476L

logistics transport support system

SUPER HERCULES · GL207-45

VOLUME 4

special technical and cost data

LOCKHEED AIRCRAFT CORPORATION

476L

ETP 250

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VOLUME 4

special technical and cost data

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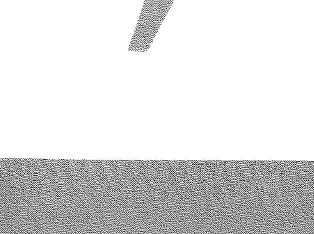
SUPER HERCULES · GL207-45



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MATS
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USAF

CONTENTS

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SUPER HERCULES · GL207-45

section 1

INTRODUCTION

This is one of seven books being submitted to describe Lockheed's proposal for Support System 476L. The complete set, prepared in accordance with the Statement of Work and augmented by guidance resulting from queries to the Air Force, is as follows:

Volume	
1	Basic Proposal
2	Substantiating and Trade-Off Data
3	Operational Data
4	Special Technical and Cost Data
5	Model Specification
6	Large Scale Drawings
7	PEP Networks

The formats of all volumes containing significant amounts of text are the same except for Volume 5, which is laid out to the customary format for Model Specifications in order that it could serve in future negotiations.

Volumes 1 thru 4 are organized in absolute conformity with the sequence and breakdown of subject headings in the Work Statement. Every decimally numbered paragraph of that document is identified by the same decimal number in this submittal and the sequencing is identical. Thus, Volumes 1 and 2 cover Work Statement Paragraphs 5.1 and 5.2, Volume 3 covers Paragraph 5.3, and Volume 4 covers Paragraph 5.4. It is hoped that this parallelism in detail and in general will facilitate review by the Air Force Evaluation Team.

Volume 1, though employing references to other volumes on occasion, is intended to be substantially self-sufficient. Volume 2, on the other hand, depends upon Volume 1 for basic subject descriptions and is intended principally to substantiate and/or expand on subjects which require more discussion than the page limit of Volume 1 would permit. Volumes 3 and 4 are reasonably independent, but do rely to a degree on familiarity with Volume 1. Volume 5 is, of course, self-sufficient, and Volumes 6 and 7 are repositories to permit easy handling of the loose data requested.

COST DATA—GENERAL

The pricing data and funding forecasts for the items in this section have been prepared on the same basis used for the similar data requirements in Volume 1 of Lockheed's proposal. For conveniences, we have inserted Formats "C" and "F" for all of the items ahead of the individual item details in order to summarize the effect of these special items on the various fiscal year fundings. Formats "D" and "E" are not considered to be applicable to the items in this section. Formats "A" for each airplane quantity follow immediately after the applicable technical description.

The net changes in engineering and tooling manhour requirements forecast for each of the changes to the basic GL 207-45 have been estimated by their respective organizations. The net production manhours, materials and direct charges, and purchased equipment requirements for such changes to the basic airplane have been estimated generally on a weight change basis. In those instances where an item proposed for subcontract in the basic GL 207-45 has been deleted by a change, the deletion has been taken at the same amounts allocated for the production of the subcontract assembly in the 132-airplane program. The quality assurance manhour requirements associated with these changes have been estimated on the same basis used in Volume 1. The reliability program in this section is in addition to the quality assurance costs proposed in the 132-airplane program. The manhours and materials requirements for this program have been established so as to assure implementation of the applicable documents.

It should be noted that the flight load survey, fatigue program, and static test are in addition to the proof load test which is priced as a part of the basic 132-airplane program. The proof load test is included in the basic price as required by the System 476L Statement of Work. However, Lockheed proposes a fatigue test program for the GL 207-45 which will include a proof load test; therefore, only the net cost of the fatigue test program, i.e., excluding cost of the proof load test, is shown in this addendum. Further, the fatigue test program priced in this addendum includes the flight load survey.

It is also contemplated that a complete unnumbered airframe structure would be manufactured for either the fatigue test or the static test, and two complete airframe structures are contemplated if both programs are implemented. The aerial refueling change has been calculated as completely new work. The alternate tail configuration has been considered to result in no change in the production cost because the effects of interrupted *production* will offset the weight savings involved.

The pricing data presented in connection with aerospace ground equipment data (AGE) on AMC forms 217 and 217A in Section 10 of this Volume have been computed on the basis of manhours and materials estimates developed by the affected engineering and manufacturing organizations.

The same rate structure used in the proposal for 132 airplanes has been followed in developing the pricing data presented in this section.

PROGRAM FUNDING SUMMARY
SPECIAL DATA REQUIREMENTS (5.4)

RDT&E and
PRODUCTION PROGRAM

FUNDING ITEM		FY 61[1]	FY 62[1]	FY 63[1]	FY 64[1]	FY 65[1]	Total[1]
5.4.1	Aerial Refueling	$ 21	$ 447	$ 825	$ 624	$ 502	$ 2,419
5.4.2	Flight Loads Survey	15	314	244	57	13	643
	Fatigue Test	206	4,414	3,434	800	194	9,048
	Static Test	158	3,379	2,629	612	149	6,927
5.4.3	Alternate Tail Configuration	68	1,449	1,094	211	11	2,833
5.4.4	Personnel Doors	(4)	(78)	(178)	(137)	(136)	(533)
5.4.5	Side Cargo Loading Door	(5)	(104)	(227)	(166)	(167)	(669)
5.4.6	Flight Deck	24	522	2,673	2,643	2,323	8,185
5.4.7	Oxygen System	5	110	405	415	360	1,295
5.4.8	Reliability Program	60	1,274	1,677	988	798	4,797
	Total Program	**$548**	**$11,727**	**$12,576**	**$6,047**	**$4,047**	**$34,945**

(1) Thousands

FORMAT "C"

SPECIAL DATA REQUIREMENTS

SUMMARY (5.4)

FISCAL YEAR EXPENDITURE (AIR FORCE) REQUIREMENTS (IN THOUSANDS)

	FY 61	FY 62	FY 63	FY 64	FY 65	FY 66	FY 67	FY 68	Total
5.4.1 Aerial Refueling	$ 18	$ 441	$ 528	$ 413	$ 523	$ 438	$ 58	—0—	$ 2,419
5.4.2 Structural Integrity									
Flight Loads	—0—	—0—	57	76	510	—0—	—0—	—0—	643
Fatigue Test	—0—	1,563	4,631	1,172	1,168	514	—0—	—0—	9,048
Static Test	—0—	1,673	4,884	370	—0—	—0—	—0—	—0—	6,927
5.4.3 Alternate Tail Configuration	59	1,427	1,187	207	5	(46)	(6)	—0—	2,833
5.4.4 Personnel Doors	(3)	(77)	(104)	(96)	(120)	(117)	(16)	—0—	(533)
5.4.5 Side Cargo Loading Door	(4)	(103)	(134)	(119)	(147)	(142)	(20)	—0—	(669)
5.4.6 Flight Deck	21	515	1,182	1,700	2,406	2,084	277	—0—	8,185
5.4.7 Oxygen	4	108	197	250	372	322	42	—0—	1,295
5.4.8 Reliability Program	110	776	1,065	969	640	609	428	200	4,797
Total	**$205**	**$6,323**	**$13,493**	**$4,942**	**$5,357**	**$3,662**	**$763**	**$200**	**$34,945**

16,618

FORMAT "F"

SUPER HERCULES · GL207-45

section **2**

AERIAL REFUELING (5.4.1)

This section covers the installation of in-flight receiver refueling capabilities using the boom aerial refueling system. The following brief description covers the mode of operation, the affected aircraft items and weight summary. A vital part of the work to be done in installing and checking out this system will be the flight test program which is also presented in detail complete with a schedule of testing. The cost information is then presented following the descriptive material.

SYSTEM DESCRIPTION

The modification for incorporating the aerial refueling capability is shown on Figure 2-1. An air refueling slipway and receptacle compatible with the standard Air Force boom aerial refueling system is mounted in the top of the crew compartment and connected to a manifold running aft through the forward center wing beam and coupled to the main fuel system crossfeed line. The slipway and receptacle are covered by hydraulically operated doors when not in use.

The subsystems contained in the air refueling system are control, signal, hydraulic, lighting, and slipway and receptacle drain system as well as slipway doors and actuating linkages, air refueling receptacle, refuel manifold, and main refuel valve. The air refueling controls consist of the master refuel switch and main refuel valve switch on the fuel system panel, the air refueling control panel located overhead between the pilot's and co-pilot's stations, and an emergency disconnect switch on each of the pilot's and co-pilot's control wheels. The signal system is used to control the refueling sequence and to indicate the sequence conditions of the system to the pilot or co-pilot. The hydraulic system functions to open or close the slipway doors and to hold or release the receptacle toggles which secure the tanker boom nozzle in the receptacle. The air refueling lighting circuit functions to illuminate the slipway, leading edges of the wing, and air refueling receptacle for night air refueling operations. The slipway and receptacle drain system provides for drainage of fuel.

The two hydraulically operated slipway doors are located immediately aft of the pilot's and co-pilot's stations and, when opened, provide an entrance to the air refueling receptacle for the tanker airplane refueling boom. The air refueling receptacle serves as an interconnect between the tanker boom and the receiver airplane refuel manifold. The refuel manifold and main fuel system crossfeed line distribute fuel from the air refueling receptacle to the individual fuel tanks. Just prior to an air refueling operation, the slipway doors and the main refuel valve are opened. The tanker boom then enters the air refueling receptacle and opens the spring-loaded sliding valve in the receptacle. The signal system is then set in operation through a series of limit switches.

The induction coil in the refueling receptacle connects the receiver airplane signal system to the tanker airplane signal system. The co-pilot selects the tank or tanks to be refueled and opens the respective fuel level control valves allowing fuel to flow from the tanker airplane through the refuel manifold and the main crossfeed line into the fuel tanks. After the tanks are filled or the fuel level control valves are closed and the refuel manifold

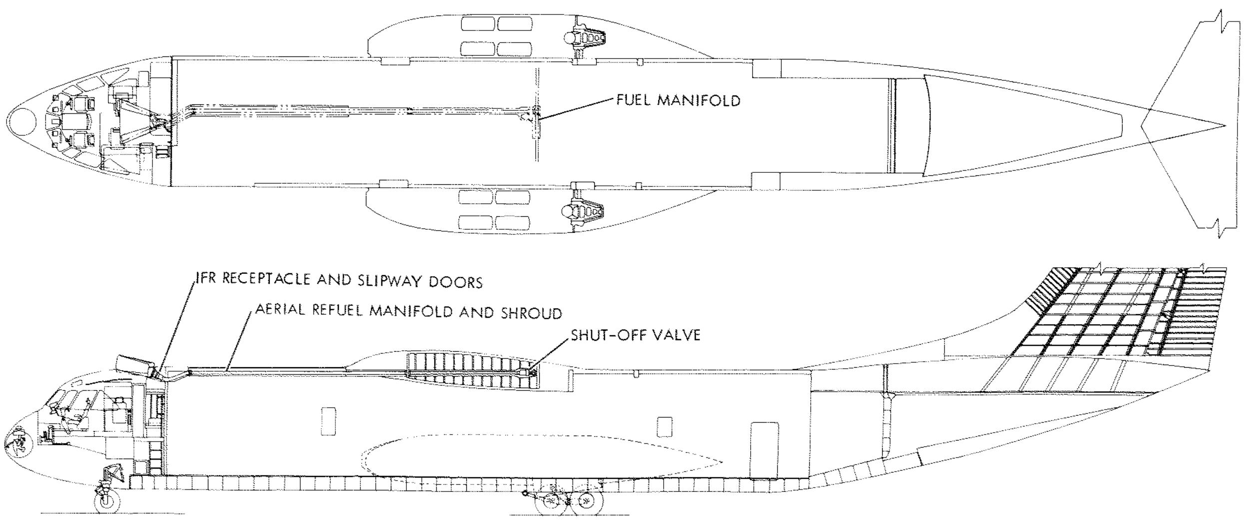


Figure 2-1—IFR RECEPTACLE INSTALLATION.

pressure builds up to the preset pressure, the pressure disconnect switch is closed causing an automatic disconnect. When the refueling operation is completed, the co-pilot closes the slipway doors and the main refuel valve.

AFFECTED ITEMS

The Very pistol is relocated off the centerline of the crew station. The front wing beam, pilot's overhead panel, hydraulic system, and electrical wiring is to be modified along with miscellaneous fuselage structures to provide the required holes and supports for the piping, wiring, shrouds, slipways, and doors composing the system.

WEIGHT SUMMARY

Aerial refueling (receiver)	
Bulkheads and modifications	160 lbs.
Doors, mechanisms and wiring	20
Receptacle unit installation	120
Total (weight increase)	300

AIR REFUELING FLIGHT TEST PROGRAM

The flight test program required to qualify the GL 207-45 airplane for air refueling (A/R) receiver operations is described herein. This program includes the flight testing necessary to establish the compatibility of the receiver-tanker combination, the adequacy of the flying boom receptacle provisions and the air refueling subsystem, and the operational suitability of the receiver airplane. The proposed flight test program scheduled to accomplish the specified objectives is presented in Figure 2-2 Throughout the flight phase indicated on the schedule, a supporting KC-135 tanker airplane will be required.

Flight Test Program

The capability and the suitability of the air refueling receiver airplane and supporting equipment will be determined and demonstrated in accordance with the Model Specification military mission requirements. This will be accomplished essentially in the manner and order of flight testing described in the following paragraphs.

Formating

Initially, sufficient flight testing will be conducted to establish compatibility between the receiver and tanker aircraft. Normal formating procedures and positions will be determined prior to actual hook-ups. Concurrently, an evaluation will be made of receiver airplane stability and control characteristics in proximity to the tanker airplane. The optimum

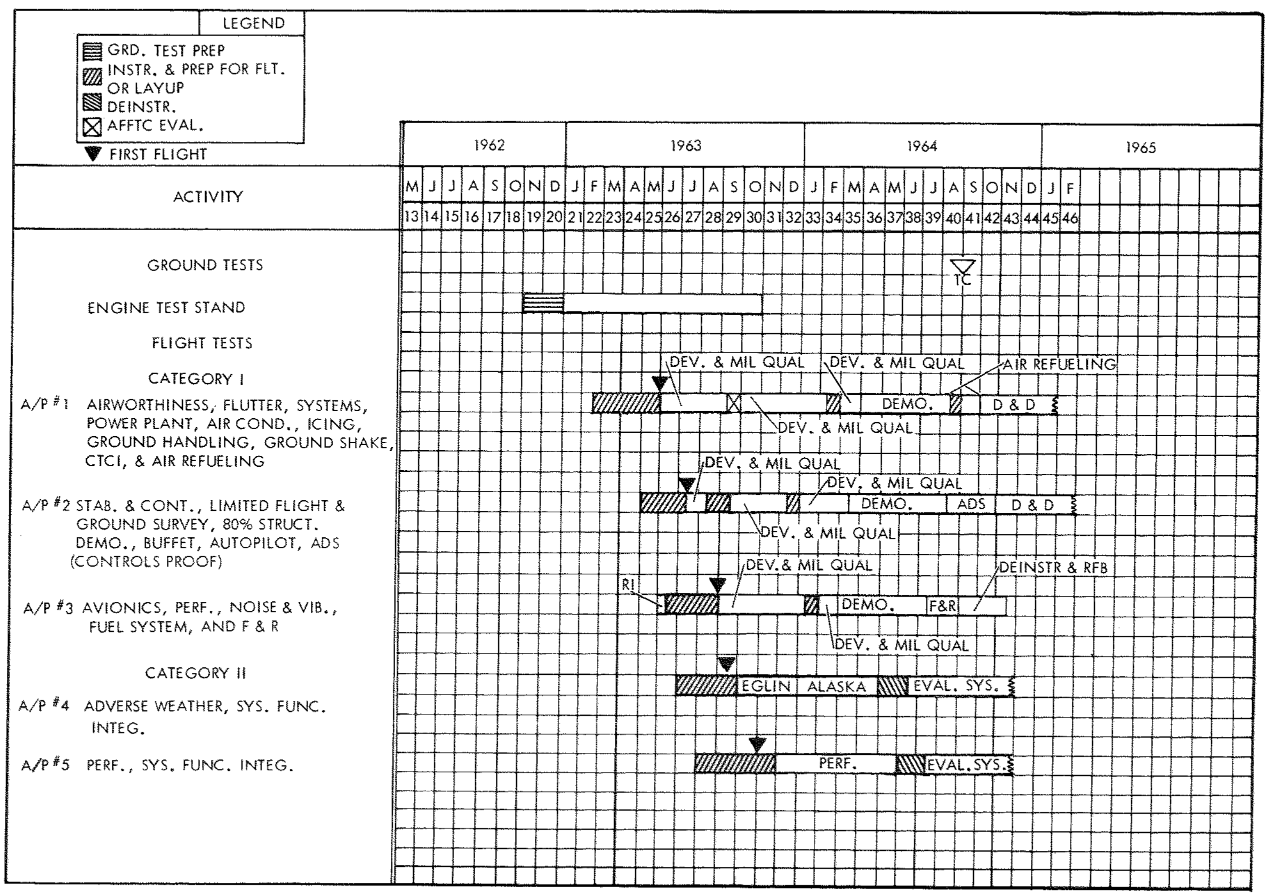


Figure 2-2—FLIGHT TEST PROGRAM SCHEDULE—AIR REFUELING RECEIVER—AIRCRAFT EVALUATION.

flight envelope of speed and altitude for refueling operations will be determined for various gross weights and the results integrated with tanker airplane performance requirements.

Receptacle Provisions

Dry-run hook-ups will be accomplished to prove the suitability of receiver receptacle placement and utilization. The location of the receptacle will be evaluated in terms of receiver-tanker orientation within the "contact envelope", pilot's visibility requirements for observing the boom nozzle location and tanker signals, and safety considerations such as possible damage from a missed contact or fuel spillage. The functional operation of the slipway doors to open, close, and lock when actuation is selected both automatically and manually will be checked at various airspeeds. The ability of the hydraulically actuated receptacle latching toggles to lock-in the boom nozzle, utilizing both normal and emergency actuation procedures, will be verified during these contacts. In conjunction with these tests, voluntary disconnects due to receiver pilot or boom operator actuation and automatic disconnects due to exceeding the boom envelope will be evaluated for satisfactory operation.

A/R Subsystem

After satisfactory completion of all preliminary evaluations, wet contacts will be conducted to thoroughly evaluate the air refueling subsystem and its components. Functional tests of the A/R control panel provisions will be made to insure that the selection and indication of subsystem operation or component actuation, using either the automatic or emergency procedures, are adequate and meet the design requirements. Operational characteristics of the A/R subsystem will be investigated to verify that the installation provisions and capabilities are adequate for successful accomplishment of mission requirements. Included in this category will be tests to demonstrate suitable pre-contact check-out and refueling sequence (tank selection), acceptable refueling schedule based on the maximum allowable fuel pressure and flow, adequate primary and secondary fuel shut-off control, and satisfactory fuel scavenging from the refueling manifold. The acceptability of normal and peak fuel pressures in the refueling manifold, fuel tank differential pressures, and tank venting characteristics will be determined by appropriate inflight measurements. The automatic disconnect feature of the boom, as actuated by a build-up or surge in refueling manifold fuel pressure, will be functionally checked for satisfactory operation.

Operational Procedures

Missions will be flown during this phase of the program for the purpose of defining and/or demonstrating the operational aspects of the GL 207-45 airplane utilizing inflight pressure refueling. All appropriate data for incorporation in the flight handbook will be obtained or verified at this time. This will include a thorough review and finalization of all normal and emergency procedures applicable to receiver aircraft A/R system operations and A/R flight operations. Also, rendezvous patterns and procedures will be established and checked for operational suitability, taking into account the compatibility of receiver-tanker mission requirements and supporting avionics equipment.

INSTRUMENTATION REQUIREMENTS

Test instrumentation necessary to demonstrate satisfactory air refueling system operation includes basic airplane quantities, fuel pressures and flows at representative points within the refueling system, fuel tank and vent differential pressures, and camera coverage of hook-ups.

The recording system employed will consist of an oscillograph and photo panel. Reference is made to Basic Proposal, Volume 1, for a discussion of instrumentation methods, data processing techniques, and supporting facilities.

