IN&FWU  NO.  2              1.97         0.53            1.25           0.90          7.77           1.25            5.25
MB&PL&TT  NO.  3             27.00         2.37            2.75           4.25         33.02           2.75           28.50

                         MEAN MMH        MEAN MMH        PERCENT         PERCENT        PERCENT        PERCENT         PERCENT
                        REPAIR MOD.     SCRAP MOD.    UNSCH.MOD.REM. MOD.REM.SHIP.  MOD.REM.SHIP.   MOD. SCRAP    REPAIRED MOD.
                         AT DEPOT        AT DEPOT     SCRAPPED ORG.  ORG./DIR.SUP.  ORG./DEPOT     AT DIR.SUP.    AT DIR.SUP.

L IN&FWU  NO.  1             52.80         1.25            0.0           30.00         70.00           0.0            20.00
R IN&FWU  NO.  2             41.90         1.25            0.0           30.00         70.00           0.0            20.00
MB&PL&TT  NO.  3            276.30         2.75            0.0           10.00         90.00           0.0            10.00

                         PERCENT         PERCENT         PERCENT       PERCENT ON     PERCENT ON       TIME         UNSCHEDULED
                       MOD.REC.SHIP.   REPAIR MOD.     SCRAP MOD.    AIRCRAFT REP.  AIRCRAFT REP.    BETWEEN       MAINTAINENCE
                       DIR.SUP/DEPOT    AT DEPOT        AT DEPOT       AT ORG.      AT DIR. SUP.     OVERHAUL        FREQUENCY

L IN&FWU  NO.  1             80.00       100.00            0.0           63.00         37.00         99999.          0.0043
R IN&FWU  NO.  2             80.00       100.00            0.0           50.00         50.00         99999.          0.0018
MB&PL&TT  NO.  3             90.00       100.00            0.0           93.00          7.00         99999.          0.0040

MISSION ABORT RATE, BASELINE TRANSMISSION. . . . . . . . . . =    0.00040 ABORTS PER FLIGHT HOUR
MISSION ABORT RATE, CANDIDATE TRANSMISSION . . . . . . . . . =    0.00042 ABORTS PER FLIGHT HOUR
MEAN ELAPSED TIME TO REPAIR BASELINE TRANSMISSION. . . . . . =    4.37    DOWN HOURS
TOTAL MMH/FH AT ORG. AND DIR. SUP.,BASELINE TRANSMISSION . . =    0.35    MMH/FH
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION DAILY INSPECTION. =    0.10    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION INTERMEDIATE INSP =    1.50    HOURS
MEAN MMH TO PERFORM SCHEDULED TRANSMISSION PERIODIC INSP . . =    2.50    HOURS
UNSCHEDULED MAINTENANCE FREQUENCY, BASELINE TRANSMISSION . . =    0.0097
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MODULARIZED TRANSMISSION - 3 MODULE DESIGN - FLEET SIZE  60 A/C

      AIRCRAFT COST OUTPUT DATA

   AIRCRAFT COST EFFECTIVENESS. . . . . . . . . . . . . . . . . . =     43.904 TON-KNOTS/MEGA$
   FLEET EFFECTIVE COST . . . . . . . . . . . . . . . . . . . . . =    610.812 MEGA $
   AIRCRAFT LIFE CYCLE COST . . . . . . . . . . . . . . . . . . . =     10.181 MEGA $

      AIRCRAFT RELIABILITY/MAINTAINABILITY OUTPUT DATA

   AIRCRAFT MISSION ABORT FAILURES PER 1000 FLIGHT HOURS. . . . . =      12.52  ABORTS/1000 FLT.HR.
   AIRCRAFT MISSION AVAILABILITY. . . . . . . . . . . . . . . . . =      0.692
   AIRCRAFT DOWN HOURS PER FLIGHT HOUR. . . . . . . . . . . . .   =      2.29
   AIRCRAFT MISSION RELIABILITY . . . . . . . . . . . . . . . . . =      0.9957

      AIRCRAFT MISSION OUTPUT DATA PER AIRCRAFT

   AIRCRAFT MISSION CAPABILITY. . . . . . . . . . . . . . . . . . =    503.23  TON KNOTS
   AIRCRAFT MISSION EFFECTIVENESS . . . . . . . . . . . . . . . . =    447.00  TON KNOTS
   TOTAL COST OF FUEL . . . . . . . . . . . . . . . . . . . . . . =    253644. $
   AVERAGE MISSION FUEL FLOW. . . . . . . . . . . . . . . . . . . =   3336.54  LBS/HOUR