PRICING INFORMATION
AERIAL REFUELING (5.4.1)

		No Year Contractor's Proposal	Qty 5
	Hours[1]	**Rate**	**Amount**[1]
Engineering			
D.L.—Basic	36	$4.11	$148
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	103
Material & Direct Charges		.56	20
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$271
Tooling			
D.L. Planning—Basic	6	$3.59	$ 22
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	5	3.59	18
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	29	3.59	104
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		115.62% DL	166
Material & Direct Charges		1.26 TMH	37
Subcontract Tooling			—0—
Total Tooling			$347
Manufacturing—(Production)			
Direct Labor	16	$2.82	$ 45
Overhead		115.62% DL	52
Material & Direct Charges			20
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$117
Quality Assurance			
Direct Labor	4	$3.39	$ 14
Overhead		115.62% DL	16
Total Quality Assurance			$ 30
G & A Expense		23.99% DL	$ 84
Total Cost			$849
Profit		8%	68
Price			**$917**

(1) Thousands

FORMAT "A"

PRICING INFORMATION
AERIAL REFUELING (5.4.1)

	Hours[1]	Rate	FY 63 Qty 31 Contractor's Proposal Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	43	$2.92	$126
Overhead		111.04% DL	140
Material & Direct Charges			124
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$390
Quality Assurance			
Direct Labor	3	$3.49	$ 10
Overhead		111.04% DL	11
Total Quality Assurance			$ 21
G & A Expense		23.00% DL	$ 31
Total Cost			$442
Profit		8%	35
Price			**$477**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
AERIAL REFUELING (5.4.1)

	Hours[1]	Rate	Amount
		FY 64 — Contractor's Proposal	Qty 48
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	41	$3.01	$123
Overhead		109.10% DL	134
Material & Direct Charges			192
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$449
Quality Assurance			
Direct Labor	3	$3.61	$ 11
Overhead		109.10% DL	12
Total Quality Assurance			$ 23
G & A Expense		22.88% DL	$ 31
Total Cost			$503
Profit		8%	40
Price			**$543**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
AERIAL REFUELING (5.4.1)

		FY 65	Qty 48
		Contractor's Proposal	
	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	32	$3.10	$ 99
Overhead		115.12% DL	114
Material & Direct Charges			192
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$405
Quality Assurance			
Direct Labor	2	$3.73	$ 7
Overhead		115.12% DL	8
Total Quality Assurance			$ 15
G & A Expense		24.40% DL	$ 26
Total Cost			$446
Profit		8%	36
Price			**$482**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

AERIAL REFUELING (5.4.1)

PROPOSAL SUMMARY
Contractor's Proposal

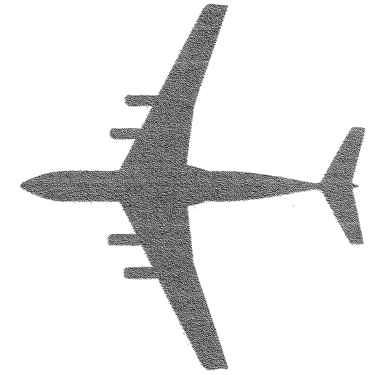
	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic	36	$4.11	148
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	103
Material & Direct Charges		.56	20
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ 271
Tooling			
D.L. Planning—Basic	6	$3.59	$ 22
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	5	3.59	18
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	29	3.59	104
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		115.62% DL	166
Material & Direct Charges		1.26 TMH	37
Subcontract Tooling			—0—
Total Tooling			$ 347
Manufacturing—(Production)			
Direct Labor	132	$2.98	$ 393
Overhead		111.96% DL	440
Material & Direct Charges			528
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$1,361
Quality Assurance			
Direct Labor	12	$3.50	$ 42
Overhead		111.90% DL	47
Total Quality Assurance			$ 89
G & A Expense		23.66% DL	$ 172
Total Cost			$2,240
Profit		8%	179
Price			**$2,419**

[1]Thousands

FORMAT "A"

SUPER HERCULES · GL207-45

section **3**



STRUCTURAL INTEGRITY (5.4.2)

This section summarizes the proposed program to accomplish a flight load survey, Reference MIL-S-5711, and a static test program to design ultimate load for all major structural components. In addition, a fatigue program in accordance with MIL-A-8866 (ASG) and WCLS-TM-58-4, to verify the service life of the airplane for 30,000 hours flight and 12,000 landings, is outlined. The flight load survey program is discussed first, followed by the static test and fatigue test programs.

A proof loads ground test, a limited air and ground load survey, and an 80% limit load structural demonstration has been proposed in Volumes 1 and 2 of this report as a minimum program to substantiate structural design on the basis of operational use of airplanes in the normal MATS or civil transport category. Throughout the work statement, however, references are made to additional capability required of the airplane over and above the normal transport category. For military transport operation of airplanes, Lockheed strongly recommends the following minimum structural test program, which includes a static test to ultimate design load and an air load survey and flight structural demonstration to 100% of design limit load.

STRUCTURAL INTEGRITY FLIGHT AND GROUND LOAD SURVEY PROGRAM

Presented herein are the flight and ground load survey programs required to establish the structural integrity of the Model GL 207-45 airplane. The flight test program includes a combined flight load survey and structural demonstration in accordance with the requirements of paragraph 4.1.1 of Specification MIL-S-5711 (USAF), and a qualification of the aerial delivery system configuration. The ground load test program includes landing tests to 80% of design sink rates and the determination of taxi maneuver limitations. The flight and ground test program schedules are shown in Figure 3-1.

Flight Load Survey Program

The combined flight load survey and structural demonstration will be conducted in accordance with paragraph 4.1.1, or Specification MIL-S-5711 (USAF). A brief description of the test program follows:

Initial Phase

The initial phase test program includes the establishing of a maneuvering grid, demonstration to 80%

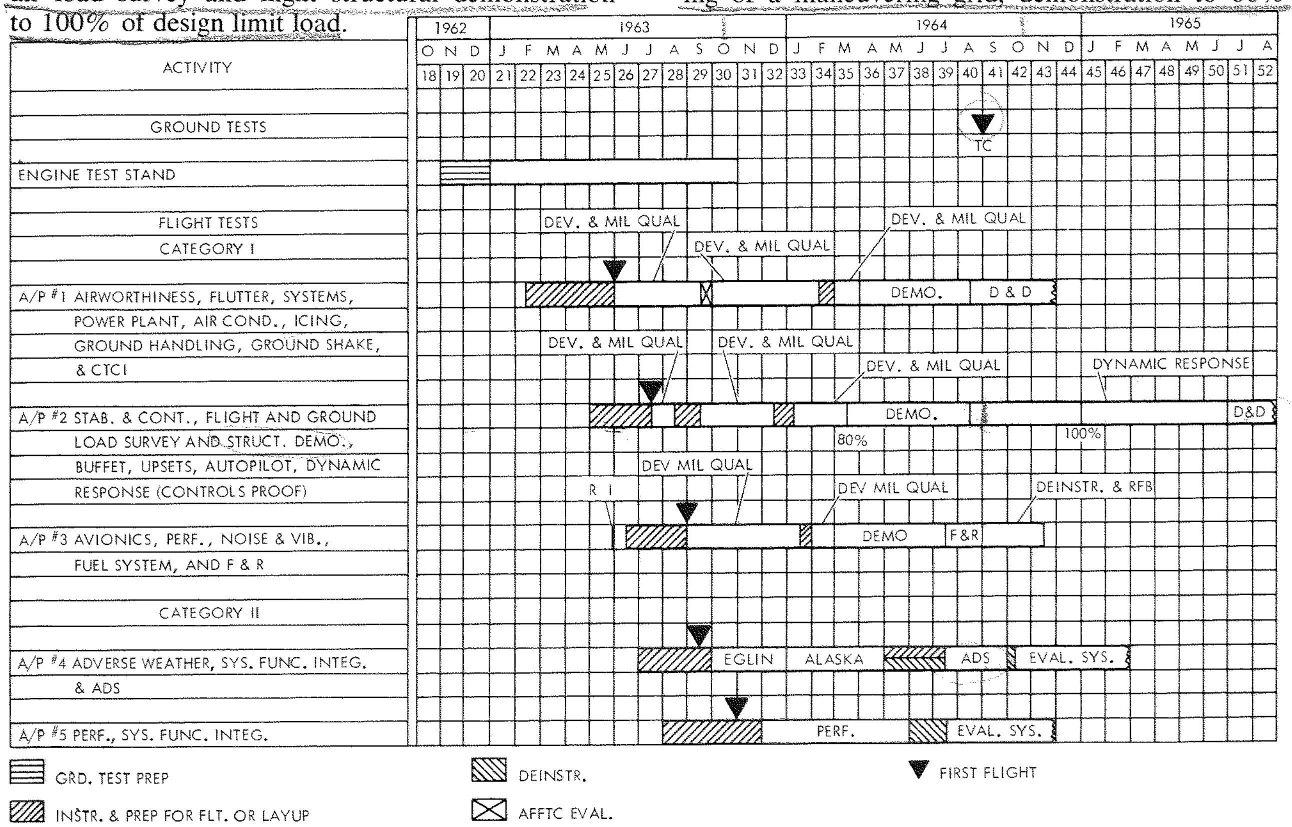


Figure 3-1—FLIGHT TEST PROGRAM SCHEDULE—7 AIRCRAFT INCLUDING 100% STRUCTURAL DEMONSTRATION.

of design criteria conditions, and the definition of suspected critical conditions as determined from flight test data.

Maneuvering Grid

A maneuvering grid will be defined up to V_D/M_D (Maximum permissible airspeeds—Mach numbers) and 80% limit maneuvering load factors by conducting roller coaster, turn, roll, and yaw maneuvers.

Clean configuration roller coaster maneuvers will be conducted at high, intermediate, and low altitudes and six airspeeds up to V_D/M_D with a forward and aft center of gravity, design take-off and landing gross weights, and power settings for level flight and idle. In addition, roller coaster maneuvers will be conducted in the landing configuration at one altitude and four airspeeds with a forward and aft center of gravity, design take-off and landing gross weights, and power settings for level flight and idle.

Turn maneuvers will be conducted under similar test conditions to define the horizontal stabilizer loads.

The data obtained from roller coaster and turn maneuvers will provide an accurate means of predicting unaccelerated and accelerated flight loads on the wing, fuselage, and horizontal stabilizer under normal operational conditions and configurations.

Uncoordinated aileron rolls will be conducted from a 1.67 "g" turn in the clean configuration at a high and low altitude and six airspeeds up to V_D/M_D with a mid center of gravity, design take-off and landing gross weights, and power for level flight. Aileron deflections will be increased incrementally, using control wheel stops, until 80% of full wheel deflection or 80% of design limit load is obtained, whichever occurs first. These data, in conjunction with the roller coaster data, will permit the prediction of critical aileron roll conditions.

Abrupt rudder kick maneuvers will be conducted at a high and low altitude and six airspeeds up to V_D/M_D with an aft center of gravity, design take-off and landing gross weights, and power for level flight. The rudder kick input will be increased incrementally using rudder pedal stops to prevent exceeding 80% of design limit load.

Design Criteria Conditions

The requirements of paragraph 4.2.2.1.2 will be satisfied by the maneuvering grid tests and the following maneuvers:

1 Abrupt Symmetrical Pullout at the conditions determined as critical analytically. An elevator control column stop will be used to control the build-up of this maneuver to 80% of design limit load.

2 Abrupt symmetrical Pullout With Abrupt Checking at the conditions determined as critical analytically. Control stops will be used in this maneuver also.

3 Rudder Maneuver—Landing Approach at the conditions determined analytically to be critical. Rudder pedal stops will control the build-up to a maximum of 80% of design limit load.

Flight Test Defined Critical Condition

The data obtained to define the maneuvering grid will be reviewed to ascertain any possible critical conditions not defined analytically. Should an apparent critical condition occur, it will be investigated and defined by flight testing.

Following the foregoing test program, airload measurements will be made during aerial delivery of unit loads up to 35,000 pounds. These data will substantiate the structural integrity of the aerial delivery configuration.

Final Phase

The final phase combined flight load survey and structural demonstration will be conducted to 100% of design limit load at the test conditions determined as critical from extrapolated initial phase data. The 100% demonstrations will be completed through a systematic build-up program. The flight test maneuvers are as follows:

1 Normal symmetrical pullout
2 Normal symmetrical pushdown
3 Gust simulation—The test conditions will be defined such that the gust loading on the wing is simulated in a normal symmetrical pullout.
4 Normal uncoordinated rolling pullout
5 Abrupt symmetrical pullout
6 Abrupt symmetrical pullout with abrupt checking
7 Flaps down pullout
8 Abrupt uncoordinated rolling pullout
9 Rudder maneuver—high speed
10 Rudder maneuver—landing approach

Ground Load Survey Program

A ground load survey program will be conducted to substantiate the structural integrity of the airplane for high sink rate landings and normal taxi maneuvers.

Landing Tests

The landing tests will be conducted at sink rates up to 80% of design limits with design take-off and landing gross weights and an aft center of gravity. Sufficient data will be obtained to permit an accurate prediction of landing loads at the design sink rates.

Taxi Tests

Taxi tests will be conducted with design take-off and landing gross weights at forward and aft center of gravity positions. The tests will include straight taxiing with maximum braking to a stop, and turns with and without braking to a stop at several ground speeds and nose gear steering angles. These data will establish taxi maneuver limitations as a function of nose gear steering angle, ground speed, and braking.

Instrumentation Requirements

Test instrumentation for the flight load survey and structural demonstration is essentially as specified in paragraphs 3.6.1 and 3.6.3 of Specification MIL-S-5711. The instrumentation for the flight and ground load survey includes basic airplane, stability and control, and load instrumentation. Instrumentation will be installed to measure loads on the wings, vertical and horizontal stabilizers, fuselage, landing gear, ramp, and wing flaps. Load measuring instrumentation will be installed on flight airplanes and the static test article.

Strain gauge installations, calibrated to known applied loads and verified during the ultimate load static test program, will be used to measure shear, bending moment, and torsion at the wing roots, at four additional spanwise locations on the right wing, at the roots of the horizontal stabilizers and vertical stabilizer, at two additional spanwise locations on the right horizontal stabilizer, and at an upper vertical stabilizer location. Bending moment measurements will be made at two additional spanwise locations on the right wing. Measurements of vertical and side bending on the fuselage and right-hand engine nacelles, right wing flap moments, aft fuselage ramp and petal door loads, horizontal stabilizer trim actuator loads, and nose gear and main landing gear vertical, side, and drag loads will also be recorded. Pitch angle, pitch acceleration, and strut torsion of the bogie main gear will also be measured.

Accelerometers for determination of inertia loads will be installed at the tips of the wings, at several locations along the elastic axis of the right wing, and at the center of gravity of the right-hand engine nacelles. Accelerations will also be measured at the center of gravity of the airplane, at forward and aft locations in the fuselage, and on the main landing gear struts. Airplane rate of descent, ground speed, landing gear strut positions, nose gear steering angle, landing gear touchdown light, and brake pressure will also be recorded during the landing and taxi tests.

The recording system employed for this program will consist of magnetic tape equipment and a photo panel. Reference is made to Volume 2, for a discussion of instrumentation methods, data processing techniques, and supporting facilities.

STATIC TEST PROGRAM

If structural integrity of the GL 207-45 airplane is demonstrated by a static ultimate load test program, the proof test program should be eliminated and the ultimate load program substituted. This program is proposed to be conducted on a structurally complete GL 207-45 airframe. The test specimen will have all the flight controls systems installed. The airframe will be tested to design ultimate loads for the critical conditions of all structural components and for all flight control systems. The major components of the airplane which will be tested under this program are the wing, fuselage, empennage, and landing gears. Other items which will be tested are the engine mountings, flaps, control surfaces, control systems, and cargo floor and/or restraint rails. Non-structural components, fuel systems, electrical systems, hydraulic systems, air-conditioning systems, and soundproofing will be omitted from the test article. Areas of the structure which are normally reinforced by pipe flanges, hydraulic fittings, or similar items will be reinforced by actual or simulated parts. After completion of the ultimate load test program, a decision will be requested during consultations with the Air Force as to the desirability of a test to destruction of major components. A major advantage of continuing tests to destruction is that actual failing strength levels can be established for most generally critical conditions, and growth of the basic structure can be confirmed. On the other side of the coin—destruction of the static test article greatly reduces its usefulness as a tool in future development programs.

The proposed test program consists of tests to design ultimate load. The tests are not listed in order of their expected completion. The order of testing will be dictated primarily by schedule considerations and test jig installation required for an airplane balance. Many of the tests listed may be critical for more than one area of the airplane structure; in which case the test conditions will be combined as far as is practical.

Wing Tests

1. Maximum upward bending
2. Maximum downward bending
3. Maximum torsion condition
4. Critical flaps loading condition

Fuselage Tests

1. Maximum upward bending—forward fuselage, aft fuselage
2. Maximum downward bending—forward fuselage, aft fuselage
3. Maximum side bending and torsion condition
4. Ultimate pressure test (no flight loads)
5. Critical flight loads combined with internal pressure as required

Landing Gear Installed on Airframe Tests

1. Main landing gear—critical load combinations
2. Nose landing gear—critical load combinations

Empennage Tests

1 Horizontal stabilizer

—Maximum upward bending

—Maximum downward bending

—Maximum torsion condition

2 Vertical stabilizer—critical side load condition

Control Surface Tests

Mounted on airplane and restrained by locked controls

1 Aileron
2 Elevator
3 Rudder
4 Flaps
5 Trim tabs
6. The primary flight control surfaces of the third airplane will be proof loaded prior to the first flight of an airplane.

Power Plant Mounting Tests

1 Critical loading conditions

Control System Tests

1 All flight controls will be tested for maximum ultimate single and combined pilot effort, and for ultimate maximum output of the boost or power units. A partial system test will be conducted on the third airplane prior to the first flight of an airplane.
2 All flight controls will be operated while loaded to 80% of the limit load for the control system, to demonstrate the lack of jamming, excessive friction, or excessive deflection. This test series will be performed on the third airplane, prior to the first airplane flight, and not on the static test article.

Miscellaneous Tests

1. Cargo floor and restraint rail tests for maximum flight loads and crash loads as required
2 Landing gear doors — critical aerodynamic loads as required
3 Aft cargo doors — critical aerodynamic loads as required

Test Procedures

The airplane will be arranged within a structural steel framework anchored to the laboratory floor. The test loads will be applied to the airplane structure in a manner which simulates the design air, inertia, or ground load distribution. Loads will be applied to the wings and other aerodynamic surfaces by hydraulic jacks through tension pads and a whiffle-tree system. Balancing loads, as required, will be applied to the fuselage by loading straps which will be riveted or bonded to the skin at frame stations, or by concentrated loads applied to appropriate locations such as engine mountings. The landing gear will be loaded by means of hydraulic jacks attached to dummy wheels mounted on the axles.

Some of the test conditions require the fuselage cabin to be pressurized. A hydrostatic tank will be used so that the fuselage can be submerged and the pressure applied hydrostatically. The arrangements will be such that the pressurization and simulated flight loads may be applied simultaneously as shown in Figure 3-2.

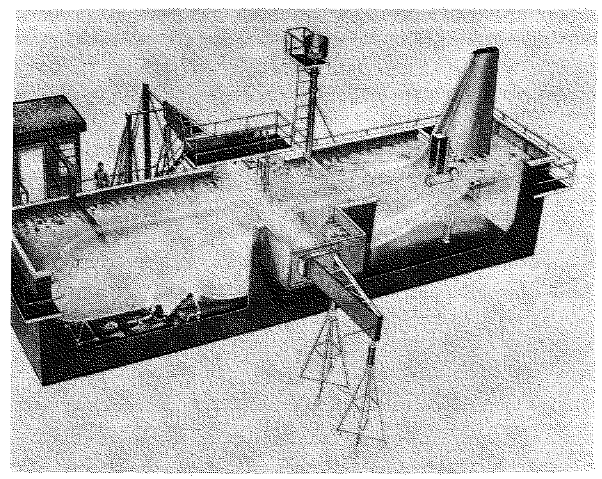


Figure 3-2—C-130A IN HYDROSTATIC TANK.

Ultimate load tests of the flight control surfaces will be conducted, using tension pads to simulate the air loads. The loads on the surface will be reacted by locking the controls system as close to the surface as possible.

Tests of the flight control systems will be conducted by loading the relevant cockpit control with the control surface blocked. Ultimate loads will be applied with and without the power boost operative, and in both directions. Determinations of system stiffness will also be made.

During all tests, loads on hydraulic jacks will be controlled by Edison load maintainers (proportional pressure controlling devices) so that all jacks will be loaded and unloaded simultaneously. Loads will be increased in increments to the desired load level with a pause at each load increment for data readout and examination of the structure. The airplane will be unloaded after limit load has been applied and structural set determined, and the airframe examined for damage. If the test is of a large, complex part of the airframe, loading will be stopped after approximately 85% of ultimate load has been applied, and a complete analysis of the data will be made to determine if there are any indications of premature failure. After this review of the data is completed, the structure will be taken to design ultimate load.

FATIGUE PROGRAM

The recent emphasis by the Air Force and the FAA on aircraft fatigue life prediction and substantiation has revealed the desirability and necessity for a thorough design, analysis, and test program for this purpose. The criteria of References 1 and 2, formulated by the Air Force, afford a logical basis for the determination of the most probable service life of an aircraft, within state-of-the-art limitations. Accordingly, a fatigue program consisting of the following four phases, is proposed for the GL 207-45 airplane.

Phase I	Fatigue Load Spectra Analysis
Phase II	Laboratory Fatigue Tests
Phase III	Dynamic Response Flight Tests
Phase IV	Statistical and Dynamic Analysis of Test Data

Lockheed is currently conducting an extensive fatigue program on the C-130B airplane which has a fatigue life goal of 30,000 flight hours and 12,000 landings. For the GL 207-45 program, it is assumed that similar requirements will apply.

Phase I — Fatigue Load Spectra Analysis

A service life analysis of all major components (wing, fuselage, empennage, landing gear) will be conducted to predict cyclic loadings according to normal service usage. The test load spectrum will be based on the expected utilization schedule of the airplane which will define operational parameters such as take-off weights, rates of climb, cruise altitudes, duration of cruise, rates of descent, airspeeds, landing weights, and the flight time and annual distribution of various types of typical missions. Approved environmental and operational load frequency data will be expanded to obtain test load schedules representative of the air loads due to gusts, buffeting and maneuvers; ground loads due to taxi and landing; fuel, equipment and structural inertia loads; and loads due to pressurization of the fuselage. Dynamic overstress effects will be accounted for in the fatigue spectrum by analytically evaluating the elastic response characteristics of the aircraft in the form of transfer functions. Methods for conducting these analyses have been developed and correlated with the results obtained from the flight test program on the C-130B. This will greatly reduce the extent to which the fatigue test results must be later modified in the event that the flight test program lags behind the laboratory fatigue test.

Phase II — Laboratory Fatigue Tests

Wing and Empennage Tests

The fatigue load spectra established in Phase I will be used to test the GL 207-45 structural components. The test specimen will be a structurally complete airplane. The seventh production airframe will be utilized for this program. All electrical equipment and wiring, as well as the control systems, will be omitted; however, holes, brackets, shelves, and other items that may cause stress concentrations or offer local restraint, and thus affect the test results, will be included. Power plants will be omitted, but the pylons will be included to provide ready attachment for loading frames through which engine thrust and inertia loads will be applied. The fuselage will include all windows, doors and pressure bulkheads, in order to provide a cyclic pressurization load evaluation of the fuselage structure.

The test will be conducted simultaneously on two separate parts of the structure. One part will consist of the wing, pylons, front and mid fuselage, and landing gear support structure with dummy gear, while the second part will consist of the complete empennage mounted on a portion of the fuselage extending aft from Fuselage Station 1078. This division of the test article offers certain advantages over testing the entire airplane as a unit. These advantages include (1) simplification of testing, since the unsymmetrical loading on the tail will not complicate the symmetrical loading system to be used on the wing, (2) elimination of the problem that arises due to the difference in the structural response of the wing and tail structure, which results in unrelated test spectrums for the two components, and (3) delays in the test of one unit, which will have a less serious effect on the time schedule established for the fatigue program.

The wing and the fuselage section forward of F.S. 1078 will be tested as a unit since there is a significant interaction between the loads applied to these components. Only symmetrical loading conditions will be applied to the wing and pylons. A pressure bulkhead and framework will be fabricated and attached to the fuselage at F.S. 1078. The framework will be of such length and configuration that the proper fuselage shear and bending moment will be introduced into the fuselage at F.S. 1078 to simulate the empennage and aft fuselage loads. The appropriate fuselage loads will be introduced through straps located at frequent intervals along the length of the fuselage, and through floor loaders placed along the length of the cargo floor.

The empennage and aft fuselage will be tested as a unit in a separate tank. A pressure bulkhead will be attached to F.S. 1078, and the specimen will be supported at this station on a mounting jig. The tail loads will be reacted by the aft fuselage through the mounting jig and straps attached along the fuselage at appropriate intervals. Normal interaction of the airplane aft pressure bulkhead and fuselage shell will be evaluated in this test.

The influence of the specimen closure bulkhead is dissipated over a very short length of fuselage and will not affect the important areas of the program. The highly redundant area of the fuselage in the vicinity of the ramp and aft cargo door will be subjected to representative unsymmetrical cyclic loads to substantiate the structural integrity of this area with respect to the proper utilization of the designed load paths.

Separate water tanks will be used to submerge the fuselage portion of wing-fuselage and empennage-fuselage test assemblies. Water will be used as the pressurizing medium for the crew and cargo compartments in order to minimize the danger of extensive damage to the specimen in the event that premature cracks appear in the pressurized structure. The wings will extend beyond the sides of the tank through flexible seals which will be installed at approximately B.L. 140L and R. The water in the pool will be monitored and controlled as closely as possible to a PH level of 7.0 to minimize corrosive action on the test specimen and loading equipment.

Lockheed has had extensive experience in this type of testing, having previously completed a fatigue test on the Model C-130A airplane, wherein cyclic loads representing 60,000 hours of flight were applied to the fuselage in the hydrostatic tank shown in Figure 3-2.

The proposed tests, however, are more extensive than the C-130A test, in that all major structural components of the GL 207-45 airplane will be tested.

It is proposed that the wings be loaded through formers attached to double-acting hydraulic jacks. Formers will be oriented parallel to the wing ribs and located along the span at appropriate intervals so as to duplicate the proper shear, moment, and torque loading of the wing for each condition of the loading spectrum as closely as is practicable. One or more double-acting hydraulic jacks will be attached to each former. The attachment point of the jack to the former, or the ratio of pressures in multiple jacks, will be varied to permit variations in center of pressure location, as well as shear and bending moment variations, during simulation of the various loading conditions included in the loading spectrum. This is the procedure being followed in the fatigue test of the C-130B. A photograph of the wing fatigue test set-up is shown in Figure 3-3. Dummy engines will be fabricated and attached to the existing engine mounts in each pylon. Double-acting hydraulic jacks will be attached to each dummy engine to simulate the appropriate thrust or drag and inertia loading of the power plants.

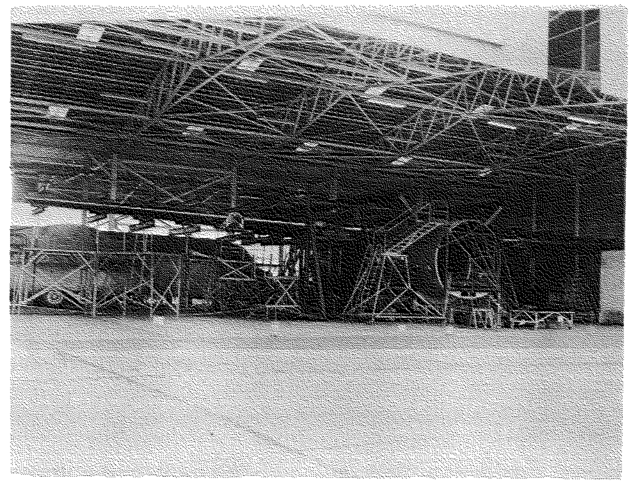


Figure 3-3—GENERAL ARRANGEMENT FOR WING FATIGUE TEST.

Suitable jigs will also be fabricated and mounted on the nose and main landing gear attachment points. Double-acting hydraulic jacks will be attached to each landing gear jig such that appropriate vertical and drag loads for taxi, landing and ground-to-air loadings can be applied to the structure.

The test loads for the wing-fuselage assembly will be reacted along the fuselage for airborne loadings, and at the dummy nose and main landing gears for grounds loads. Hydraulic jacks acting on straps attached to fuselage frames, longerons, and loading frames located along the length on the cargo floor will be used to balance the air loads applied to the wing. The vertical and horizontal loading equipment will be securely fastened to the surrounding structure of the water tank, which will be a stationary structure due to the large mass of water contained in the tank. However, to insure that local deformations of the tank structure will not adversely affect the loads being applied to the fuselage, the tank will be anchored at intervals to a 9-inch-thick concrete slab.

The horizontal and vertical tail structure will be loaded in a manner similar to the wing. Formers, parallel to the ribs, will be located at appropriate intervals along the surfaces. The weight of all formers, loading jigs, and hydraulic cylinder pistons used in loading the airplane will be properly counterbalanced by either dead weights or compensation in the hydraulic pressures used in the jacks. A photograph of a similar set up for the C-130B empennage fatigue test is shown in Figure 3-4.

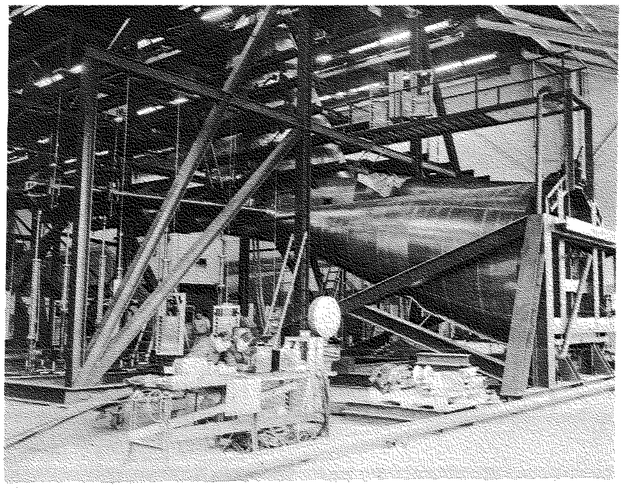


Figure 3-4—GENERAL ARRANGEMENT FOR EMPENNAGE FATIGUE TEST CYCLE.

The loading spectrum will be divided into blocks representing 5% of the desired fatigue life, or 1,500 flight hours and 600 landings. Each block will contain a full range of loads from the various sources of fatigue damage. A typical subspectrum will include a schedule of loads representing the taxi condition, followed by an appropriate number of ground-to-air cycles. Fuselage pressurization cycles will be applied simultaneously with the ground-to-air cycles. Additional fuselage pressure cycles will be applied with a lg flight condition to meet the requirement of 20,000 pressure cycles. This will be followed by the application of the loads due to gust, maneuver and landing which are superimposed on a lg load and steady cabin pressure. The subspectrum will be repeated until the fatigue life goal is achieved or until the degree and frequency of failures rules it impractical to continue the test.

All program loading and control will be accomplished from a centralized location. High-pressure, high-capacity hydraulic pumps will supply the power to operate the hydraulic jacks, while a water pump will supply water to a given head height to pressurize the fuselage. To the extent practical, all symmetrically-located hydraulic jacks will be supplied by equal-length lines. The control systems used for these tests will be the automatic control equipment supplied by Research, Inc., of Hopkins, Minnesota, which is currently being used on the C-130B fatigue test program. This is a servo valve-type control system with special safety provisions incorporated in the design. A view of the cycling and load controls and the servo valve amplifier channels is shown in Figure 3-5. The load distribution and its build-up in the structure will be monitored by suitable strain gages at appropriate locations in the structure and by load cells connecting the jacks to the formers.

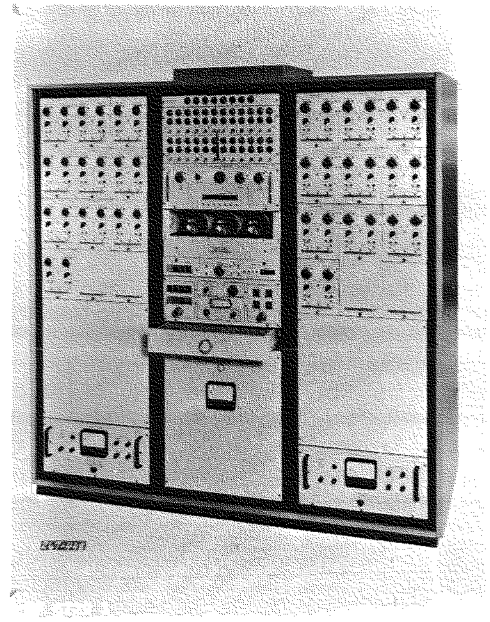


Figure 3-5—LOAD—CYCLE CONTROL CONSOLE.

Instrumentation for this test will consist primarily of strain gages and load cells. Large numbers of strain gages will not be employed, since detailed information concerning stress levels and distributions will be obtained from the static test program being conducted on the airplane. Rather, strain gages will be located at appropriate locations on the structure where the character of the loads being applied can be identified for control purposes. Strain gages and possible crack detection wires will also be located in areas where theoretical analysis or the results of tests on component parts indicate that fatigue cracks may develop. Strains will be recorded for all loading conditions prior to the initiation of cycling to insure proper distribution of load in all components of the structure. The strains will also be recorded at appropriate intervals during the cyclic history of the test to detect any redistribution of load. Also, certain key gages and load cells will be monitored continuously throughout the test program, and the entire structure will be subjected to periodic inspections to detect cracks, failed rivets, or other evidence of structural distress.

Main and Nose Landing Gear Tests

The fatigue life of the GL 207-45 landing gear is based on 30,000 flight hours, which include 12,000 taxi, take-off and landing operations. The fatigue test load spectrum will meet the requirements of MIL-A-8866 as a minimum, and will include fatigue loads data generated by Lockheed's studies of, and experience with, the P2V, Constellation, and C-130 aircraft. The test equipment will be similar to that used for the C-130 fatigue program, featuring semi-automatic control of loads and application of cycles to the test speciman.

Main Landing Gear

The main landing gear fatigue tests will be performed with test equipment similar to that used on the C-130 gear. Methods, procedures and distributions of loads within the basic unit spectra will be based on C-130 operational and flight test data. These values will be modified if necessary to include data obtained from the GL 207-45 flight test program. However, it is anticipated that such changes will be minor in nature and extent.

Combinations of vertical, fore-and-aft, and side landing impact loading will be applied to the test specimen, including the effects of spin-up and spring-back forces for a range of landing speeds, gross weights, and airplane attitudes at contact. Similar combinations of loading will be applied for taxi, turning, pivoting and braking loads. One design limit vertical load will be applied to the gear for each 1000 landings.

Nose Landing Gear

The nose landing gear tests will also be performed with equipment set-up and procedure similar to that used for the C-130, as illustrated in Figure 3-6.

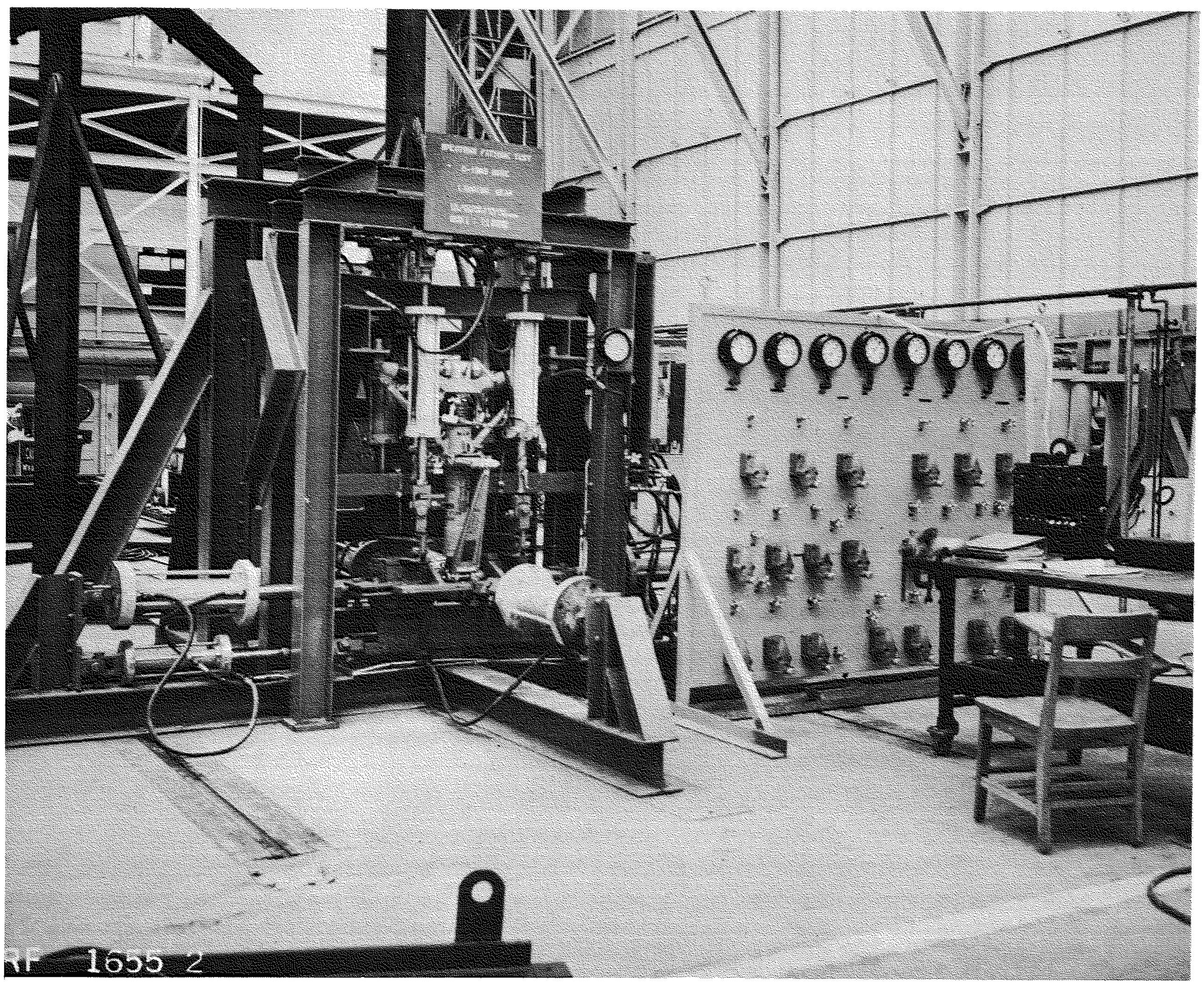


Figure 3-6—C-130B NOSE GEAR FATIGUE TEST.

In addition to the types of loading applicable to the main gear, steering and turning loads will be an important part of the spectrum for the GL 207-45 nose gear, since it is subjected to these loads in controlling the path of the airplane for ground operations. Differential braking loads and engine power, lateral gusts, and maneuver loads on the vertical tail at the higher taxi speeds all contribute to these effects. As with the main gear, MIL-A-8862 requirements and C-130 experience, as well as analytically determined values for the GL 207-45, will be included in the fatigue test spectrum for the gear. One cycle of limit vertical load per 1000 landings will also be included in the spectrum.

Phase III — Dynamic Response Flight Tests

A dynamic response test program will be conducted in accordance with Technical Memorandum WCLS-TM-58-4, "Detail Requirements for Structural Fatigue Certification". The tests include atmospheric gusts, buffet, and ground load investigations from which the elastic response characteristics of the structure to dynamic loading conditions can be determined. Instrumentation will be installed to measure gust velocities, load magnitudes and distributions. As shown in Figure 3-1 the dynamic response test program follows the completion of the 100% structural demonstration.

It should be noted that adherence to the 476L Statement of Work appears incompatible with the requirements of WCLS-TM-58-4, which implies that the results of the dynamic response test program should be used to refine the load spectrum for the fatigue test program. Scheduling of the two programs is such that this requirement can not be satisfied. If this situation proves unsatisfactory, it can be remedied by delaying the fatigue test program and/or adding an additional test airplane, which would be used exclusively for the dynamic response test program.

Dynamic Response Test Program

Gust, buffet and ground load investigations will be conducted to satisfy the dynamic response test requirements of WCLS-TM-58-4. A brief description of the test program follows.

Gust Investigation

The gust investigation includes flights through turbulent air at several airspeeds in the clean and landing configurations with combinations of fuel and cargo covering the operational envelope. These data will define the gust and airplane response spectrums.

Buffet Investigation

A high and low-speed buffet investigation will be conducted in the clean and landing configurations at 1.0, 1.5, and 2.0 load factors. These tests will be conducted at three altitudes with an intermediate gross weight and center of gravity to define stall and Mach buffet intensities.

Ground Loads

The ground loads program will include landing and taxi tests of sufficient scope to satisfy the applicable test requirements.

Landings

Landing tests will be conducted at various sink rates, touchdown attitudes, and loading configurations to determine the loads for the landing conditions anticipated during the service life of the airplane.

Taxiing

The taxi test program includes taxiing over runways of different roughness, normal taxiing, and taxiing over ($1-\cos\omega t$) shaped ramps. The test conditions and configurations will cover the operational envelope.

Program Instrumentation Requirements

The instrumentation for the dynamic response test program includes that used in the flight load survey and structural demonstration program with the addition of a gust head.

Phase IV — Statistical and Dynamic Analysis of Test Data

Appropriate statistical and dynamic parameters will be calculated from the flight test data to provide information as follows:

(a) To more accurately determine flexible airplane dynamic response, particularly for those components where adequate theoretical values are not readily obtainable.

(b) To assess the accuracy and to refine the predicted service life of analysis performed earlier.

(c) To modify the component fatigue test spectra based on the more accurate transfer funtion and peak count data acquired.

(d) To derive load response ratios to c.g. accelerations, which will allow a more valid interpretation of VGH records to be obtained in service operations of GL 207-45 aircraft.

In addition, the test program covers a broad range of test conditions so that if the basic missions of an aircraft are changed in the course of its operations, these improved transfer functions will enable a quick revision of the fatigue loads spectra for the new mission profiles. Thus, any reduction in remaining service life can be determined immediately, without waiting for new VGH data to become available for these flight conditions.

General Basis For Dynamic Analysis

Although both civil and military specifications require the consideration of flexibility effects in any transient loading conditions, the exact method to be used is seldom indicated. Fatigue damage is a complex phenomena which can best be analyzed by statistical procedures. Consequently, the flight test program is designed to yield sufficiently large data samples to insure statistical reliability. For flight conditions exhibiting random or repetitive response characteristics, the methods of generalized harmonic analysis will be applied to determine the statistical properties of structural loads experienced on and within the airplane. Peak loads ratios or cumulative frequencies of occurrence will be evaluated for the more discrete-appearing loads phenomena, such as landing, braking, and turning conditions.

Theoretical Development

If it is assumed that the load or disturbing phenomena is "stationary random", then its statistical properties will be invarient from one valid sample to another, taken at random from a given population. The variations cannot be described as a definite function of time, but the statistical properties can be determined from the power spectral density of the random function, as follows:

If $A(\omega)$ is the amplitude of the frequency component ω of the random function, $y(t)$, then an approximate interpretation of the power spectrum $\Phi(\omega)$ may be expressed as

$$\Phi(\omega) = \lim_{\theta \to \infty} \frac{4\pi}{\theta} \left| A(\omega) \right|^2$$

where θ is the time duration of the sample. However, for practical applications, a routine digital computation scheme has been developed in Reference 3 for the evaluation of power spectra from test data. This procedure has been successfully applied by Lockheed in a fatigue certification program for the C-130B, Reference 4, similar to the one described herein for the GL 207-45. A detailed description of the analysis program may be found in Reference 4, but a few of the more important quantities will be summarized here:

The root mean square, σ, of the amplitude, y, is determined from

$$\sigma^2 = \left| \int_0^\infty \Phi(\omega)\, d\omega \right| - (\bar{y})^2$$

where $\bar{y}$ is the arithmetic mean of y.

If K_i is the positive number of standard deviations from the mean, and the probability function is Gaussian distributed, then the "peak-count," N_i, can be calculated as the probable number of times per unit time the function, y, will exceed a magnitude of $y_i = K_i\sigma$.

$$N_i(y_i) = \frac{1}{2\pi\sigma}\, e^{\frac{-(y_i-\bar{y})^2}{2\sigma^2}} \left[\int_\infty^0 \omega^2 \Phi(\omega)\, d\omega \right]^{1/2}$$

The power spectral output, $\Phi_0(\omega)$, in terms of load (or stress) at a given location in an aircraft is related to an input spectrum, $\Phi_I(\omega)$, as follows:

$$\Phi_0(\omega) = |T_0(\omega)|^2 \Phi_I(\omega)$$

The transfer function as obtained is the absolute magnitude of a frequency response function under steady state conditions, and it will not, in general, describe transient pulse loadings such as are encountered in landing and braking.

Similarly, a cross-power spectral density, $\Phi_{0I}(i\omega)$, directly correlating both input and output, may be evaluated as shown in Reference 4, and a transfer function calculated as follows:

$$T_{0I}(i\omega) = \Phi_{0I}(i\omega) / I_I(\omega)$$

Both the amplitude and phase of T is indicated in this case. However, for a linear system, if no cross-correlation exists, the magnitude of both T_{0I} and T_0 should be identical.