      TRANSMISSION COST OUTPUT DATA PER AIRCRAFT

   TOTAL COST OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . =      1726. $
   TRANSMISSION NON-RECURRING COST. . . . . . . . . . . . . . . . =     19363. $
   TRANSMISSION RECURRING COST. . . . . . . . . . . . . . . . . . =    163504. $
   TRANSMISSION ACQUISITION COST CONTRIBUTION TO LCCA . . . . . . =    182667. $
   TRANSMISSION INITIAL SPARES COST CONTRIBUTION TO LCCA. . . . . =     79345. $
   TRANSMISSION REPLENESHMENT SPARES COST CONTRIBUTION TO LCCA. . =     66387. $
   TRANSMISSION GSE INITIAL TOOLING COST CONTRIBUTION TO LCCA . . =      1967. $
   TRANSMISSION GSE REPLENESHMENT TOOLING COST CONTR. TO LCCA . . =      2738. $
   TRANSMISSION ORGANIZATION MAINTENANCE COST . . . . . . . . . . =     11283. $
   TRANSMISSION DIRECT SUPPORT MAINTENANCE COST . . . . . . . . . =      1715. $
   TRANSMISSION DEPOT MAINTENANCE COST. . . . . . . . . . . . . . =     64636. $
   TRANSMISSION SHIPPING COST BETWEEN ORG.  AND DEPOT . . . . . . =      2273. $
   TRANSMISSION SHIPPING COST BETWEEN DIRECT SUPPORT AND DEPOT. . =       266. $
   TRANSMISSION SHIPPING COST BETWEEN DEPOT AND FIELD . . . . . . =      1834. $
   TRANSMISSION TOTAL SHIPPING COST BETWEEN MAINTENANCE LEVELS. . =      4373. $
   TRANSMISSION TOTAL MAINTENANCE COST. . . . . . . . . . . . . . =     82207. $
   QUANTITY OF SHIPPING CONTAINERS. . . . . . . . . . . . . . . . =       1.27

      TRANSMISSION RELIABILITY/MAINTAINABILITY OUTPUT DATA

   TRANSMISSION MAINTENANCE DOWN-HOURS PER FLIGHT HOUR. . . . . . =     0.034
   TRANSMISSION MEAN TIME BETWEEN UNSCHEDULED REMOVAL REQ.O.HAUL=     429      FLIGHT HOURS
   MEAN ELAPSED TIME TO REPAIR TRANSMISSION . . . . . . . . . . . =     3.40     DOWN HOURS
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT ORG.  . . . . =     0.2733   MMH/FLIGHT HOUR
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DIRECT SUP. . =     0.0394   MMH/FLIGHT HOUR
   TRANSMISSION MEAN MAINT.HOURS PER FLIGHT HOUR AT DEPOT . . . . =     0.5099   MMH/FLIGHT HOUR
   TRANSMISSION UNSCHEDULED MAINTENANCE FREQUENCY . . . . . . . . =   0.0101
   SPARES PRODUCTION RUN,  L IN&FWU NO.  1. . . . . . . . . . . . =     0.79
   SPARES PRODUCTION RUN,  R IN&FWU NO.  2. . . . . . . . . . . . =     0.79
   SPARES PRODUCTION RUN,  MB&PL&TT NO.  3. . . . . . . . . . . . =     0.79
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RUNNING INSTRUCTIONS

The following instructions describe the format for inputting data into the computer program of the mathematical model given in Appendix II.

Computer running time is approximately 80 seconds for compilation plus 2 seconds per case.

CARD 1

COLUMN	1 to 80	Any comment or remark. This statement is printed verbatum on the output	

CARD 2

*COLUMN	10	Number of modules per main transmission	
*COLUMN	20	Number of baseline aircraft	

CARD 3

COLUMN	1 to 8	Name of module number 1	
COLUMN	9 to 16	Name of module number 2	
.	. . .	. . . . .	
.	. . .	. . . . .	
.	. . .	. . . . .	
COLUMN	8n-7 to 8n	Name of module number n	

CARD 4

COLUMN	1 to 10	Life-cycle cost of baseline aircraft	$
COLUMN	11 to 20	Cost of fuel	$/lb
COLUMN	21 to 30	Number of main transmissions per aircraft	
COLUMN	21 to 40	Factor for general and administrative overhead plus profit	

CARD 5

COLUMN	1 to 10	Mission abort rate, baseline aircraft	aborts/F.H.
COLUMN	11 to 20	Down-hours per flight-hour, baseline aircraft	down hr/F.H.