Fatigue Test Spectra Derivation

The diversified mission capabilities of the GL 207-45 system under consideration indicate that the fatigue life will be dependent upon the sequential dynamic loading characteristics of the airplane as well as the nature of repeated load applications. The preceding formulae reveal that a routine set of calculations on airplane load measurements will yield a peak count, N_i, suitable for repeated load or stress spectra determination.

Gust Loads

In a purely theoretical service life analysis, transfer functions are derived for major aircraft components by state-of-the-art methods of analysis on analog or digital computers, as in Reference 5. These functions are then applied to equations (5), (4), (2), and (3) in sequence to obtain output spectra and peak count loads from a known input spectra, such as that for atmospheric turbulence given in specifications, Reference 2.

The overall statistical reliability of input-output spectra from most flight test data is subject to question, however, because of the relatively small sample obtained. For example, the C-130B tests covered less than 0.03% of the anticipated service usage. Fortunately, statistically valid transfer functions can be obtained using equations (4) or (5) over relatively small stationary-random segments of data. These functions can, in turn, be applied to more reliable input spectra on runway roughness, Reference 6, or low level atmospheric turbulence spectra from the more extensive B-66 tests and others.

The peak-count loads derived in this manner are limited to a single set of flight conditions, such as fuel and cargo weight, speed, altitude, and flap setting. Either the transfer function of the input power spectrum depends on one or more of these parameters. The percent, P_j, of total life time spent in each configuration, j, must be determined from the multiplicity of mission profiles in use or planned for the airplane. Then this percentage is used as a weighing factor to synthesize a single peak-count, N_T, for each basic maneuver, such as gust penetration, as follows:

$$N_T(y_i) = \sum_{j=1}^{n} \frac{P_i}{100} N_j(y_i)$$

Details of similar procedures may be found in Reference 7 for fatigue spectra determination.

In the interpretation of VGH data, a commonly used concept in converting from c.g. accelerations to wing loads is that of a dynamic magnification factor. Root-mean-square amplification as defined in Reference 5 is easy to determine, but a more significant value may be solved as follows:

$$\delta = \Delta M_f(N_i) / \Delta M_r(N_i)$$

where:

$\Delta M_f(N_i)$ is the dynamically measured (flexible body) incremental load as a function of frequency of exceedance. $\Delta M_r(N_i)$ is the incremental load computed from c.g. accelerations, $\Delta n(N_i)$, as a function of frequency of exceedance.

The expression $\Delta M_r(N_i)$ can be computed as:

$$\Delta M_r(N_i) = Q \Delta n(N_i)$$

where Q is the static load per unit c.g.m acceleration under steady flight conditions, (either calculated or from controlled test maneuvers).

Taxi and Ground Handling Loads

Statistical loads distributions for taxiing response can be determined from Equations (1) thru (6). However, an additional test is proposed for taxiing over a corrugated ground profile as suggested in Reference 8. Nonlinear phenomena are present which may make Equation (4) inapplicable. A ground loads research program, Reference 9, presently being conducted by Lockheed, is attempting to prove that Fourier series harmonic analysis will provide a more valid transfer function for taxiing.

Landing Loads

Landing impacts represent a discrete loads phenomena which cannot be described adequately by steady state random process theory as in the gust or taxi response analyses. Therefore, an alternative analysis will be made involving parameter studies of the type $\frac{\Delta M_{max}}{\Delta n_g}$ where ΔM_{max} is the maximum incremental wing bending moment, and ΔN_g is the incremental gear load factor.

Buffet Loads

Buffeting is a physical phenomenon that is difficult to describe by analytical techniques. The most appropriate techniques for obtaining loads ratios or transfer functions will be determined by analysis of preliminary samples of the data. Probably, only peak count or peak loads ratios will yield realistic and applicable values for this flight condition.

Turning and Towing

The analysis of turning and towing conditions will consist of a study of the center of gravity response to resultant gear reaction forces. Peak count analysis may also be applicable, and some data will be tabulated in this manner.

Data Processing and Reliability

Data handling and reduction will be performed automatically by use of magnetic tape recording. The data will be supplied to an IBM 7090 computer via digital tapes for analysis by the methods discussed as shown schematically in Figures 3-7 and 3-8.

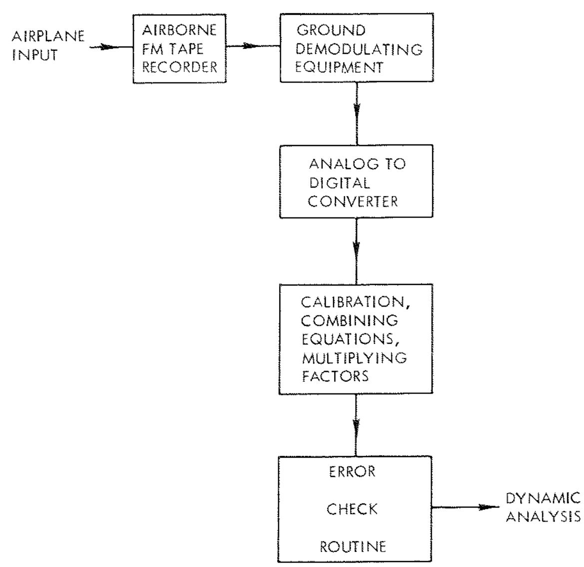


Figure 3-7—DATA PREPARATION CALIBRATION AND CHECKING.

Confidence limits and data scatter will be evaluated by conventional methods, such as the chi-squared reliability test shown in Figure 3-9.

The interaction of airplane motions with direct gust velocity probe measurements shall be removed from turbulence data. The gust response data may reveal a marked spanwise variation of turbulence, since the GL 207-45 is a large-span swept-wing airplane. Such phenomena were encountered in the tests of Reference 10. In such a situation, cross-power spectral methods are more accurate. Attempts will be made to determine the error in transfer functions derived from power spectral density analyses.

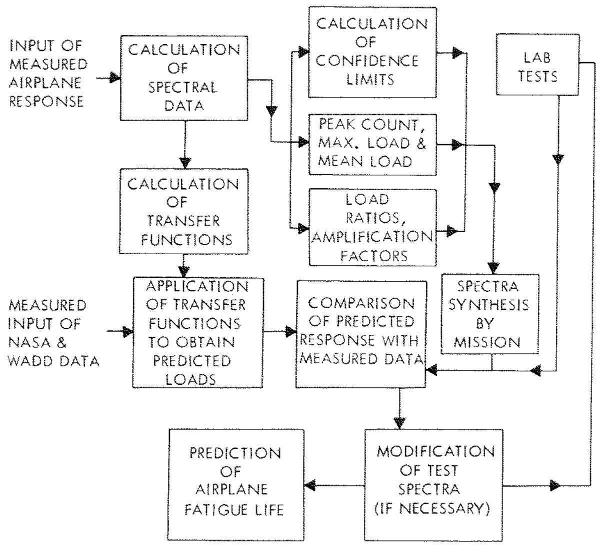


Figure 3-8—SUMMARY FLOW DIAGRAM OF MAJOR DYNAMIC ANALYSIS STEPS.

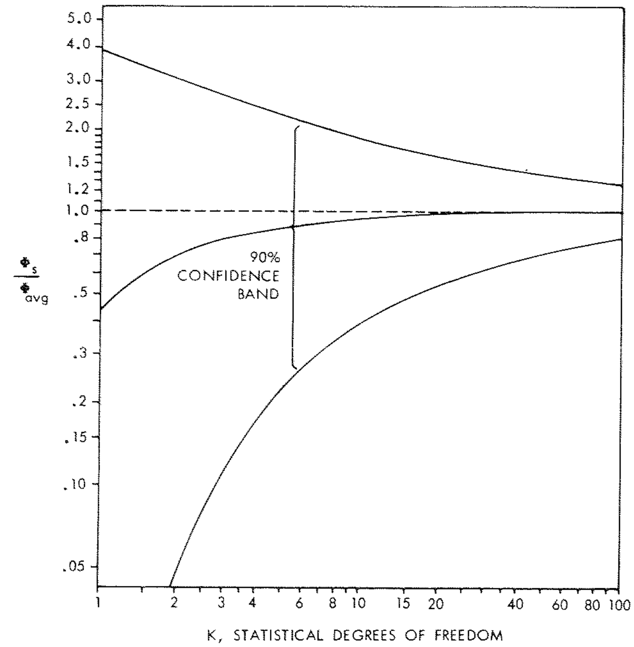


Figure 3-9—LIABILITY ESTIMATES.

Presentation of Results

The results of the flight test data analysis will be presented in terms of loads ratios, loading cycles at various amplitudes, and transfer functions for major structural components. Any major or significant changes that become apparent will be considered for incorporation in the component fatigue test spectra, if scheduling permits, as shown in Figure 3-8.

A final report will be submitted as shown in the Program Schedule shown in Figure 3-10. Major conclusions will be summarized along with recommendations for further applications of results should fatigue failures occur and VGH data become available from field operations.

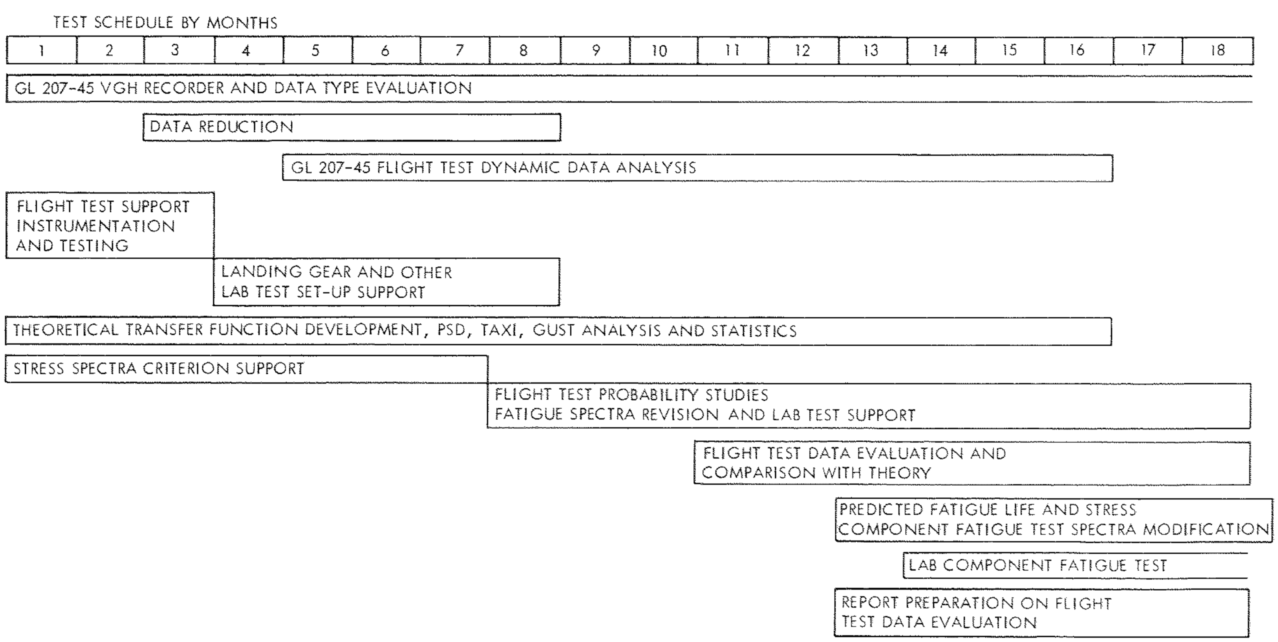


Figure 3-10—DYNAMIC RESPONSE AND FATIGUE TEST ANALYSIS PROGRAM.

PRICING INFORMATION
FLIGHT LOADS SURVEY (5.4.2)

		No Year Contractor's Proposal	
	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic	68	$4.11	$279
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	194
Material & Direct Charges		.56	38
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$511
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			
Overhead			
Material & Direct Charges			
Purchased Equipment			
Subcontracting			
Total Manufacturing			
Quality Assurance			
Direct Labor	2	$3.39	$ 7
Overhead		115.62% DL	8
Total Quality Assurance			$ 15
G & A Expense		23.99% DL	$ 69
Total Cost			$595
Profit		8%	48
Price			**$643**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

FATIGUE TEST (5.4.2)

	Hours[1]	Rate	No Year Contractor's Proposal Amount[1]
Engineering			
D.L.—Basic	424	$4.11	$1,743
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	1,212
Material & Direct Charges		.56	237
Technical Data			—0—
Subcontracting			—0—
Total Engineering			$3,192
Tooling			
D.L. Planning—Basic	2	$3.59	$ 7
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	—0—		—0—
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	—0—		—0—
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		115.62% DL	8
Material & Direct Charges		1.26 TMH	—0—
Subcontract Tooling			—0—
Total Tooling			$ 15
Manufacturing—(Production)			
Direct Labor	474	$2.82	$1,337
Overhead		115.62% DL	1,546
Material & Direct Charges			254
Purchased Equipment			—0—
Subcontracting			953
Total Manufacturing			$4,090
Quality Assurance			
Direct Labor	42	$3.39	$ 142
Overhead		115.62% DL	164
Total Quality Assurance			$ 306
G & A Expense		23.99% DL	$ 775
Total Cost			$8,378
Profit		8%	670
Price			**$9,048**

[1]Thousands

FORMAT "A"

4761 Lockheed

PRICING INFORMATION

STATIC TEST (5.4.2)

	Hours[1]	Rate	No Year Contractor's Proposal Amount[1]
Engineering			
D.L.—Basic	197	$4.11	$ 810
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	563
Material & Direct Charges		.56	110
Technical Data			—0—
Subcontracting			—0—
Total Engineering			$1,483
Tooling			
D.L. Planning—Basic	2	$3.59	$ 7
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	—0—		—0—
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	—0—		—0—
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		115.62% DL	8
Material & Direct Charges		1.26 TMH	—0—
Subcontract Tooling			—0—
Total Tooling			$ 15
Manufacturing—(Production)			
Direct Labor	474	$2.82	$1,337
Overhead		115.62% DL	1,546
Material & Direct Charges			254
Purchased Equipment			—0—
Subcontracting			953
Total Manufacturing			$4,090
Quality Assurance			
Direct Labor	38	$3.39	$ 129
Overhead		115.62% DL	149
Total Quality Assurance			$ 278
G & A Expense		23.99%	$ 548
Total Cost			$6,414
Profit		8%	513
Price			**$6,927**

[1]Thousands

FORMAT "A"

REFERENCES

1 WLCS-TM-58-4, "Detail Requirements for Structural Fatigue Certification Programs," Wright Air Development Center, Air Research and Development Command, U.S.A.F., 27 June 1958.

2 Annon, MIL-A-8866 (ASG) "Military Specification Airplane Strength and Rigidity, Repeated Loads and Fatigue, U.S.A.F., 18 May 1960.

3 Press, H., Tukey, J. W., "Power Spectral Methods of Analysis and Application in Airplane Dynamics", Bell Telegraph System Monograph 2606, June 1956.

4 Theisen, J. G., "Statistical Analysis of Dynamic Response Tests", Lockheed Aircraft Corporation, Georgia Division, ER-4415, 27 May 1960.

5 Theisen, J. G., "Power Spectral Analysis of Continuous Turbulence Effects on the Lockheed Hercules", Lockheed Report ER-3693, 27 February 1959.

6 Thompson, W. E., "Measurements and Power Spectra of Runway Roughness at Airports in Countries of the North Atlantic Treaty Organization", NACA-TN 4303, July 1958.

7 Jackson, C. E., Thorson, K. R., Wherry, J. E., Dempster, J. B., "The Influence of Dynamic Loads on Aircraft Fatigue," Proceedings, *Fatigue of Aircraft Structures,* WADC Symposium, WADC TR-507, pp. 449-478, August 1959.

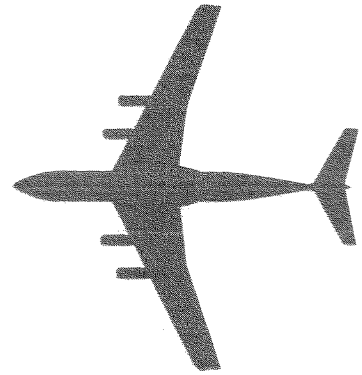
8 Houbolt, J. C., Walls, J. H., and Smiley, R. F., "On Special Analysis of Runway Roughness and Loads Developed During Taxiing", NACA TN 3484, Washington, July 1955.

9 Theisen, J. G., and Crenshaw, B. M., et al, "Criteria Development, Dynamic Loads Induced by Ground Operation of Aircraft", Lockheed Aircraft Corporation, Georgia Division, Report ETP-205, 8 April 1960.

10 Coleman, T. L., Press, H., and Meadows, M. T., "An Evaluation of Effects of Flexibility on Wing Strains in Rough Air for a Large Swept-Wing Airplane by Means of Experimentally Determined Frequency-Response Functions Process Techniques Employed", NACA TN-4291, July 1958.

SUPER HERCULES · GL207-45

section 4



ALTERNATE TAIL CONFIGURATION (5.4.3)

In response to the request for an analysis of the possible penalties (from an aircraft structural, weight, and aerodynamic standpoint) of the configuration of the tail, which includes the aerial delivery capabilities, the following information is submitted. The configuration used and shown on Figure 4-1 does not involve any aerodynamic penalty because it has been configured as discussed in Volume 1, Section 1, to provide a minimum drag fuselage afterbody equivalent to, or better than, a symmetrically streamlined aft fuselage. The upsweep provided in this modified aft end is a basic requirement to provide the straight-in tail loading. However, since the fairing doors are not loaded by fuselage pressurization due to the unique ramp/pressure door arrangement ahead of them, they are of relatively light but stiff structure due to their natural structurally efficient triangular shape with box-like cross sections. The mechanism to operate these doors, including the locks and latches, will not be greatly changed due to the removal of an aerial delivery requirement. This is primarily due to the fact that the aerial delivery speed (200 knots) limit does not require excessive structural material to carry the tail loads while the door is open nor does it cause large increases in skin gage of the doors or extensive resizing of the actuator cylinder and door operating mechanism. This latter item is part of the effect of not opening the doors to more than 16 degrees with a consequent minimum disturbance to the stream flows at the aft end of the fuselage.

Figure 4-1—CARGO LOADING DOORS—AFT.

In configuring a commercial version, there could be some in-line changes in localized areas on the doors and in the upper aft fuselage structure. New parts would be installed for weight savings on the actuating system which would result in a lightening of the items shown on Figure 4-2.

The estimate of weight for the changes that would be made if the airplane were designed for a commercial version only, using the uncompromised straight-in tail loading, would be:

Doors (skinning, edging members, and hinges)	—170 lbs.
Actuation and locking systems	—50 lbs.
Structure (upper aft fuselage, longerons, local gussets, and hinge supports)	—80 lbs.
Total for commercial version (weight savings)	—300 lbs.

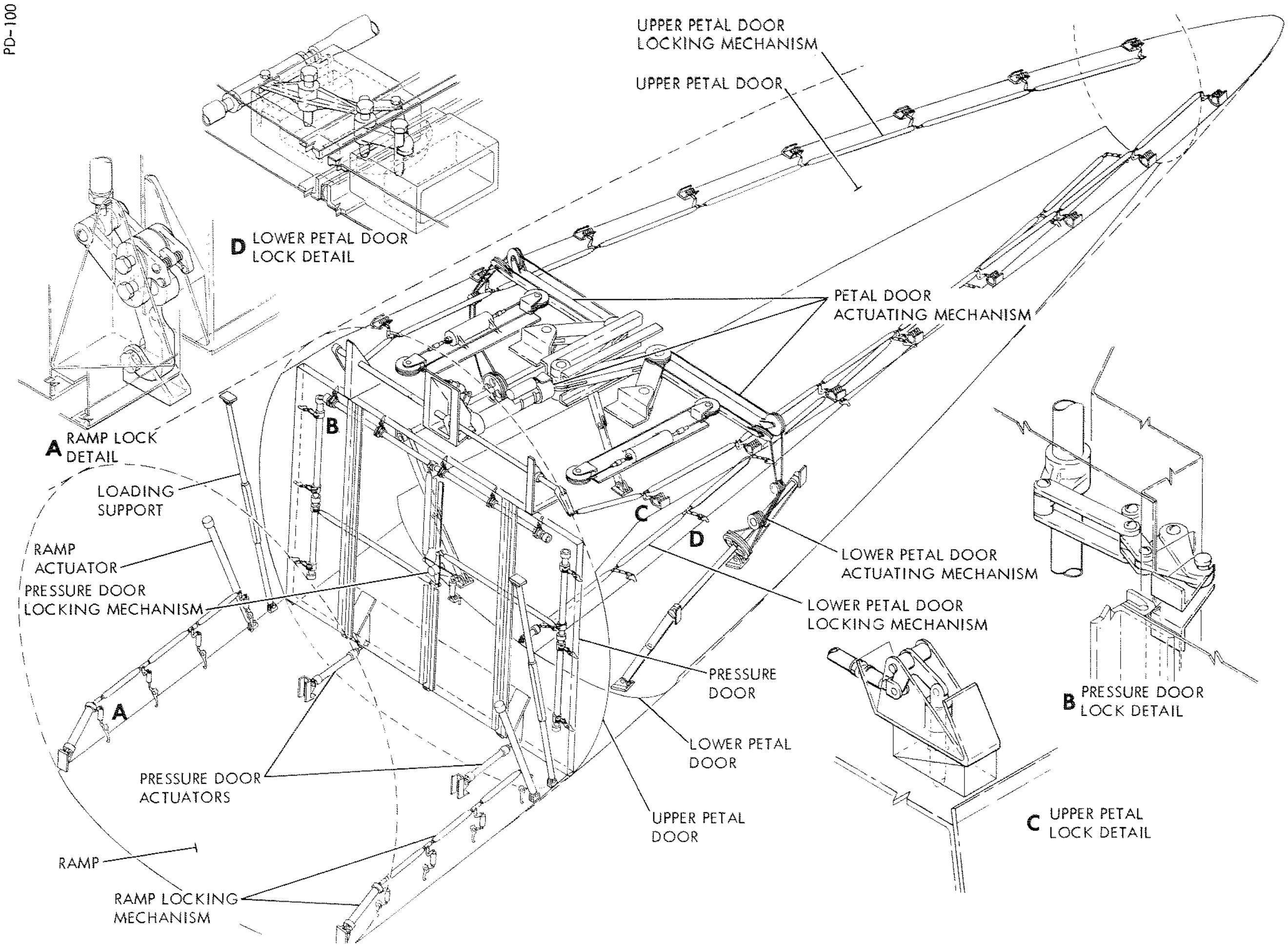


Figure 4-2—AFT CARGO DOOR ACTUATING MECHANISM.

PRICING INFORMATION
ALTERNATE TAIL CONFIGURATION (5.4.3)

	Hours[1]	No Year Contractor's Proposal Rate	Qty 5 Amount[1]
Engineering			
D.L.—Basic	71	$4.11	$ 292
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	203
Material & Direct Charges		.56	40
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ 535
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$2,126
Total Tooling			$2,126
Manufacturing—(Production)			
Direct Labor			—0—
Overhead			—0—
Material & Direct Charges			—0—
Purchased Equipment			—0—
Subcontracting			$ (5)
Total Manufacturing			$ (5)
Quality Assurance			
Direct Labor	3	$3.39	$ 10
Overhead		115.62% DL	12
Total Quality Assurance			$ 22
G & A Expense		23.99% DL	$ 72
Total Cost			$2,750
Profit		8%	220
Price			**$2,970**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
ALTERNATE TAIL CONFIGURATION (5.4.3)

	Hours[1]	Rate	Amount[1]
		FY '63	Qty 31
		Contractor's Proposal	
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			—0—
Overhead			—0—
Material & Direct Charges			—0—
Purchased Equipment			—0—
Subcontracting			$ (31)
Total Manufacturing			$ (31)
Quality Assurance			
Direct Labor			—0—
Overhead			—0—
Total Quality Assurance			—0—
G & A Expense			
Total Cost			$ (31)
Profit		8%	(2)
Price			**$ (33)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
ALTERNATE TAIL CONFIGURATION (5.4.3)

	Hours[1]	Rate	FY '64 Qty 48 Contractor's Proposal Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			—0—
Overhead			—0—
Material & Direct Charges			—0—
Purchased Equipment			—0—
Subcontracting			$((48)
Total Manufacturing			$ (48)
Quality Assurance			
Direct Labor			—0—
Overhead			—0—
Total Quality Assurance			—0—
G & A Expense			—0—
Total Cost			$ (48)
Profit		8%	(4)
Price			**$ (52)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
ALTERNATE TAIL CONFIGURATION (5.4.3)

	Hours[1]	Rate	FY '65 Qty 48 Contractor's Proposal Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			—0—
Overhead			—0—
Material & Direct Charges			—0—
Purchased Equipment			—0—
Subcontracting			$ (48)
Total Manufacture			$ (48)
Quality Assurance			
Direct Labor			—0—
Overhead			—0—
Total Quality Assurance			—0—
G & A Expense			—0—
Total Cost			$ (48)
Profit		8%	$ (4)
Price			**$ (52)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

ALTERNATE TAIL CONFIGURATION (5.4.3)

		PROPOSAL SUMMARY Contractor's Proposal	
	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic	71	$4.11	$ 292
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	203
Material & Direct Charges		.56	40
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ 535
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$2,126
Total Tooling			$2,126
Manufacturing—(Production)			
Direct Labor			—0—
Overhead			—0—
Material & Direct Charges			—0—
Purchased Equipment			—0—
Subcontracting			$ (132)
Total Manufacturing			$ (132)
Quality Assurance			
Direct Labor	3	$3.39	$ 10
Overhead		115.62% DL	12
Total Quality Assurance			$ 22
G & A Expense		23.99% DL	$ 72
Total Cost			$ 2,623
Profit		8%	210
Price			**$ 2,833**

[1]Thousands

FORMAT "A"

SUPER HERCULES · GL207-45

section 5

PERSONNEL DOOR (5.4.4)

The personnel/paratroop doors shown on Figure 5-1 are removed along with the framing, supports, and operating systems and replaced with fuselage frames and skins on both sides of the fuselage. The weight saving is 182 lbs.

AFFECTED ITEMS

Fuselage structure modified
Door supports and operating systems removed

WEIGHT STATEMENT

Personnel Doors, Removal of	
Doors	—246
Skin and frame replacement	+ 64
Total	—182 lbs.

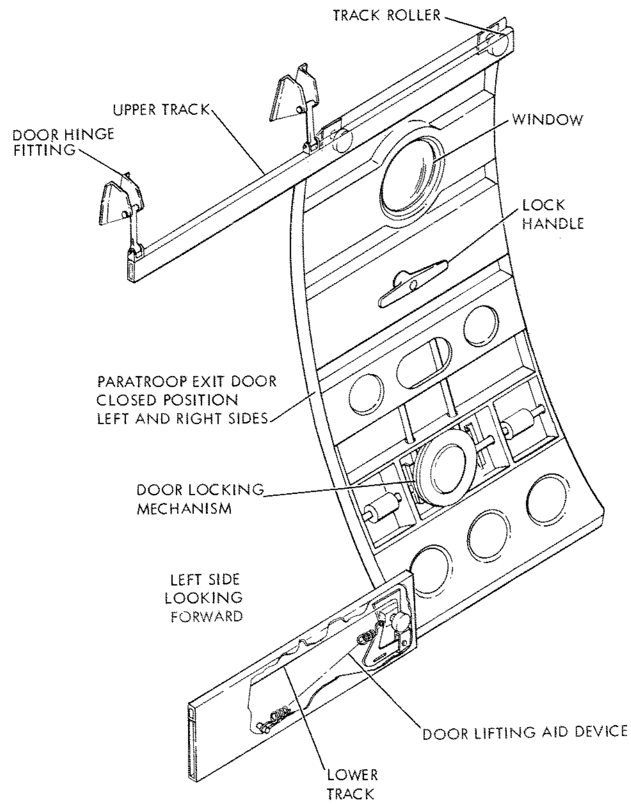


Figure 5-1—AFT ENTRY/PARATROOP DOOR.

PRICING INFORMATION
PERSONNEL DOORS (5.4.4)

	Hours[1]	No Year Contractor's Proposal Rate	Qty 5 Amount[1]
Engineering			
D.L.—Basic	(6)	$4.11	$ (25)
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	(17)
Material & Direct Charges		.56	(3)
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ (45)
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$ (96)
Total Tooling			$ (96)
Manufacturing—(Production)			(1)
Direct Labor	3	$2.82	$ 8
Overhead		115.62% DL	9
Material & Direct Charges			(1)
Purchased Equipment			—0—
Subcontracting			(19)
Total Manufacturing			$ (3)
Quality Assurance			
Direct Labor			—0—
Overhead			—0—
Total Quality Assurance			—0—
G & A Expense		23.99% DL	$ (4)
Total Cost			$ (148)
Profit		8%	(12)
Price			**$(160)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
PERSONNEL DOORS (5.4.4)

	Hours[1]	FY 63 Qty 31 Contractor's Proposal Rate	Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$ (49)
Total Tooling			$ (49)
Manufacturing—(Production)			
Direct Labor	8	$2.92	$ 23
Overhead		111.04% DL	26
Material & Direct Charges			(5)
Purchased Equipment			—0—
Subcontracting			(115)
Total Manufacturing			$ (71)
Quality Assurance			
Direct Labor	1	$3.49	$ 3
Overhead		111.04% DL	3
Total Quality Assurance			$ 6
G & A Expense		23.00% DL	$ 6
Total Cost			$ (108)
Profit		8%	(9)
Price			**$ (117)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
PERSONNEL DOORS (5.4.4)

		FY 64	Qty 48
		Contractor's Proposal	
	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	9	$3.01	$ 27
Overhead		109.10% DL	29
Material & Direct Charges			(7)
Purchased Equipment			—0—
Subcontracting			(178)
Total Manufacturing			$ (129)
Quality Assurance			
Direct Labor	1	$3.62	$ 4
Overhead		109.10% DL	4
Total Quality Assurance			$ 8
G & A Expense		22.88% DL	$ 7
Total Cost			$ (114)
Profit		8%	(9)
Price			**$ (123)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

PERSONNEL DOORS (5.4.4)

	Hours[1]	Rate	Amount[1]
		FY 65	**Qty 48**
		Contractor's Proposal	
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	7	$3.10	$ 22
Overhead		115.12% DL	25
Material & Direct Charges			(7)
Purchased Equipment			—0—
Subcontracting			(178)
Total Manufacturing			$ (138)
Quality Assurance			
Direct Labor	1	$3.73	$ 4
Overhead		115.12% DL	5
Total Quality Assurance			$ 9
G & A Expense		24.40% DL	$ 6
Total Cost			$ (123)
Profit		8%	(10)
Price			**$ (133)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
PERSONNEL DOORS (5.4.4)

		PROPOSAL SUMMARY	
		Contractor's Proposal	
	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic	(6)	$4.11	$ (25)
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	(17)
Material & Direct Charges		.56	(3)
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ (45)
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$ (145)
Total Tooling			$ (145)
Manufacturing—(Production)			
Direct Labor	27	$2.96	$ 80
Overhead		111.25% DL	89
Material & Direct Charges			(20)
Purchased Equipment			—0—
Subcontracting			(490)
Total Manufacturing			$ (341)
Quality Assurance			
Direct Labor	3	$3.67	$ 11
Overhead		109.09% DL	12
Total Quality Assurance			$ 23
G & A Expense		22.73% DL	$ 15
Total Cost			$ (493)
Profit		8%	(40)
Price			**$ (533)**

[1]Thousands

FORMAT "A"

section 6

SIDE CARGO LOADING DOOR (5.4.5)

The side cargo loading door shown on Figure 6-1 is removed along with the fuselage framing, door supports, manual hydraulic operating system, and door and lock warning light systems. The area occupied by the door and framing is replaced by required fuselage frames and skin. Weight saving is 200 lbs.

AFFECTED ITEMS

Fuselage structure modified
Door supports, controls, locks, and warning light systems removed

WEIGHT STATEMENT

Side Cargo Door Removal of	
Doors and mechanism	—314
Skin and frame replacement	+114
Total savings	—200 lbs.

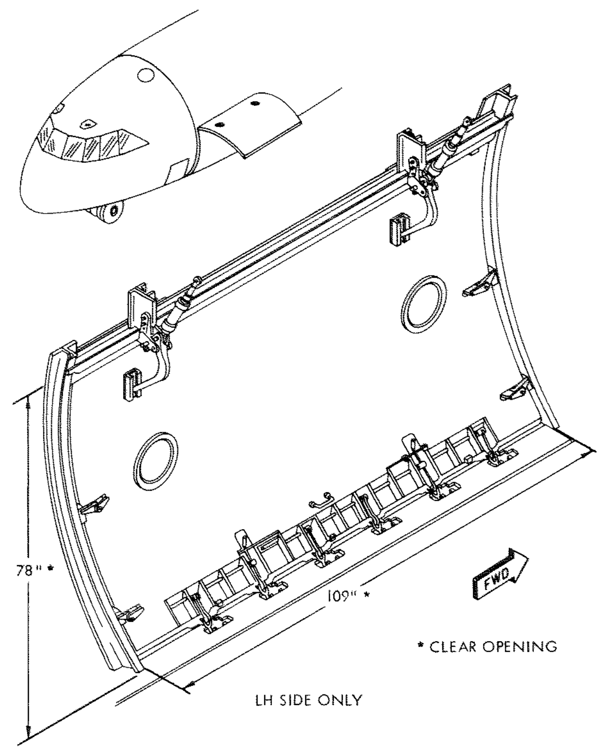


Figure 6-1—CARGO LOADING DOOR FORWARD.

PRICING INFORMATION
SIDE CARGO LOADING DOOR (5.4.5)

	Hours[1]	No Year Contractor's Proposal Rate	Qty 5 Amount[1]
Engineering			
D.L.—Basic	(6)	$4.11	$ (25)
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	(17)
Material & Direct Charges		.56	(3)
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ (45)
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$ (153)
Total Tooling			$ (153)
Manufacturing—(Production)			
Direct Labor	5	$2.82	$ 14
Overhead		115.62% DL	16
Material & Direct Charges			(3)
Purchased Equipment			—0—
Subcontracting			(24)
Total Manufacturing			$ 3
Quality Assurance			
Direct Labor			—0—
Overhead		—0—	—0—
Total Quality Assurance			—0—
G & A Expense		23.99% DL	$ (3)
Total Cost			$ (198)
Profit		8%	(16)
Price			**$ (214)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

SIDE CARGO LOADING DOOR (5.4.5)

	Hours[1]	Rate	Amount[1]
		FY 63	Qty 31
		Contractor's Proposal	
Engineering			
D.L.—Basic			
D.L. Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$ (79)
Total Tooling			$ (79)
Manufacturing—(Production)			
Direct Labor	15	$2.92	$ 44
Overhead		111.04% DL	49
Material & Direct Charges			(16)
Purchased Equipment			—0—
Subcontracting			(150)
Total Manufacturing			$ (73)
Quality Assurance			
Direct Labor	1	$3.49	$ 3
Overhead		111.04% DL	3
Total Quality Assurance			$ 6
G & A Expense		23.00%	$ 11
Total Cost			$ (135)
Profit		8%	(11)
Price			**$ (146)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

SIDE CARGO LOADING DOOR 5.4.5)

FY 64 Qty 48

	Hours[1]	Contractor's Proposal Rate	Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	16	$3.01	$ 48
Overhead		109.10% DL	52
Material & Direct Charges			(24)
Purchased Equipment			—0—
Subcontracting			(232)
Total Manufacturing			$ (156)
Quality Assurance			
Direct Labor	1	$3.62	$ 4
Overhead		109.10% DL	4
Total Quality Assurance			$ 8
G & A Expense		22.88% DL	$ 12
Total Cost			$ (136)
Profit		8%	(11)
Price			**$ (147)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
SIDE CARGO LOADING DOOR 5.4.5)

		FY 65 Contractor's Proposal	Qty 48
	Hours[1]	**Rate**	**Amount[1]**
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	13	$3.10	$ 40
Overhead		115.12% DL	46
Material & Direct Charges			(24)
Purchased Equipment			—0—
Subcontracting			(232)
Total Manufacturing			$ (170)
Quality Assurance			
Direct Labor	1	$3.73	$ 4
Overhead		115.12% DL	5
Total Quality Assurance			$ 9
G & A Expense		24.40% DL	$ 11
Total Cost			$ (150)
Profit		8%	(12)
Price			**$ (162)**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
SIDE CARGO LOADING DOOR (5.4.5)

PROPOSAL SUMMARY

Contractor's Proposal

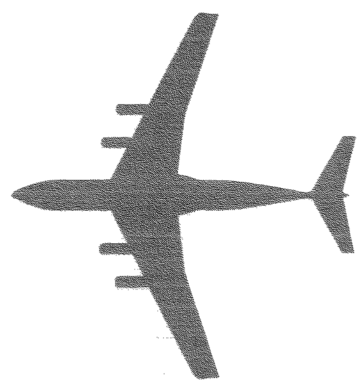
	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic	(6)	$4.11	$(25)
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	(17)
Material & Direct Charges		.56	(3)
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$(45)
Tooling			
D.L. Planning—Basic			—0—
D.L. Planning—Sustaining			—0—
D.L. Tool Design—Basic			—0—
D.L. Tool Design—Sustaining			—0—
D.L. Tool Mfg.—Basic			—0—
D.L. Tool Mfg.—Sustaining			—0—
Overhead			—0—
Material & Direct Charges			—0—
Subcontract Tooling			$(232)
Total Tooling			$(232)
Manufacturing—(Production)			
Direct Labor	49	$2.98	$ 146
Overhead		111.64% DL	163
Material & Direct Charges			(67)
Purchased Equipment			—0—
Subcontracting			(638)
Total Manufacturing			$ (396)
Quality Assurance			
Direct Labor	3	$3.67	$ 11
Overhead		109.09% DL	12
Total Quality Assurance			$ 23
G & A Expense		23.48% DL	$ 31
Total Cost			$ (619)
Profit		8%	(50)
Price			**$ (669)**

[1]Thousands

FORMAT "A"

SUPER HERCULES · GL207-45

section 7



FLIGHT DECK (ALTERNATE) (5.4.6)

An alternate flight deck arrangement as shown in Figure 7-1 provides three reclining seats in addition to the normal crew seats and the flight check seat which remain the same as in the basic arrangement shown in Figure 7-2. The two bunks on the aft flight deck bulkhead of the basic arrangement are relocated to a fore and aft position on the right side of the compartment. The galley is retained in its same position.

The crew compartment is extended 45 in. from the basic length. Reinforcement of the floor, to withstand the 16g loads of the reclining seats, and lengthening of the control lines, ducts, and wiring is required.

The nose gear and crew entrance door remain the same, but move forward with the crew area of the fuselage as the 45-in. extension in the fuselage is inserted.

The additional weight is approximately 1750 lbs. and includes the furnishings, installation and structure.

AFFECTED ITEMS

Fuselage extended 45 in. with new structure
Floor in crew station reinforced
Controls, ducts, wiring, and piping lengthened
Added 3 of 16g reclining seats

WEIGHT STATEMENT

Alternate Flight Deck	
Fuselage structure (45-in. extension)	1,380
Insulation, sound proof, trim, etc.	250
Equipment and accommodations	120
Total (weight increase)	1,750 lbs.

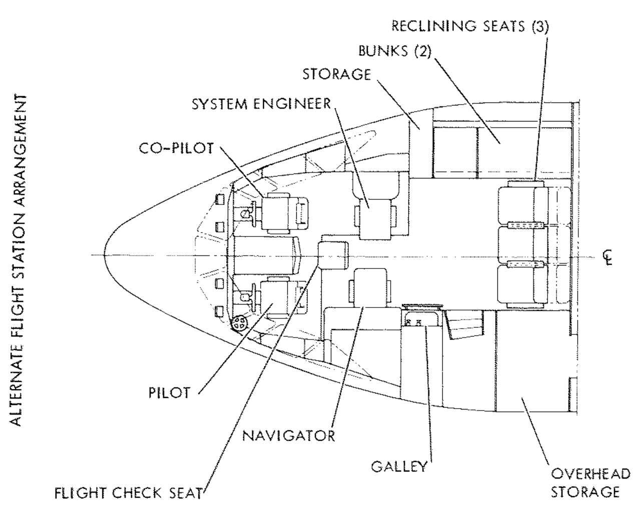


Figure 7-1—ALTERNATE FLIGHT STATION ARRANGEMENT.

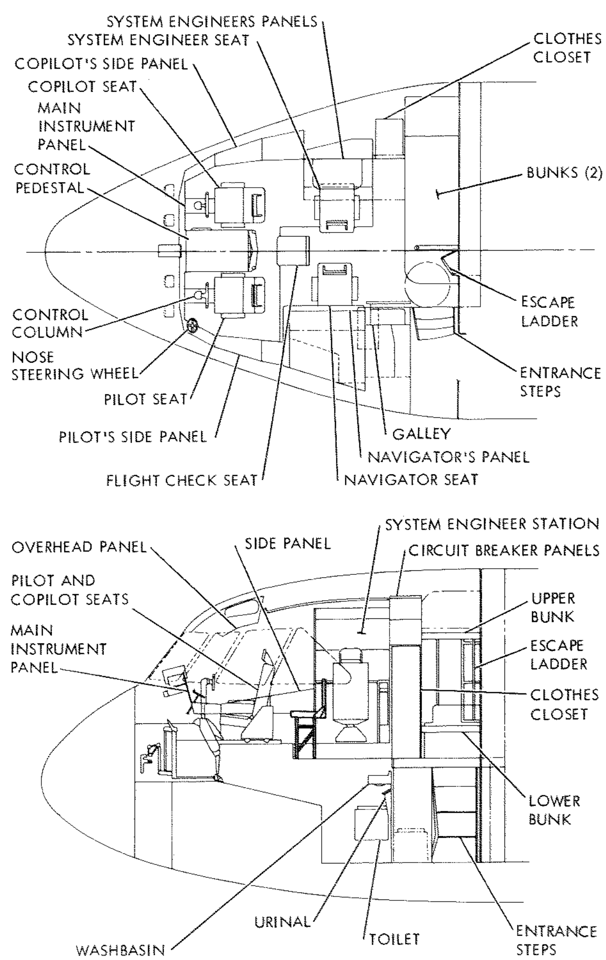


Figure 7-2—FLIGHT STATION ARRANGEMENT

PRICING INFORMATION

FLIGHT DECK (ALTERNATE) (5.4.6)

	Hours[1]	Rate	Amount[1]
		No Year — Contractor's Proposal	Qty 5
Engineering			
D.L.—Basic	10	$4.11	$ 41
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	29
Material & Direct Charges		.56	6
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ 76
Tooling			
D.L. Planning—Basic	9	$3.59	$ 32
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	4	3.59	14
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	18	3.59	65
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		115.62% DL	128
Material & Direct Charges		1.26 TMH	23
Subcontract Tooling			—0—
Total Tooling			$ 262
Manufacturing—(Production)			
Direct Labor	73	$2.82	$ 206
Overhead		115.62% DL	238
Material & Direct Charges			65
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$ 509
Quality Assurance			
Direct Labor	7	$3.39	$ 24
Overhead		115.62% DL	28
Total Quality Assurance			$ 52
G & A Expense		23.99% DL	$ 92
Total Cost			$ 991
Profit		8%	79
Price			**$1,070**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
FLIGHT DECK (ALTERNATE) (5.4.6)

	Hours[1]	Rate	Amount[1]
		FY '63 Contractor's	Qty 31 Proposal
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic	3	$3.73	11
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	2	3.73	7
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	8	3.73	30
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		111.04% DL	53
Material & Direct Charges		1.26 TMH	10
Subcontract Tooling			—0—
Total Tooling			$ 111
Manufacturing—(Production)			
Direct Labor	210	$2.92	$ 613
Overhead		111.04% DL	681
Material & Direct Charges			403
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$1,697
Quality Assurance			
Direct Labor	17	$3.49	$ 59
Overhead		111.04% DL	66
Total Quality Assurance			$ 125
G & A Expense		23.00% DL	$ 166
Total Cost			$2,099
Profit		8%	168
Price			**$2,267**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

FLIGHT DECK (ALTERNATE) (5.4.6)

	Hours[1]	FY '64 Contractor's Proposal Rate	Qty 48 Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	227	$3.01	$ 683
Overhead		109.10% DL	745
Material & Direct Charges			624
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$2,052
Quality Assurance			
Direct Labor	18	$3.62	$ 65
Overhead		109.10% DL	71
Total Quality Assurance			$ 136
G & A Expense		22.88% DL	$ 171
Total Cost			$2,359
Profit		8%	189
Price			**$2,548**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
FLIGHT DECK (ALTERNATE) (5.4.6)

	Hours[1]	FY '65 Contractor's Rate	Qty 48 Proposal Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Bfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	186	$3.10	$ 577
Overhead		115.12% DL	664
Material & Direct Charges			624
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$1,865
Quality Assurance			
Direct Labor	14	$3.73	$ 52
Overhead		115.12% DL	60
Total Quality Assurance			$ 112
G & A Expense		24.40% DL	$ 153
Total Cost			$2,130
Profit		8%	170
Price			**$2,300**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
FLIGHT DECK (ALTERNATE) (5.4.6)

	Hours[1]	Rate	Amount[1]
		PROGRAM SUMMARY Contractor's Proposal	
Engineering			
D.L.—Basic	10	$4.11	$ 41
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	29
Material & Direct Charges		.56	6
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ 76
Tooling			
D.L. Planning—Basic	12	$3.58	$ 43
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	6	3.50	21
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	26	3.65	95
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		113.84% DL	181
Material & Direct Charges		1.26 TMH	33
Subcontract Tooling			—0—
Total Tooling			$ 373
Manufacturing—(Production)			
Direct Labor	696	$2.99	$2,079
Overhead		111.98% DL	2,328
Material & Direct Charges			1,716
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$6,123
Quality Assurance			
Direct Labor	56	$3.57	$ 200
Overhead		112.50% DL	225
Total Quality Assurance			$ 425
G & A Expense		23.48% DL	$ 582
Total Cost			$7,579
Profit		8%	606
Price			**$8,185**

[1]Thousands

FORMAT "A"

SUPER HERCULES · GL207-45

section 8

OXYGEN SYSTEM ALTERNATE (5.4.7)

The alternate oxygen system that is readily adaptable to changes from a cargo to a troop/air-evacuation mission is shown in Figure 8-1. Piping, fittings, brackets, and mask support clips for 95 troop outlets and 76 litter patient outlets are provided along both sides of the cargo compartment. Connections to four portable liquid oxygen supplies are provided at the aft ends of each longitudinal supply line.