CARD 6

COLUMN	1 to 10	Aircraft mission capability, baseline	ton-kt
COLUMN	11 to 20	Aircraft mission effectiveness, baseline	ton-kt
COLUMN	21 to 30	Efficiency of baseline transmission	%
COLUMN	31 to 40	Efficiency of candidate transmission	%

CARD 7

COLUMN	1 to 10	Fuel flow of average mission, baseline aircraft	lb/hr
COLUMN	11 to 20	Service life	yr

*Integers - right adjusted

CARD 7

COLUMN	21 to 30	Average mission time	hr
COLUMN	31 to 40	Annual utilization of aircraft	F.H.
COLUMN	41 to 50	Daily utilization of aircraft	F.H.
COLUMN	51 to 60	Weight of baseline transmission	lb
COLUMN	61 to 70	Weight of candidate transmission	lb

For each of the following input data items, one value is required for each module. For "n" equal to eight or less modules one card is required for each data item. For "n" greater than eight and less than or equal to sixteen, two cards are required for each data item. For "n" greater than sixteen and less than or equal to twenty, three cards are required for each data item (n = number of modules).

CARD 8

COLUMN	1 to 10	Module no. 1 container cost	$
COLUMN	11 to 20	Module no. 2 container cost	$
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n container cost	$

CARD 9

COLUMN	1 to 10	Module no. 1 initial GSE tooling cost	$
COLUMN	11 to 20	Module no. 2 initial GSE tooling cost	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n initial GSE tooling cost	$

CARD 10

COLUMN	1 to 10	Module no. 1 mean material cost to repair on aircraft	$
COLUMN	11 to 20	Module no. 2 mean material cost to repair on aircraft	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n mean material cost to repair on aircraft	$

CARD 11

COLUMN	1 to 10	Module no. 1 mean material cost to repair at DS	$
COLUMN	11 to 20	Module no. 2 mean material cost to repair at DS	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n mean material cost to repair at DS	$

CARD 12

COLUMN	1 to 10	Module no. 1 mean material cost to repair at depot	$
COLUMN	11 to 20	Module no. 2 mean material cost to repair at depot	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n mean material cost to repair at depot	$

CARD 13

COLUMN	1 to 10	Module no. 1 nonrecurring cost	$
COLUMN	11 to 20	Module no. 2 nonrecurring cost	$
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n nonrecurring cost	$

CARD 14

COLUMN	1 to 10	Module no. 1 recurring cost	$
COLUMN	11 to 20	Module no. 2 recurring cost	$
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n recurring cost	$

CARD 15

COLUMN	1 to 10	Module no. 1 cost to ship from cont. U.S. to field	$
COLUMN	11 to 20	Module no. 2 cost to ship from cont. U.S. to field	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n cost to ship from cont. U.S. to field	$

CARD 16

COLUMN	1 to 10	Module no. 1 cost to ship from depot to field	$
COLUMN	11 to 20	Module no. 2 cost to ship from depot to field	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n cost to ship from depot to field	$

CARD 17

COLUMN	1 to 10	Module no. 1 cost to ship from field to depot	

CARD 17

COLUMN	11 to 20	Module no. 2 cost to ship from field to depot	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 20	Module no. n cost to ship from field to depot	$

CARD 18

COLUMN	1 to 10	Module no. 1 cost to prepare to ship from field to depot	$
COLUMN	11 to 20	Module no. 2 cost to prepare to ship from field to depot	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n cost to prepare to ship from field to depot	$

CARD 19

COLUMN	1 to 10	Module no. 1 cost to prepare to ship from direct support to depot	$
COLUMN	11 to 20	Module no. 2 cost to prepare to ship from direct support to depot	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n cost to prepare to ship from direct support to depot	$

CARD 20

COLUMN	1 to 10	Module no. 1 cost to prepare to ship from depot to field	$
COLUMN	11 to 20	Module no. 2 cost to prepare to ship from depot to field	$
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n cost to prepare to ship from depot to field	$

CARD 21

COLUMN	1 to 10	Cost of acquisition, baseline transmission	$
COLUMN	11 to 20	Cost of initial spares, baseline transmission	$
COLUMN	21 to 30	Cost of replenishment spares, baseline transmission	$
COLUMN	31 to 40	Cost of maintenance, baseline transmission	$

CARD 21

COLUMN	41 to 50	Cost of initial tooling, baseline transmission	$
COLUMN	51 to 60	Cost of replenishment tooling, baseline transmission	$