An electrical oxygen-quantity sensing line with connectors for each portable liquid oxygen converter is installed, and an oxygen quantity gage is installed on the co-pilot's side panel. The weight increase is 270 lbs.

AFFECTED ITEMS

Modify fuselage structure to provide holes for lines install mountings, and supports for outlets.

Add lines, fittings, brackets, and mask support clips.

WEIGHT STATEMENT

Oxygen System (permanent provisions)	
Plumbing	204
Supports and brackets	16
Equipment (valves, etc.)	50
Total (increase)	270 lbs.

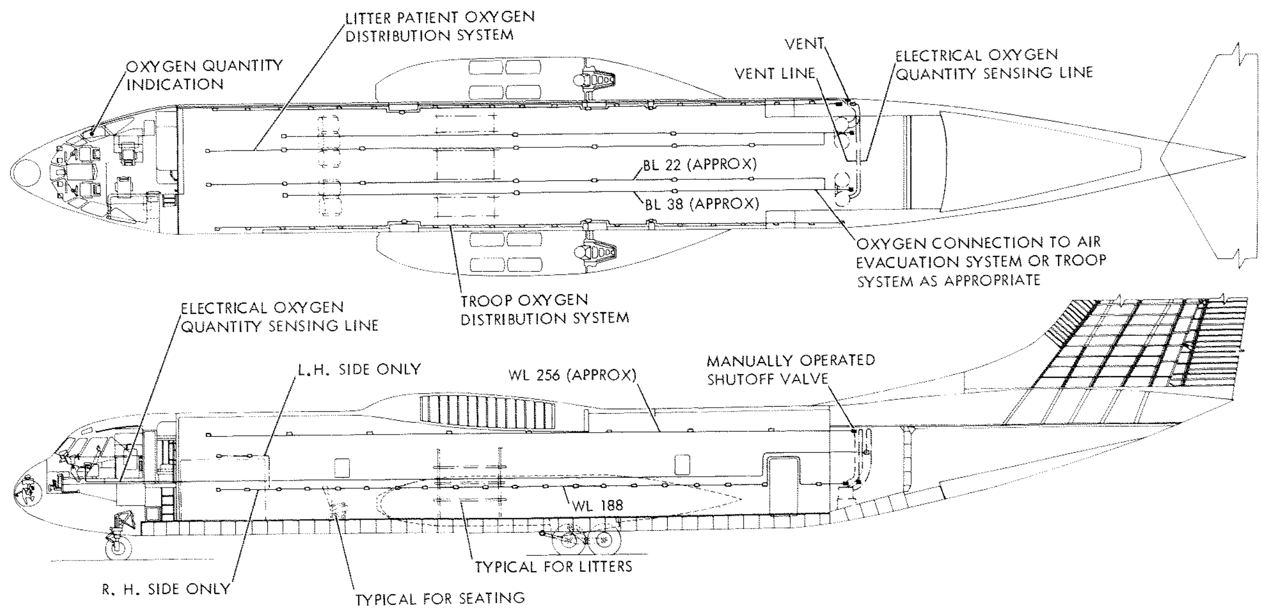


Figure 8-1—PERMANENT OXYGEN OUTLET PROVISIONS.

PRICING INFORMATION
OXYGEN SYSTEM (ALTERNATE) (5.4.7)

			No Year	Qty 5
			Contractor's	Proposal
	Hours[1]	Rate		Amount[1]
Engineering				
D.L.—Basic	5	$4.11		$ 21
D.L.—Sustaining	—0—			—0—
Overhead		69.55% DL		15
Material & Direct Charges		.56		3
Technical Data & Handbooks				—0—
Subcontracting				—0—
Total Engineering				$ 39
Tooling				
D.L. Planning—Basic	5	$3.59		$ 18
D.L. Planning—Sustaining	—0—			—0—
D.L. Tool Design—Basic	1	3.59		4
D.L. Tool Design—Sustaining	—0—			—0—
D.L. Tool Mfg.—Basic	2	3.59		7
D.L. Tool Mfg.—Sustaining	—0—			—0—
Overhead		115.62% DL		34
Material & Direct Charges		1.26 TMH		3
Subcontract Tooling				—0—
Total Tooling				$ 66
Manufacturing—(Production)				
Direct Labor	11	$2.82		$ 31
Overhead		115.62% DL		36
Material & Direct Charges				10
Purchased Equipment				—0—
Subcontracting				—0—
Total Manufacturing				$ 77
Quality Assurance				
Direct Labor	1	$3.39		$ 3
Overhead		115.62% DL		3
Total Quality Assurance				$ 6
G & A Expense		23.99% DL		$ 20
Total Cost				$208
Profit		8%		17
Price				**$225**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
OXYGEN SYSTEM (ALTERNATE) (5.4.7)

	Hours[1]	Rate	Amount[1]
		FY 63 Contractor's	Qty 31 Proposal
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	32	$2.92	$ 93
Overhead		111.04% DL	103
Material & Direct Charges			62
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$258
Quality Assurance			
Direct Labor	2	$3.49	$ 7
Overhead		111.04% DL	8
Total Quality Assurance			$ 15
G & A Expense		23.00% DL	$ 23
Total Cost			$296
Profit		8%	24
Price			**$320**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
OXYGEN SYSTEM (ALTERNATE) (5.4.7)

	Hours[1]	Rate	FY 64 Qty 48 Contractor's Proposal Amount[1]
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	35	$3.01	$105
Overhead		109.10% DL	115
Material & Direct Charges			96
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$316
Quality Assurance			
Direct Labor	3	$3.61	$ 11
Overhead		109.10% DL	12
Total Quality Assurance			$ 23
G & A Expense		22.88% DL	$ 27
Total Cost			$366
Profit		8%	29
Price			**$395**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
OXYGEN SYSTEM (ALTERNATE) (5.4.7)

	Hours[1]	Rate	Amount[1]
		FY 65 Contractor's	Qty 48 Proposal
Engineering			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Technical Data & Handbooks			
Subcontracting			
Total Engineering			
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor	29	$3.10	$ 90
Overhead		115.12% DL	104
Material & Direct Charges			96
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$290
Quality Assurance			
Direct Labor	2	$3.73	$ 7
Overhead		115.12% DL	8
Total Quality Assurance			$ 15
G & A Expense		24.40% DL	$ 24
Total Cost			$329
Profit		8%	26
Price			**$355**

[1]Thousands

"FORMAT "A"

PRICING INFORMATION

OXYGEN SYSTEM (ALTERNATE) (5.4.7)

PROPOSAL SUMMARY

Contractor's Proposal

	Hours[1]	Rate	Amount[1]
Engineering			
D.L.—Basic	5	$4.11	$ 21
D.L.—Sustaining	—0—		—0—
Overhead		69.55% DL	15
Material & Direct Charges		.56	3
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$ 39
Tooling			
D.L. Planning—Basic	5	$3.59	$ 18
D.L. Planning—Sustaining	—0—		—0—
D.L. Tool Design—Basic	1	3.59	4
D.L. Tool Design—Sustaining	—0—		—0—
D.L. Tool Mfg.—Basic	2	3.59	7
D.L. Tool Mfg.—Sustaining	—0—		—0—
Overhead		115.62% DL	34
Material & Direct Charges		1.26 TMH	3
Subcontract Tooling			—0—
Total Tooling			$ 66
Manufacturing—(Production)			
Direct Labor	107	$2.98	$ 319
Overhead		112.23% DL	358
Material & Direct Charges			264
Purchased Equipment			—0—
Subcontracting			—0—
Total Manufacturing			$ 941
Quality Assurance			
Direct Labor	8	$3.50	$ 28
Overhead		110.71% DL	31
Total Quality Assurance			$ 59
G & A Expense		23.68% DL	$ 94
Total Cost			$1,199
Profit		8%	96
Price			**$1,295**

[1]Thousands

FORMAT "A"

section 9

RELIABILITY PROGRAM

SUMMARY

The reliability program proposed for the Logistic Transport Support System 476L is a logical continuation and extension of the existing and operationally proven C-130 reliability program. The latter program includes all capabilities necessary to meet the requirements of the Statement of Work and its referenced documents. The current level of effort is presently limited to that required by existing contracts; however, this will be expanded in an orderly, economical, and practical manner to meet the requirements established by the effectiveness analysis to be conducted after contract award.

The proposed reliability program for System 476L provides for maximum utilization of existing procedures, techniques, and experience to meet the reliability requirements established for this particular system. The program makes extensive use of the proven capabilities and techniques of the Georgia Division to ensure practical and economic realization of the reliability program objectives. These include the collection, processing, and maintenance of complete and detailed historical records; the electronic computer programs such as actuarial analyses, failure mode analyses, and inspection evaluation analysis based upon the historical data; and reliability control techniques developed through processing and analyzing data by analog and/or digital computers. It is felt of first importance that these up-to-date and highly refined techniques be utilized to the fullest in the maintenance of a reliability program for a specific weapon or support system.

For example, there is currently at hand in the Georgia Division a complete, detailed record of every significant maintenance action taken on the C-130 series aircraft for a three-year period. These records also contain complete, summarized maintenance data on a number of commercial aircraft collected over an extended period, in cooperation with several major airlines.

The resulting techniques developed from those data now permit the prediction of reliability to surprisingly high confidence levels, in advance of the availability of test and operational data. They permit evaluation of system configuration and component selection to a high degree of accuracy, and hence permit the evolution of greatly improved test programs. Finally, they permit prompt, accurate, and thorough evaluation of problems.

A number of these techniques have recently been formulated into computer programs which permit complete, accurate, mechanized analyses of C-130 experience under use conditions. It has been determined that the basic technology is, to a great extent, directly applicable to System 476L which, from the functional system standpoint, is a growth version of the C-130 series aircraft. It follows that for the System 476L, the areas in which effort must be concentrated, the type effort necessary for maximum effectiveness, and the areas which should be retained can, in all likelihood, be predetermined with extraordinary accuracy.

ORGANIZATION

Consistent with its concept of total control and reliability, the Georgia Division has established reliability control as a line function at branch level, equivalent in its organizational level of responsibility to engineering, manufacturing, and finance. In this organizational relativity the reliability control function is in no sense subordinate to the organizations over which it is to exercise control. The effectiveness of this arrangement has been conclusively demonstrated by the reliability of the C-130 aircraft.

Reliability Branch Organization

The reliability branch is the line organization of the director of reliability, who reports directly to the Vice President and General Manager of the Georgia Division. It is composed of five organizations which, together with the engineering branch, exert total reliability control over the Georgia Division products. These organizations are quality control division, reliability engineering department, field service department, flight operations department, and reliability administrative services.

PROGRAM

The reliability program for System 476L is designed to meet the requirements of Paragraph 5.4.8. of the Statement of Work and its referenced documents in a practical and economical fashion, and to conform to the cost philosophy defined in Paragraph 1.3. The program emphasizes controls which treat reliability in its broad sense and ensure optimization of reliability, maintainability, supportability, availability and economy. Due to the functional similarity of the GL 207-45 to the highly reliable C-130, emphasis of the program is directed toward those areas in which configuration change is necessary or reliability improvement is desirable. Simplification of system configuration based on C-130 experience is strongly emphasized.

Design and Development

Primary emphasis of the program is centered in the design and development area; reliability engineers are consequently assigned early in the project to monitor the design through the preliminary and project phases. Extensive use is made of historical data on C-130 aircraft to support the design effort and to permit selection of the most reliable component or component types in the initial stages.

As the design progresses, functional block diagrams of the system series and parallel combinations are developed and maintained. The correlation of historical data with these diagrams permits reliability predictions concurrent with the design progress, and reliability predictions for alternate design configurations assist in the selection of the optimum configurations.

The application of historical data to systems design identifies components and subsystems requiring special maintainability consideration and design changes are then executed to reflect the new requirements. Mechanized Inspection Evaluation Reports provide data which allow scheduled maintenance cycles to be established based upon demonstrated system requirements. These data will permit economical schedules to be established for GL 207-45 aircraft. Operational data are also used in the preparation of purchase and tests specifications in order that known requirements can be thoroughly evaluated to avoid the selection or specification of marginal equipment.

Appropriate reliability tests are conducted at both the component and system levels, with primary emphasis on system tests in which component interaction can be observed and evaluated. Reliability tests, using the same components and fixtures, are ordinarily conducted subsequent to design development and qualification test completion; however, all tests are considered to be valid reliability tests and are closely monitored by skilled reliability engineers of appropriate background and experience.

Vendor and Subcontractor Reliability Control

The program of vendor and subcontractor reliability control for System 476L is an extension of the vendor reliability control program presently in operation at the Georgia Division. Expansion of the level of effort together with diversification of the existing procedures and techniques for the System 476L program ensures the satisfaction of the requirements established by the effectiveness studies.

Specification Control

Historical data are to be used extensively in the preparation of purchase and test specifications to ensure adequate reliability. With data on the modes of failure of current equipment, it is possible to ensure that specified environmental conditions, performance requirements, safety margins and other factors affecting reliability will substantially reduce recurrence of previously experienced difficulties. Appropriate test specifications will be drawn as assurance that design or specification changes in fact reduce or eliminate recurrence of previous difficulties.

Vendor and Subcontractor Selection

Vendors selected for bid proposals are selected from the corporate approved supplier directory. New vendors are surveyed for capability, including reliability control, prior to being requested to bid. Proposals are evaluated by both engineering and reliability personnel, using a point rating system. The relative point rating establishes an order of preference from a technical standpoint and is evaluated with other considerations in making a final selection.

Vendor and Subcontractor Monitoring

The performance of a vendor in meeting contractual requirements is continuously monitored. Vendor design, manufacturing controls, test programs, test equipment, and test results are monitored both by reliability branch personnel in the field and in-plant. Copies of all vendor data, including test results, failure analyses, and corrective action, are maintained in the reliability data center. Vendors are assisted in establishing suitable reliability training programs where the need is indicated.

Performance Evaluation

The performance of vendors and subcontractors is continuously evaluated from all points of view. Included in the performance evaluation are incoming quality, the results of acceptance and production tests, the results of system reliability tests, and the performance of equipment during category testing and operational use. All performance evaluations are consolidated in a final evaluation for use in future selection processes.

Corrective Action

Inadequacies detected in each step of the vendor performance evaluation are immediately made available to the vendor, and mutually acceptable corrective action is determined and scheduled. Continuous monitoring of vendor product performance in operational use permits a continuous flow of feed back information and pin-points marginally reliable equipment, thereby ensuring continuous product improvement where there is an indicated need.

Manufacturing Reliability Control

A preventive-type manufacturing reliability control program is conducted to ensure against degradation of reliability during the manufacturing cycle. The program is based upon maintaining quality levels established jointly by manufacturing, quality control, and reliability engineering. Deviations from established quality levels result in an immediate analysis of cause. Preliminary analysis by reliability engineers establishes cause factors which are then thoroughly analyzed by quality engineers in a capability study. The capability study provides the basis for immediate correction of the cause factors; subsequent follow-up determines the adequacy of the correctives.

Other manufacturing reliability controls are incorporated in acceptance testing, production testing, and flight testing. Each of these ensures, at the earliest possible point in the production cycle, that all preceding operations are satisfactory.

Operational Use

A continuous program of operational surveillance, data feedback, failure analysis, and corrective action is planned throughout the operational use of the GL 207-45 aircraft. Data collection programs and mechanized data reduction and analysis programs currently in use on the C-130 aircraft are directly applicable to the GL 207-45 aircraft and are used to provide optimum operational support. On frequently scheduled intervals, these computer programs provide an evaluation of achieved reliability; define reliability and maintenance problem areas; pinpoint unreliable components; and evaluate scheduled maintenance and overhaul cycle effectivity. To promote earliest possible corrective actions and the achievement of reliability growth objectives, reliability engineers are assigned to category test programs and operational bases to conduct complete detailed analyses of component failures and failure causes. This information is immediately transmitted to the Reliability Engineering Department for analysis and to Project Engineering for corrective action.

Failure Analysis

Failure analysis is greatly facilitated by complete operational data, mechanized data reduction, and computer data analysis. Computer programs establish analysis priorities and reduce manual analyses to the point where judgment must be applied. Computer-produced actuarial analyses provide prompt and more accurate evaluation of failure effects. Failure mode analyses, which are computer produced, permit immediate identification of corrective action approach. Final failure analysis is performed by skilled analysts with carefully processed data at their disposal.

Corrective Action

Corrective action is taken as promptly as possible with primary emphasis given to problems affecting safety of flight or exerting serious influence on mission capability. In all other cases priorities for action are established by the relative effect of the problem and the cost of correction. Retroactive problem correction is reduced to a minimum, and corrective action is for the most part on an attrition basis.

Reliability Monitoring Program

Monitoring points are established to assess reliability progress. At each point, a progress report is prepared, progressive requirements are established for the next monitoring point and activities for the next period are defined. Monitoring points presented in this addendum are tentative and generally conform to the recommendations of Air Force Specification Bulletin No. 506.

Mathematical and Statistical Analysis

Mathematical methods are applied throughout the reliability program wherever they are felt to be meaningful or useful. Mathematical treatment of reliability allows quantitative standards and measurements as a basis for reliability evaluation and control, and statistical analysis of data provides guidelines for specific corrective action.

Quantitative Reliability Requirements

These requirements are established as standards by which reliability achievement can be evaluated. A reliability requirement for the complete support system is determined as a result of the effectiveness analysis. This requirement is allocated to successive levels of subsystems and components. The allocation process used is an adaptation of that recommended by AGREE, whereby allowable failures are distributed according to an assignment of risk based on comparative importance and complexity. Requirement figures are in the form of mean-time-to-failure (MTF), which is the average operating time between failures. The relationship of reliability and MTF is expressed by the exponential survival function, $R = e^{\frac{-t}{m}}$, where t is the time of operation and m is MTF. For the GL 207-45, t is taken to be five hours, which is the expected time of flight for a typical mission.

With the exponential equation, the reliability requirement for the support system is converted to an allowable number of failures for 1,000,000 hours of aircraft operation. These failures are allocated to sublevels by use of complexity and importance factors, assuming that the rate of failure of equipment is proportional to complexity and that allowable failure rate is limited by the importance of that equipment to mission success.

A relative numerical complexity factor is assigned to each item, consistent with the total complexity of the given sublevel. This assignment is based on an engineering analysis of the design and function of each item, with allowance for the number of parts or components present, principles of operation, state-of-the-art, and similar considerations. Importance factors are computed quantitatively from experience data as the ratio of inflight aborts to total inflight discrepancies, a computation made possible by the comprehensive operational data available for the C-130 aircraft.

With complexity and importance factors assigned to all system sublevels, failures are distributed in proportion to the assigned factors. Mathematical probability equations are used to express the relationships of parallel and series combinations which are present at each sublevel, as displayed by reliability block diagrams. Allowable failures are thus allocated to individual items down to component level, and these are converted to required MTF.

Reliability Predictions and Measurements

Quantitative predictions and measurements of achieved reliability are computed from available success and failure data at each major stage in the development, manufacture, and operation of the GL 207-45 aircraft. These calculations, when combined with the quantitative requirements, provide the basis for an overall reliability evaluation of the aircraft and all sublevels. Measurement of achieved reliability determines the effectiveness of the program and identifies those areas where improvement is necessary.

Definitions necessary for reliability measurement are directed toward operational reliability under actual field conditions. Failure is defined as any malfunction which could degrade mission accomplishment. This conservative definition and the ground rules established for the use of failure data provide a broad base for total reliability evaluation.