CARD 22

COLUMN	1 to 10	Ratio of GSE replenishment tooling to initial GSE tooling for transmission	-
COLUMN	11 to 20	Ratio of initial spares to total replenishment spares	-
COLUMN	21 to 30	Labor rate, civilian maintenance personnel	$/hr
COLUMN	31 to 40	Labor rate, military maintenance Personnel	$/hr

CARD 23

COLUMN	1 to 10	Mission abort rate, baseline transmission	aborts/FH
COLUMN	11 to 20	Mission abort rate, candidate transmission	aborts/FH
COLUMN	21 to 30	Mean elapsed time to reapir baseline transmission	down hrs
COLUMN	31 to 40	Total MMH/FH at organizational and direct support, baseline	MMH/FH
COLUMN	41 to 50	Mean MMH to perform scheduled daily transmission inspection	MMH
COLUMN	51 to 60	Mean MMH to perform scheduled intermediate transmission inspection	MMH
COLUMN	61 to 70	Mean MMH to perform scheduled periodic transmission inspection	MMH
COLUMN	71 to 80	Unscheduled maintenance frequency, baseline transmission	1/FH

CARD 24

COLUMN	1 to 10	Module no. 1 attrition rate	modules/FH
COLUMN	11 to 20	Module no. 2 attrition rate	modules/FH
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n attrition rate	modules/FH

CARD 25

COLUMN	1 to 10	Module no. 1 mean elapsed time to repair	down hr
COLUMN	11 to 20	Module no. 2 mean elapsed time to repair	down hr
.	. . .	. . . . . .	. .
.	. . .	. . . . . .	. .
.	. . .	. . . . . .	. .
COLUMN	10n-9 to 10n	Module no. n mean elapsed time to repair	down hr

CARD 26

COLUMN	1 to 10	Module no. 1 mean time between unscheduled removal	flight hr
COLUMN	11 to 20	Module no. 2 mean time between unscheduled removal	flight hr
.	. . .	. . .	. .
.	. . .	. . .	. .
.	. . .	. . .	. .
COLUMN	10n-9 to 10n	Module no. n mean time between unscheduled removal	flight hr

CARD 27

COLUMN	1 to 10	Module no. 1 mean MMH to inspect on aircraft	MMH
COLUMN	11 to 20	Module no. 2 mean MMH to inspect on aircraft	MMH
.	. . .	. . . . . .	. .
.	. . .	. . . . . .	. .
.	. . .	. . . . . .	. .
COLUMN	10n-9 to 10n	Module no. n mean MMH to inspect on aircraft	MMH

CARD 28

COLUMN	1 to 10	Module no. 1 MMH to repair on aircraft	MMH
COLUMN	11 to 20	Module no. 2 MMH to repair on aircraft	MMH
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to repair on aircraft	MMH

CARD 29

COLUMN	1 to 10	Module no. 1 MMH to remove from aircraft	MMH
COLUMN	11 to 20	Module no. 2 MMH to remove from aircraft	MMH
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to remove from aircraft	MMH

CARD 30

COLUMN	1 to 10	Module no. 1 MMH to requisition	MMH
COLUMN	11 to 20	Module no. 2 MMH to requisition	MMH
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to requisition	MMH

CARD 31

COLUMN	1 to 10	Module no. 1 MMH to install on aircraft	MMH
COLUMN	11 to 20	Module no. 2 MMH to install on aircraft	MMH
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to install on aircraft	MMH

CARD 32

COLUMN	1 to 10	Module no. 1 MMH to inspect in field	MMH
COLUMN	11 to 20	Module no. 2 MMH to inspect in field	MMH
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to inspect in field	MMH

CARD 33

COLUMN	1 to 10	Module no. 1 MMH to scrap in field	MMH
COLUMN	11 to 20	Module no. 2 MMH to scrap in field	MMH
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to scrap in field	MMH

CARD 34

COLUMN	1 to 10	Module no. 1 MMH to inspect at direct support	MMH
COLUMN	11 to 20	Module no. 2 MMH to inspect at direct support	MMH
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to inspect at direct support	MMH

CARD 35

COLUMN	1 to 10	Module no. 1 MMH to repair at direct support	MMH
COLUMN	11 to 20	Module no. 2 MMH to repair at direct support	MMH
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n MMH to repair at direct support	MMH

CARD 36

COLUMN	1 to 10	Module no. 1 MMH to scrap at direct support	MMH

CARD 36

COLUMN	11 to 20	Module no. 2 MMH to scrap at direct support	MMH
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
COLUMN	10n-9 to 10n	Module no. n MMH to scrap at direct support	MMH