The basic reliability measure used is mean-time-to-failure (MTF), which is defined as the ratio of total exposure hours to total failures. Using this life parameter, reliability is computed by the exponential equation, with an operation time requirement of five hours. When data are limited at system or subsystem level, reliabilities are computed as a combination of component values. A mathematical model of system reliability, as a function of reliabilities at successive sublevels, is derived from an engineering design analysis. Reliability block diagrams are used to display parallel and series relationships at each level, and component values are applied to the model to allow prediction of expected reliability. During the design stage, component failure rates are assigned on the basis of similarity to existing equipment of known reliability. The extensive experience data available at Lockheed makes this approach possible, with valid prediction results.

During early test phases, when sufficient data are not available for true measures of MTF, alternate prediction methods are used. These include discrete calculations from attribute data of the ratio of successes to total trials and calculations from variable data, comparing distributions of pertinent parameters with specified performance limits.

Failure Data Analysis

Comparison of required and predicted reliability values identifies areas of required improvement. Guides to corrective actions are developed through detailed analysis of recurring failure types, failure modes, and failure conditions. Complete historical data are analyzed to determine failure trends and projected future performance levels. Component interactions and induced failures are evaluated through analysis of collated data for complete systems and subsystems, and environmental effects are evaluated by comparison of data accumulated under varied conditions.

Data analyses are facilitated by the completely mechanized processing of data. The reliability mechanization program developed by Lockheed includes several computer programs for complex analyses, recurring calculations, and data summaries; and further applications of computers are possible within the present program framework. Computer programs currently used include an operational reliability and maintenance summary, a how-malfunction summary, an inspection evaluation program, and an actuarial analysis. Each of these has important applications directly applicable to the GL 207-45. The actuarial analysis is a major analytical tool, and Lockheed has developed highly refined applications of this technique to aircraft reliability, largely through the C-130 data collection program.

Data analysis also provides a sound basis for direction of maintenance and logistic efforts. Maintenance requirements are a major consideration in overall reliability evaluation, and the maintenance data available for the C-130 aircraft are the most valid source of information applicable to the System 476L. Analysis of these data permits development of optimum maintenance cycles, overhaul periods, and inspection schedules. Application of such data to the areas of spares procurement and fly-away kit requirements can result in substantial cost reductions.

Reliability Data Center

The reliability data center is an integral section of the reliability engineering department and is the focal point for reliability data generated and collected by the Georgia Division. Comprehensive data coverage by the data center includes the areas of materials receiving, manufacturing, testing, and the operational use of aircraft by both military and commercial customers. Operational data include an historical record of three years experience with the C-130, providing complete coverage of significant maintenance actions. In addition, operational data for commercial aircraft, including jet transports, are received through reciprocal agreements with several airlines.

The reliability data collected by Lockheed have led to the development of extremely proficient capabilities in data processing and data analysis. A completely mechanized program has been established by the data center for the coding, processing, reduction and storage of reliability data. Coding and, processing procedures are altogether compatible with the provisions of AF 66-1, T.O. 00-20A-1, and T.O. 00-35D-54.

Computer programming has been integrated into the data system to accomplish complex analyses and summaries. An operational reliability and maintenance summary is produced, permitting immediate reliability evaluation at component level. The computer actuarial analysis has extensive applications such as establishing maintenance and overhaul cycles, failure trends, and significant life characteristics. This analytical technique, which in the past has had only limited application, is now applied at component level by Lockheed. Other computer programs in use include a failure mode analysis and an inspection evaluation; each is directly applicable to the GL 207-45, and the framework of the mechanization program provides for efficient expansion and sophistication of computer techniques.

The centralization of all reliability data functions in the data center provides effective application of feedback principles in all areas of effort for the System 476L program. The extensive use of reliability data at Lockheed is described throughout this addendum.

Reliability Calculations

A preliminary reliability design analysis has been performed for the GL 207-45 aircraft. This analysis includes allocation of quantitative reliability requirements to minor subsystem level based on an initial reliability goal of 90% for the complete airborne system, and prediction of achieved reliability from minor subsystem level up to complete system level based on C-130 experience data. Numerical examples of the methods used and actual calculations are shown for the hydraulic system.

Preliminary analyses for the GL 207-45 are based on Lockheed definitions and ground rules. A comparison has been made of required and predicted values at subsystem level to isolate those areas in which the predicted reliability does not meet the required level. The subsystems which are considered to be potential reliability problem areas, as determined by this preliminary evaluation, are itemized. Concentration of effort in these areas is planned early in the System 476L program to ensure prompt upgrading of reliability to satisfactory levels.

ORGANIZATION AND CAPABILITIES

RELIABILITY BRANCH ORGANIZATION

The Reliability Branch of the Georgia Division is the line organization of the Director of Reliability, who reports directly to the Vice President and General Manager as shown in Figure 9-1. Its organizational level of responsibility parallels that of the Engineering, Manufacturing, and Finance Branches.

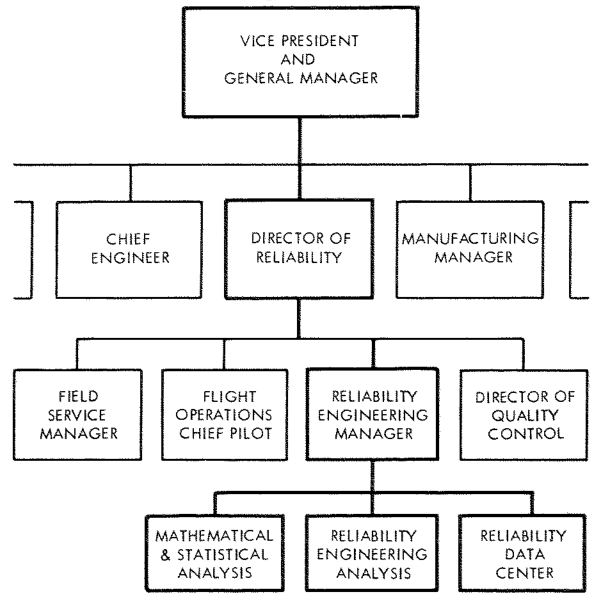


Figure 9-1—RELIABILITY BRANCH ORGANIZATION CHART.

The Reliability Branch is responsible for the development and conduct of all reliability programs associated with the Georgia Division's products, and is composed of five organizations which, together with the Engineering Branch, are responsible for total reliability control. These organizations are the Reliability Engineering Department, Quality Control Division, Flight Operations Department, Reliability Administrative Services Department, and Field Service Department.

The effectiveness of this organization has been impressively demonstrated in the reliability of the C-130 aircraft. The effective integration of effort necessary to achieve the reliability objectives is inherent in the organizational structure. The application of this broadly experienced organization to the GL 207-45 program ensures high initial reliability and accelerated improvement in reliability.

The office of Safety and Reliability Staff Engineer has been created within the Engineering Branch to ensure complete integration of effort between the Engineering and the Reliability Branches. This office serves as Engineering spokesman on reliability matters, as focal point of major interbranch relationship, coordinates related engineering effort, prevents duplication of effort, and ensures prompt and effective communication. Interbranch organizational relationships are shown in the action flow diagram in Figure 9-2.

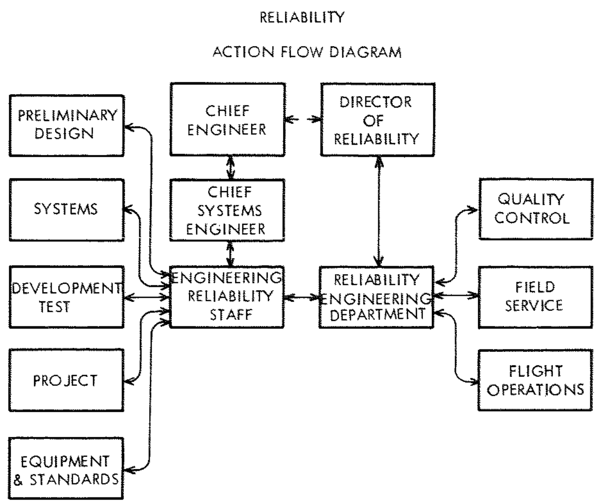


Figure 9-2—RELIABILITY ENGINEERING ACTION FLOW DIAGRAM.

Reliability Administrative Services Department

The Reliability Administrative Services Department is responsible for budgetary and procedural control for the branch. Its primary tasks are the coordination of procedures which are generated or revised within the program, and the budgeting and control of the program funding. Also included are the coordination of budgeting and the scheduling of effort within supporting organizations. Responsibility for coordination of PEP within the Reliability Branch is also vested in this department.

Reliability Engineering Department

The Reliability Engineering Department has specific responsibility for the development, implementation and control of all reliability programs for the Georgia Division and is vested with the authority required to ensure the achievement of program objectives. This organization presently has the capability and experience to meet the requirements of all current military and commercial specifications for reliability control and a proved capability to support the System 476L requirements. The functional structure of the Reliability Engineering Department provides (1) engineering analysis, (2) mathematical and statistical analysis, and (3) a reliability data center. It is staffed largely by graduate engineers, personnel with extensive experience in component design, mathematical and statistical analyses, data system development, and computer programming. Since its inception, the department has developed a number of advanced capabilities which provide a well established and practical approach to the achievement of reliability.

Reliability Engineering Analysis

This group is composed of reliability engineers with broad technical backgrounds and with many years of practical experience in the design and testing of airborne equipment. All personnel are thoroughly familiar with Government reliability documents and are experienced in effectuating reliability programs. This group is responsible for the engineering aspects of the reliability control program.

Mathematical and Statistical Analysis

All mathematical analyses required by the System 476L program are executed by the mathematical and statistical group; a group composed of personnel with extensive educational backgrounds and experience in this specialized field plus supplemental experience in computer programming, design of data recording procedures and forms, and design of experiments.

Reliability Data Center

Reliability records of the Georgia Division are centralized in this group which is responsible for receipt, processing, programming, and reporting of all in-plant, vendor, and operational reliability data. The group is staffed by personnel of appropriate educational backgrounds implemented by extensive experience in the various aspects of data system development and control. The equipment necessary for support of the reliability control program is located within the Reliability Engineering Department. Relatedly, many computer programs have been developed for the Georgia Division IBM 704 and 705 computers.

RELIABILITY PROGRAM

The reliability program for the Support System 476L proposal is a continuation and extension of the existing operationally proved C-130 program expanded to meet the requirements of the Statement of Work.

The Statement of Work specifies that contractual reliability requirements and criteria will be based upon an effectiveness analysis which will be conducted after program release under close direction from the Air Force. Pending establishment of detail numerical requirements and specific criteria, the program has been developed to emphasize controls which ensure maximum practical maintainability, supportability, availability, and economy.

Due to the similarity of the GL 207-45 to the C-130 aircraft, maximum benefit is derived from the complete historical data available on the C-130 aircraft. This data is used extensively to guide the design. Every effort is made to retain designs which have proved reliable. Design effort is concentrated in those areas where the new configuration of the aircraft makes new system configurations necessary and where historical data shows design change for reliability improvement is desirable. Simplification of system configuration based on operational experience with the highly reliable C-130 is stressed.

DESIGN AND DEVELOPMENT

Primary emphasis of the reliability program for the System 476L is centered in the area of design and development. Every effort is made to ensure that reliability in the design is considered in the sense of ensuring the highest practical degree of maintainability, supportability, availability and economy. Historical data is used to support the evaluation of these aspects and arrive at the optimum level which will ensure maximum effectiveness of the GL 207-45 aircraft.

Design Surveillance and Support

Reliability engineers are assigned to the project at its inception and follow the design through both preliminary and project phases. Initial effort associated with the design is the support of design personnel with analyses of historical data available in the reliability data center. The use of the available data allows comparisons to be made of the reliability of various approaches to functional system configuration and pinpoints individual components in which reliability improvement is desirable.

Because of the availability of detailed records on the C-130, system performance is well established. These systems have been evaluated with respect to requirements of the System 476L. As a result of careful consideration, the functional systems of the GL 207-45 are either very similar to or growth versions of the successful C-130 systems. Design of these systems has matured to the point where system improvement is accomplished by simplification rather than by additions and increased complexity. The GL 207-45 system designs are well beyond the characteristic improvement-by-complexity cycles which are identified with new developments and new concepts. Full effort is devoted to reliability upgrading by standardization and simplification.

As the design progresses beyond the conceptual point, analyses are made of individual components. These analyses are both comparative to select the better of two or more components and qualitative to determine if design improvement can be made to increase reliability. In support of these analyses, collected historical data in reduced form are used to pinpoint those areas where more specific and detailed qualitative data are required. This supplementary information is evaluated and correlated with the reduced data and furnished to design and project engineers, for making decisions based upon actual operational experience.

The collection of failure data to the extent accomplished with the C-130 provides a new, valuable tool in the hands of the design engineer, enhanced by current data available from the airlines. Exchanges have been made with the major airlines, and these data are utilized in conjunction with the Lockheed data to ensure maximum design reliability. Thus, significant improvements are obtained in needed areas, but the risk of resorting to components and systems of unknown capability is reduced or eliminated. With this design support, the customer obtains a new aircraft with a higher initial reliability and a greater potential for development than that normally associated with a new product.

These quantitative and qualitative data permit reliability engineers to support Project Engineering: (1) by response to specific requests to Reliability Engineering regarding a system or component and (2) by Reliability Engineering initiated investigations which emanate from the monitoring of designs. This previously demonstrated close tie-in between project, staff, and reliability provides insurance of good initial design, a team effort toward operational evaluation for further upgrading, and tight-loop "failure-to-fix" cycle in the event of operational difficulties.

Reliability engineers also begin development of reliability block diagrams based upon the applicability rule that all parts and components necessary for the function of a subsystem are included. Each part is shown in its series or parallel combination. The block diagrams, which serve multiple purposes, are kept up to date with the design as it develops and provide a comprehensive picture of the system for ready reference. Periodically, they are reproduced and provided to the mathematical group of Reliability Engineering for reliability requirements analyses and reliability prediction.

Alternate configurations are statistically analyzed at the request of project design personnel, project reliability engineers, or at the discretion of Reliability Engineering. This approach offers an additional parameter upon which to base configuration selection or a basis for configuration change to increase reliability.

The block diagrams serve the additional purpose of providing a schematic of the system for use in the failure effects analyses. Since they show series and parallel combinations of all components required to operate the system, they provide for simplicity and accuracy in the analyses.

As the design develops to the point where purchase and test specifications are being prepared, a mechanized report showing failure cause and aircraft age for each failure is utilized by the reliability engineers to guide the specification preparation. This report provides background to ensure that component and subsystem purchase specifications recognize those problems which have previously existed and prevent their recurrence. The report also provides the necessary insight to ensure that qualification, reliability, and acceptance tests adequately explore those conditions.

Reliability engineers assigned to the project assist in conducting surveys of potential new suppliers to ensure that they have an adequate reliability organization and program.

Subsequent to vendor selection and request for proposal, reliability engineers evaluate proposed vendor design using a point rating system. This system recognizes not only the potential reliability of the design, but also such aspects as the vendor's performance, predicted component reliability, and program adequacy. Past performance in correcting inadequacies, and the proposed test procedures and techniques of the vendor are also evaluated by this system. These evaluations and similar point ratings made by project design engineers are given full consideration in vendor selection. Subsequent to vendor selection, reliability engineers monitor vendor products in the pre-production and production conformance evaluations.

All Lockheed conducted tests including development, qualification, acceptance, and system and component reliability are monitored by reliability engineers. In addition to participation in the preparation of test outlines and requirements, reliability engineers evaluate early test results and expedite necessary corrective action.

During production phases of the program, acceptance and manufacturing records are constantly monitored to detect problem areas and to effect early corrective action through design change, changes in skill levels, tooling changes, or through other means. Of particular importance is the change to procedures and requirements as a preventive measure to avoid recurrence of similar problems. An important part of the production surveillance is the participation in the teardown and analysis of malfunctioning components. Data resulting from teardown evaluations are supplied to Project Engineering and to vendors so that product improvement is continuing and timely.

Subsequent to the delivery of the aircraft to the customer, reliability engineers participate in analysis of malfunction and failure data received from the field. Results of these analyses are also submitted to the project and to vendors to ensure prompt corrective action, eliminating potential problem areas as early as possible.

Reliability engineers on the project also have the responsibility of furnishing the project support in the form of analyses, actuarial studies, reliability achievement graphs and reports, and such other documentation as may be needed in contacts with the Air Force.

These engineers support Staff Engineering and project design personnel with analyses of historical data for maintenance design. These data disclose those components or system elements requiring special maintainability considerations, such as optimum accessibility, frequent servicing requirements, more frequent inspections or protection from environmental conditions. The GL 207-45 has a distinct advantage in that complete operational and maintenance data on its predecessor, the C-130 aircraft, are available to the design engineer. The availability to the designer of scheduled and unscheduled maintenance actions for every component and system, manhours required, how malfunction information, action taken data, etc., permits a more complete and thorough approach to maximum reliability with minimum maintenance.

Maximum use is made of historical data in design trade-offs. Since replacement, repair, mission abort records, and other information are available to the designer, appropriate consideration is given to initial cost, spares support requirements, aircraft availability and utilization, total maintenance cost, and other items which warrant evaluation.

The reliability program emphasizes consideration of the effect of the human factor on reliability throughout the life of the system. In the design, every possible precaution is taken to ensure that human actions required are normal and well within the capability of the average person. Maintenance design recognizes not only the needs of the system hardware and maintenance requirements but also the inherent shortcomings of maintenance personnel. Adequate training is provided to ensure that manufacturing, maintenance and operating personnel are made fully aware of their contribution to product reliability.

Adequate consideration is given to trade-offs throughout the life of the system. In the design, careful analysis of performance versus reliability requirements is made. Minor increases in performance at the expense of unwarranted complexity are avoided. Historical information allows design factors to be weighed in the light of factual data and provides clear insight into the cost of unnecessary complexity to achieve minor improvements.

Major trade-offs are considered in the effectiveness analysis where all factors are carefully weighed to provide an optimum balance of each factor and maximum system effectiveness. Particular emphasis is placed on the utilization of those advanced techniques developed by the Georgia Division to reduce overall cost of achieving a high-level reliability.

Statistical trade-offs are also made during program monitoring and in each potential problem area, the most economical corrective action is taken which will achieve the statistical result necessary. If the state-of-the-art prevents economical corrective action on a particular component, and economic corrective action can be taken on other components which will permit the subsystem to meet its requirements, that course will be followed.

Reliability Test Program

The Reliability Engineering Department monitors all phases of all test programs conducted by Engineering from initial research and development through flight testing of the complete aircraft. Reliability engineers assist in the preparation of test documents to ensure that maximum useful reliability data are obtained. In a time-phased development program, components and systems are continually re-evaluated as a result of data derived from early testing. Analyses of all test failures and recommendations for corrective action are made by Reliability Engineering.

Test specifications for each component, subsystem and system are established early in the reliability program based on the analysis of the complete aircraft, fully utilizing C-130 historical data. These specifications define the test phases, reliability parameters, environmental conditions to be simulated, number of units to be tested, and the endurance cycles necessary. In the initial development stage of the test specifications, statistical and engineering analyses of all reliability factors are used to establish reliability boundaries for each system, subsystem and component. Simultaneous analysis determines the performance capabilities that must be proved by test to assure reliable performance.

Development Testing

Prior to qualification testing, all items incorporating fresh concepts or design criteria previously unused by Lockheed, undergo a design evaluation period.

The vendor's first article, usually an early production prototype, is subjected to an Engineering First Article Evaluation. Reliability Engineering closely monitors all test procedures and results to ensure required feedback. Requirements are compared with test results. If similar system requirements are applicable on C-130, field failure history is studied. On the basis of this evaluation, corrective action is recommended as required.

Functional system mock-up design is normally started at the time of contract go-ahead and completed by the time of 90% functional release. Fabrication of the mock-up starts two to three months prior to 90% functional release and checkout of the mock-up is accomplished immediately subsequent to fabrication. Reliability Engineering reviews mock-up installations with laboratory personnel to ensure that adequate allowance has been made for reliability testing. Subsequent system tests are carefully monitored to assure early assimilation of reliability data at system, subsystem and component levels.

Individual mock-ups of critical systems and subsystems are made where environmental system testing is considered desirable. These mock-ups, which are constructed using actual production components, simulate the aircraft systems, but are made more compact to facilitate testing in the various environmental chambers. Precautions are taken to maintain proper system relationships.

Reliability Engineering assists in obtaining close correlation between test and predicted environments. Simulated flight conditions are duplicated as nearly as is practical. Data derived from simulated system environmental tests are compared with the results obtained from tests conducted on the major mock-ups, under plant ambient conditions, to determine environmental influences.

Qualification Testing

The use of unproved components is held to an absolute minimum. Historical data are used to determine components which have demonstrated high reliabilities in C-130 applications. Those items which have proved reliable are retained where possible.

Where new requirements dictate the use of components which have no background of historical data, GL 207-45 components are chosen from standard or off-the-shelf items. When this choice involves the use of qualified products lists, it must be established that the item chosen has been environmentally tested at the required level.

These procedures have the effect of reducing the number of new and unproved items required, thus reducing the necessary qualification testing.

When qualification testing is required, specification documents defining all technical requirements are prepared. These documents include reliability input to substantiate adequacy and severity of environmental, proof, and pressure tests. The qualification test and production item conformance test phases are also evaluated to assure proper reliability coverage. Additional reliability tests, complete with all details such as number of test items, severity and endurance of tests are recommended in the specification document.

The vendor qualification test procedure is thoroughly reviewed and compared with qualification test requirements of the specification document. Reliability assists Engineering in determining whether qualification testing should be accomplished inplant, at the vendor location, or at a certified test laboratory. If tests are conducted outside the plant, they are monitored by Lockheed.

Vendor test procedures are also examined closely as to reliability aspects when approval of a new item similar to a previously qualified item is being considered. Special attention is given to vendor reliability test data, severity of environmental testing, and actual operating conditions when comparing the new item with the one previously qualified. Only where the validity of the comparison is beyond question is qualification testing of the new component waived.