CARD 37

COLUMN	1 to 10	Module no. 1 MMH to inspect at depot	MMH
COLUMN	11 to 20	Module no. 2 MMH to inspect at depot	MMH
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
COLUMN	10n-9 to 10n	Module no. n MMH to inspect at depot	MMH

CARD 38

COLUMN	1 to 10	Module no. 1 MMH to repair at depot	MMH
COLUMN	11 to 20	Module no. 2 MMH to repair at depot	MMH
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
COLUMN	10n-9 to 10n	Module no. n MMH to repair at depot	MMH

CARD 39

COLUMN	1 to 10	Module no. 1 MMH to scrap at depot	MMH
COLUMN	11 to 20	Module no. 2 MMH to scrap at depot	MMH
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
•	• • •	• • • • • • • •	•
COLUMN	10n-9 to 10n	Module no. n MMH to scrap at depot	MMH

CARD 40

COLUMN	1 to 10	Module no. 1 percent unscheduled removals scrapped in field	%
COLUMN	11 to 20	Module no. 2 percent unscheduled removals scrapped in field	%
•	• • •	• • • •	•
•	• • •	• • • •	•
•	• • •	• • • •	•
COLUMN	10n-9 to 10n	Module no. n percent unscheduled removals scrapped in field	%

CARD 41

COLUMN	1 to 10	Module no. 1 percent unscheduled removals shipped field to DS	%
COLUMN	11 to 20	Module no. 2 percent unscheduled removals shipped field to DS	%
•	• • •	• • • • •	•
•	• • •	• • • • •	•
•	• • •	• • • • •	•

CARD 41

COLUMN	10n-9 to 10n	Module no. n percent unscheduled removals shipped field to DS	%

CARD 42

COLUMN	1 to 10	Module no. 1 percent unscheduled removals shipped field to depot	%
COLUMN	11 to 20	Module no. 2 percent unscheduled removals shipped field to depot	%
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n percent unscheduled removals shipped field to depot	%

CARD 43

COLUMN	1 to 10	Module no. 1 percent received at direct support, scrapped	%
COLUMN	11 to 20	Module no. 2 percent received at direct support, scrapped	%
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n percent received at direct support scrapped	%

CARD 44

COLUMN	1 to 10	Module no. 1 percent received at direct support, repaired	%
COLUMN	11 to 20	Module no. 2 percent received at direct support, repaired	%
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n percent received at direct support, repaired	%

CARD 45

COLUMN	1 to 10	Module no. 1 percent received at direct support, shipped to depot	%
COLUMN	11 to 20	Module no. 2 percent received at direct support, shipped to depot	%
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
COLUMN	10n-9 to 10n	Module no. n percent received at direct support, shipped to depot	%

CARD 46

COLUMN	1 to 10	Module no. 1 percent received at depot, repaired	%

CARD 46

COLUMN	11 to 20	Module no. 2 percent received at depot, repaired	%
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n percent received at depot, repaired	%

CARD 47

COLUMN	1 to 10	Module no. 1 percent received at depot, scrapped	%
COLUMN	11 to 20	Module no. 2 percent received at depot, scrapped	%
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n percent received at depot, scrapped	%

CARD 48

COLUMN	1 to 10	Module no. 1 percent of on aircraft repairs at organizational	%
COLUMN	11 to 20	Module no. 2 percent of on aircraft repairs at organizational	%
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n percent of on aircraft repairs at organizational	%

CARD 49

COLUMN	1 to 10	Module no. 1 percent of on aircraft repairs at direct support	%
COLUMN	11 to 20	Module no. 2 percent of on aircraft repairs at direct support	%
.	. . .	. . . . .	.
.	. . .	. . . . .	.
.	. . .	. . . . .	.
COLUMN	10n-9 to 10n	Module no. n percent of on aircraft repairs at direct support	%

CARD 50

COLUMN	1 to 10	Module no. 1 time between overhaul	flt-hr
COLUMN	11 to 20	Module no. 2 time between overhaul	flt-hr
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
.	. . .	. . . . . .	.
COLUMN	10n-9 to 10n	Module no. 3 time between overhaul	flt-hr

CARD 51

COLUMN	1 to 10	Module no. 1 unscheduled maintenance frequency	1/FH
COLUMN	11 to 20	Module no. 2 unscheduled maintenance frequency	1/FH
.	. . .	. . . .	.
.	. . .	. . . .	.
.	. . .	. . . .	.
COLUMN	10n-9 to 10n	Module no. n unscheduled maintenance frequency	1/FH

REPEAT CARDS 1 TO 51 FOR AS MANY CASES AS REQUIRED

PHYSICALLY LAST CARD IN DATA

COLUMN 1, 2, and 3 "END"