Qualification tests performed by vendors are monitored by Lockheed representatives, who also inspect the test set-ups prior to testing. These representatives also collect additional information required to supplement normal flow of feedback data supplied by the vendor. Qualification tests which are conducted inplant, including the design of test set-ups and test procedures, are monitored by reliability engineers.

Test results are evaluated and compared with predicted reliabilities. If potential degradation of reliability is involved, corrective action is recommended and reviewed with Engineering and decisions made regarding the extent of further testing required on the modified component.

At the completion of qualification testing conducted outside the plant, components are normally returned to the Georgia Division for detailed inspection and evaluation. Further testing may be conducted on any components whose reliability status is questionable.

Reliability Testing

The participation, by reliability engineering, in the initial stages of the testing program enables reliability evaluations to commence at an early stage in the development of the GL 207-45.

While the importance of qualification tests at component level is fully recognized, extensive system and subsystem testing is planned, under simulated flight conditions. Emphasis on system testing is based on past experience at the Georgia Division, where problems concerned with interactions between components and transient effects on various subsystems have been successfully overcome by this method.

Additional functional endurance tests in subsystems or systems are used to extend operating time on components and systems to establish failure rates.

The test stands or mock-ups of the hydraulic systems and flying controls include a reliability record panel which has elapsed time meters and counters for recording time and cycles of operation of all major components. Records for minor components are determined by reference to the recording instruments of a major component in the same system. All reports include operational time and number of cycles of operation, which information is recorded in the reliability data center for use during reliability engineering evaluation.

Where qualification and development testing shows a system or subsystem to be marginally reliable, special tests are prepared by reliability engineering in conjunction with Project engineering. The reliability engineer evaluates the test log data to detect areas of performance degradation, and locates units that may have had intermittent or incipient failures. Failed or malfunctioning units receive detailed inspection and corrective action. Modified units are functionally retested in the system with increased stress limits imposed in the critical area to determine that corrective action is effective.

Since the validity of actual operational data is superior to all forms of test data, the reliability test program is reorientated after the scheduled delivery of the 10th production aircraft. At this stage, the field failure data is fed back to the reliability data center and analyzed to help determine the pattern of further testing.

Design Reliability Evaluation

Analyses are conducted to evaluate each system solely from a reliability standpoint both during design and as designs are completed. Particular attention is given to flight safety items and items whose failure would result in serious degradation of mission accomplishment. Attention is also emphasized in those systems having a preliminary reliability less than that established by Lockheed as necessary to achieve the desired level of mission accomplishment.

These evaluations are conducted jointly by the engineering and statistical analysis groups, together with support from the data center. A system is broken down into its principal components and failure rates are assigned on the basis of historical records. Both military and airline records are utilized, with adjustments made for significant differences in operational environments or usages. Where data are not available on a completely new or radically different component, failure rates are assigned on the basis of state-of-the-art experience.

When the initial design is completed, a combined engineering and mathematical analysis is performed to develop a mathematical model which describes the functional relationships of the components and subsystems within the complete system. This model consists of mathematical probability equations which express subsystem reliability as the proper combination of component reliabilities. Component and subsystem failure rates are then computed from available failure data and substituted into the probability equations to give reliability predictions at component, subsystem, and system levels.

During the development stage, test data which becomes available on new GL 207-45 items are employed as supplementary information to evaluate and modify prediction figures based on C-130 data and other sources. As test data accumulate, emphasis in predicting is transferred to that data source for new and different items. Test data, however, never give as high a confidence level as operational experience data and are used only as a supplementary source in areas where experience data are available. Upon completion of system block diagrams, functional analyses are made to determine those areas which contribute most significantly to reliability degradation. Methods to upgrade reliability are then investigated jointly by Reliability and Engineering, and steps are taken to ensure timely improvement. Reliability coordinates with Engineering in the review of proposed designs submitted by component suppliers prior to manufacturing go-ahead. Use is made of historical data, both from a standpoint of similar component operational shortcomings and the supplier's previous record. Here again, the strong similarity between the GL 207-45 and C-130 systems is of particular value.

VENDOR AND SUBCONTRACTOR RELIABILITY CONTROL

The Georgia Division has in existence a vendor and subcontractor reliability control program fully capable of meeting System 476L requirements. These requirements will be accomplished to the maximum practical extent as determined by the effectiveness analysis. The supplier reliability program emphasizes controls in the selection, monitoring, training, and performance evaluation of vendors and subcontractors to ensure reliability achievement commensurate with requirements.

Specification Control

Historical data are used extensively to ensure that all specification documents provide adequate consideration of reliability. These data define those areas where experience has shown that inadequate attention has been given in the past. From modes of failure of previous equipment, it is possible to determine where environmental conditions have been inadequately recognized, where insufficient safety margins have been provided, and where performance characteristics have been marginal. It is then possible to ensure that purchase specifications for a similar type of equipment adequately recognize these conditions, preventing recurrence of undesirable characteristics while retaining desirable characteristics.

Test specifications also incorporate the benefit of past experience since knowledge of past equipment inadequacies permits thorough exploration of capability in these areas during the test program. Vendor test programs are carefully inspected for specification conformity.

The vendor is furnished with all pertinent information establishing the requirement for his component, the subsystem of which it is a part and the environments and performance conditions which it must meet, thus allowing him to analyze his equipment realistically.

Vendor and Subcontractor Selection

Vendors, subcontractor and associate contractors are carefully selected. Design surveillance is the initial process in this selection since every endeavor is made during the initial design to select components with a demonstrated reliability achievement or components of a type known to be reliable. Reliability performance of components of new design configuration can be predicted by breaking the design down into its individual functions on which past experience exists.

Subsequent to design selections, proposals are requested from vendors included in the approved supplier directory, a Lockheed interdivisional listing of those suppliers who have been individually surveyed and found to have adequate facilities, controls, financial ratings, and performance. If a new vendor is to be considered, his capability is surveyed prior to request for proposal. Reliability control capability and corrective action policy are included in the survey criteria.

Proposals submitted by vendors are carefully evaluated by Engineering from a performance capability standpoint and by Reliability Engineering from a reliability standpoint. An individual point rating is made by each of these organizations using historical data as applicable to evaluate the various factors. The relative point rating of the individual proposals indicates the order of preference from a technical standpoint and is given full consideration in the final vendor selection. Final selection is based upon the evaluation of the technical aspects of acceptable proposals in comparison to other factors.

Vendor and Subcontractor Monitoring

Subsequent to the selection of a vendor, all aspects of his performance of contractual requirements are carefully monitored by the Reliability Branch. These include his design, manufacturing controls, test programs, test equipment, and test results. Complete reports of test findings showing failures and their causes and results, in addition to success data, are transmitted to the reliability data center.

The need for a suitable training program as a part of a vendor's reliability program is emphasized and assistance in its development is made available.

Performance Evaluation

The performance of vendors and subcontractors is continuously monitored and evaluated. Engineering first article evaluation, production first article evaluation, acceptance tests, and production tests are a part of this evaluation. Additional means of evaluating vendor performance are records of incoming quality and inplant performance which are maintained in the data center as explained elsewhere. A more significant evaluation of vendor performance is obtained from the performance of his products in design development and reliability testing accomplished at the system level and performance of his products in the field.

Corrective Action

Vendors and subcontractors are advised of the performance of their products as early as possible in each phase of evaluation. If the incoming quality of his products deviates from established values, he is immediately informed and his corrective action monitored. Product inadequacies discovered in any phase of the tests are immediately called to his attention and mutually agreeable corrective action is undertaken. Analyses of malfunctions and failures occurring inplant are made wherever possible with the vendor's assistance, or if not practical, the results of such analyses are immediately furnished to the vendor for corrective action.

An operational history of vendor components is developed and the continuous analysis of component performance permits a comparison of capabilities under operating versus test conditions. Reliability engineers are assigned to cover category testing and also to cover operational bases, thus permitting early detailed analyses of equipment discrepancies and prompt corrective action. The use of actuarial analyses permits accurate prediction of component inadequacies far in advance of using normal mean-time-to-failure techniques. The combined use of actuarial analysis and teardown analysis in the field permits positive corrective action to be taken in a timely manner and resulting effectiveness to be promptly determined.

The continuous analysis of operational data ensures that all inadequacies are defined and that the vendors and subcontractors are promptly made aware of performance trends to enable suitable action.

MANUFACTURING RELIABILITY CONTROL

Production Reliability

In addition to the standard quality assurance effort, an inplant reliability control program of the preventive type is conducted to assure minimum degradation of reliability during manufacture. This program to identify and correct potential problem areas is a cooperative effort of Reliability Engineering, Quality Assurance, and Manufacturing.

The basis of this inplant control program is the establishment of quantitative quality goals as a yardstick for manufacturing quality performance. Corrective action is initiated when the goals are not achieved. Reliability Engineering personnel collaborate with Quality Assurance and Manufacturing management personnel in establishing quality goals, initially based on past experience and industry standards. Manufacturing personnel are indoctrinated in the concepts involved and the procedures required for application of the program as a manufacturing improvement device.

A continuous system for the collection of inplant discrepancies is maintained to measure achievement against these goals. All discrepancy reports are coded processed and integrated into the data system by the reliability data center. Incoming data are introduced into the data system daily and mechanized computations are made weekly to determine current achieved quality levels by component and area of responsibility.

Detailed analyses of in-plant discrepancy data are made by Reliability Engineering to identify operations or processes that have repeated discrepancies. When these analyses are completed, the results are provided to the Quality Control Standards Department. This department then conducts necessary quality engineering capability studies, along with guidelines indicated by the analytic results, to pinpoint the problem areas and discrepancy causes. Based upon these studies, recommendations are made for specific corrective action, such as process change, tooling correction or special training requirements. If the state-of-the-art for production of a particular component appears to be such that corrective action cannot readily be effected, Project Engineering is called upon to make an engineering change.

All corrective actions are reviewed by Reliability Engineering and Quality Assurance to ensure that such actions have been effective. If recurring discrepancies and adverse trends indicate that the recommended changes did not achieve the desired result, further attention is concentrated in the deficient area.

Data analysis also permits an evaluation of quality control effectiveness. This is accomplished through comparison of achieved incoming quality levels with average outgoing quality levels for each inspection point. The average outgoing quality levels are computed on the basis of the number of discrepancies discovered after the applicable quality control inspection has been accomplished.

Where such comparison indicates an excessive outgoing level, quality control personnel are alerted to the condition and additional personnel are assigned, techniques are revised and, if needed, special training initiated.

To further ensure maintenance of high standards of performance among quality control personnel, a skills inventory is maintained. This inventory uses IBM cards punched with coded information concerning an individual's experience, training and other special qualifications. Periodic review of the skills inventory ensures that all personnel have been appropriately qualified for the job they are performing. This inventory also enables job assignments to be made with assurance that the individuals assigned to jobs are qualified to perform at a satisfactory level.

Manufacturing Testing

During the production stage of the aircraft, Reliability Engineering participation in testing is concentrated in the areas of manufacturing acceptance tests, production tests, and flight tests.

Manufacturing Acceptance Testing

Manufacturing acceptance testing phase consists of production item conformity investigation and follow-on acceptance testing.

After successfully passing all qualification tests, the vendor submits one of his early production articles for conformity investigation. In addition, he supplies copies of the vendor first production article conformance inspection report to substantiate his conformance to Lockheed requirements. A conformity investigation committee is responsible for conducting the complete investigation. This committee consists of representatives of quality control, affected test lab, project engineering, equipment and standards, planning, and reliability engineering.

The first run test is performed with the committee present after the article is first visually and dimensionally checked against specification documents. The preliminary manufacturing functional test procedure is checked carefully to ensure that the test fulfills the intent of the functional test requirement and that the test equipment is adequate. The written test procedure at this stage is a flexible document and changes are made as necessary throughout the first run.

Test data are maintained in log form and success or failure reports are fed back to the reliability data center where comparisons are made with data on previously used similar components. Changes are made as necessary to test procedures to more realistically and adequately simulate operational requirements. In the event of a component failure during the first run, the component is disassembled and a dimensional comparison is made against vendor blueprints with corrective action taken by the vendor as required. The manufacturing functional test procedure is then written in final form, incorporating all changes.

Acceptance Testing

Following satisfactory demonstration on production item conformity investigation, sample acceptance testing is conducted on each delivered lot. Required sample size is determined statistically by the Quality Control organization and reviewed by Reliability Engineering.

The manufacturing functional test procedure is followed strictly in all acceptance tests. Reliability Engineering is notified if any failures or performance weaknesses are encountered. In the event of an indication of reliability degradation or a deviation of production units from acceptable standards, the vendor is contacted and requested to institute immediate corrective action. If any one of the production samples tested fails to pass the acceptance tests, the entire lot is suspect, an increased number of samples is tested, and further failures may result in the rejection of the entire lot.

Reliability Engineering maintains a suspense file on all current surveillance items. Periodic review and follow-up investigations ensure continuous long-range reliability upgrading on production items.

Production Testing

Production testing is very similar to the previously discussed acceptance testing. However, it is conducted at system level rather than at the component level. It is performed on the flight line on production aircraft to the requirements of a system manufacturing functional test procedure.

Reliability Engineering reviews these test procedures to establish adequate performance investigation criteria. The first run is again monitored and the test procedure revised as necessary to assure practical follow-on testing and feedback of success or failure data to the reliability data center. Here complete failure histories at the system level are maintained and reliability trends are constantly under surveillance. As failures which may affect production system reliability are discovered, corrective action is taken immediately.

Flight Test

The flight test phase is the initial proving ground which permits preliminary evaluation of achieved reliability of the production aircraft. All systems simulated on functional mock-up are tested under actual flight conditions. In addition, systems such as the pressurization system which can be completely tested only in their operational environment are thoroughly evaluated for conformance to their requirements. Functional reliability testing is conducted on all systems in conjunction with the airworthiness evaluations scheduled early in Category I testing.

Reliability environments are checked in all systems by means of thermocouples, accelerometers, pressure gages, and other necessarily specialized instrumentation. The flight test instrumentation group assists Reliability Engineering by ensuring required data can be collected. Copies of all flight test failure data down to the component level are transmitted directly to the reliability data center.

Evaluation

Reliability calculations using data obtained from tests of production articles verify that manufacturing processes and methods do not unduly degrade the inherent design reliability. Such tests include qualification tests, reliability tests, simulated flight tests, and production and quality control functional acceptance tests. Particular emphasis is placed on the data obtained through the extensive flight test program conducted with the first production aircraft. Testing of production articles is necessarily limited by economic considerations, and while sample sizes and test durations often do not provide sufficient data for valid reliability measurements, they do permit detection of any sharp deviations in reliability from that obtained during the development phase. Previously computed values are weighed in the light of such data and modified as necessary.

Training

Reliability training is conducted for all levels of personnel with lectures on reliability concepts an integral part of training. In management, engineering, and shop skills programs, the importance of reliability and the role of the individual in achieving reliability are emphasized. The total reliability effort of Lockheed is explained, with discussion of the reliability program and the techniques and procedures necessary for its accomplishment. The contribution of each employee to end-product reliability is presented along with training in his special area of responsibility.

In addition to the standard training programs with their emphasis on reliability, representative individuals closely associated with the reliability program receive individual training in the Reliability Engineering Department. This individual training covers all the general concepts and techniques with detailed explanations tailored to his needs. The manner in which the reliability program can assist him in his job and how he can contribute to the reliability program are discussed thoroughly.

Lockheed is prepared to provide assistance and guidance for vendor personnel in the planning of training programs in the control of reliability.

OPERATIONAL USE

In compliance with the requirements of the Statement of Work and the requirements of MIL-R-26674, a measurement of achieved reliability in the operational phases will be provided. A continuous program of field surveillance, data feedback, operational analysis, and corrective action investigation is now in use on C-130 programs. Preparation for the reliability program begins in the design, manufacturing, and Category I flight test stages. Experience and technical knowledge gained during these stages directs attention to problem areas and provides maximum benefits from post-delivery performance data.

Field Surveillance and Data Feedback

Reliability engineers are assigned at operational sites to obtain success and failure data necessary to evaluate performance and initiate corrective action. In addition to the personal observations of operational usage, these engineers are responsible for the collection of maintenance data for submittal to the reliability data center for machine processing. To minimize data collection costs and to attain maximum coverage of operational data, standard Air Force maintenance records are reproduced. Over three years experience in the collection of all maintenance data on C-130 aircraft has proved that the reproduction of such records is a practical, successful method of field data collection.

In addition to the collection of the Form 26 and 781 maintenance records, detailed Lockheed service trouble reports (STR) are prepared when unusual, flight safety, or recurring serious failures occur. These reports contain detailed information concerning the conditions of failure, suspected failure causes, and recommended corrective action. These data are immediately coded and processed so that updated performance trends and failure information are readily available.

The monitoring of customer accelerated flight test programs provides advance information on operational trends and provides advance warning of areas requiring investigation and possible reliability upgrading. These data are compared with available historical data on C-130, DC-8, -707, and CV-880 aircraft, and suspected areas are highlighted in subsequent operational monitoring.

Teardown Program

Experience has shown that in spite of the valuable information derived from normal field maintenance records, additional information is often necessary—such as specific details of failure causes. Earlier data collection programs are primarily quantitative in nature and provide information necessary to ascertain whether or not performance is satisfactory, and establish trends in some areas. However, in many instances such data provide insufficient basis for constructive corrective action. The normal maintenance records do not always reflect enough information to provide the level of follow-through visualized in the forward looking reliability program proposed for System 476L. Consequently, additional failure data is required.

Reliability field representatives, whose sole responsibility is reliability improvements, provide necessary supplementary information. These representatives are assigned to observe on-site functional equipment teardowns and failure analyses and to submit results of such teardowns to the reliability data center. After a teardown analysis, each piece of equipment is returned to its pre-teardown condition and processed through normal Air Force channels. If desired, a copy of the report can accompany the discrepant items. In the event that field teardown reveals that additional analysis is necessary, the extensive facilities of Lockheed are available. When advisable, arrangements are made to have the part shipped into the Lockheed engineering research laboratory for evaluation.

The field reliability engineer is in an excellent position to investigate failures of related components and evaluate them from a standpoint of induced failures. When analysis at the data center indicates any such suspect condition, field reliability engineers for on-site investigation assist in rapid and effective corrective action. The savings from early recognition of induced failures are actually compounded. An error in design change would delay effective corrective action until after completion of design change, field incorporation, and sufficient operational use to recognize that the problem continues. Thus, valid data feedback is not only valuable in assessing the cause of failure, but provides the means to ensure that improvements have actually been achieved.

Failure Analysis

Evaluation of operational data is systematic. There are certain fundamental concepts followed in each evaluation; however, each evaluation is flexible and takes into consideration all known operational conditions and related component effects.

Analyses may be divided into any number of categories, such as:

- High failure rate investigation
- Time change span determination
- Component modification evaluation
- Vendor evaluation
- New equipment evaluation
- New model configuration study
- Sequential evaluation of system failures

In such analyses, evaluation is accomplished with the support of printouts of reduced data. All available tools of evaluation are used, including failure summaries, trends, actuarials, and other modes of data assembly.

Maximum use is made of comparison techniques, such as field versus production versus qualification test failure data. Where two vendors are used, failure rates and causes for each product are compared and evaluated. Where component configuration modifications have been made, early versus late configuration failure rates are compared.

Particular attention is given to induced failures. One faulty component can have a substantial effect on performance of other components; similarly, improvement of a discrepant item can improve operation of other units by an even greater margin. Complete system analysis is conducted to ensure that corrective action is taken on the proper unit.

Examples of failure analyses are shown in Figures 9-3 thru 9-8. On each figure, a brief statement of object and findings is shown. Each of these analyses was initiated in connection with reliability upgrading on C-130 aircraft.

C-130B A.C. GENERATOR ACTUARIAL STUDY

OBJECT:
INVESTIGATE REPORTED C-130B GENERATOR INFANT FAILURE PATTERN.

FINDINGS:
1. INFANT FAILURE PATTERN DOES NOT EXIST
2. WEAROUT - PROBABLY BRUSHES - CAUSES ABNORMAL FAILURES AFTER 400 HOURS.

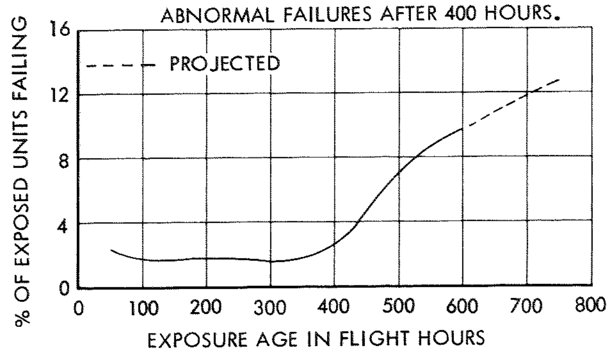


Figure 9-3—C-130B AC GENERATOR ACTUARIAL STUDY.

OBJECT: DETERMINE POTENTIAL OF BRUSHLESS GENERATORS.

FINDINGS: OPERATIONAL PERFORMANCE IS SUBSTANTIALLY BETTER THAN FOR CONVENTIONAL GENERATORS.

SUMMARY

TYPE GENERATOR	AIRCRAFT AND USAGE	TOTAL FLIGHT HOURS	AVERAGE FLIGHT HOURS PER UNSCHEDULED REPLACEMENT
BRUSHLESS	AIRLINE B-707	228,162	1,988
BRUSH	AIRLINE DC-8	59,287	1,198
BRUSH	MILITARY C-130	179,147	781

Figure 9-4—BRUSHLESS GENERATOR INVESTIGATION.

Figure 9-9 shows the close correlation of the failure pattern of electronic equipment in two models of aircraft, the F-100 and the C-130. One curve is the failure pattern of the ARC-34 transmitter-receiver unit as obtained by ARINC on a special study contract for the F-100. The other curve is derived from the Lockheed data and shows the failure pattern for the ARC-34 installed on C-130 aircraft. The failure patterns are surprisingly similar. The fact that studies with such high validity can be conducted for all components of a complete weapon system on a routine basis, without need for special data collection contracts, is of particular importance to the System 476L program.

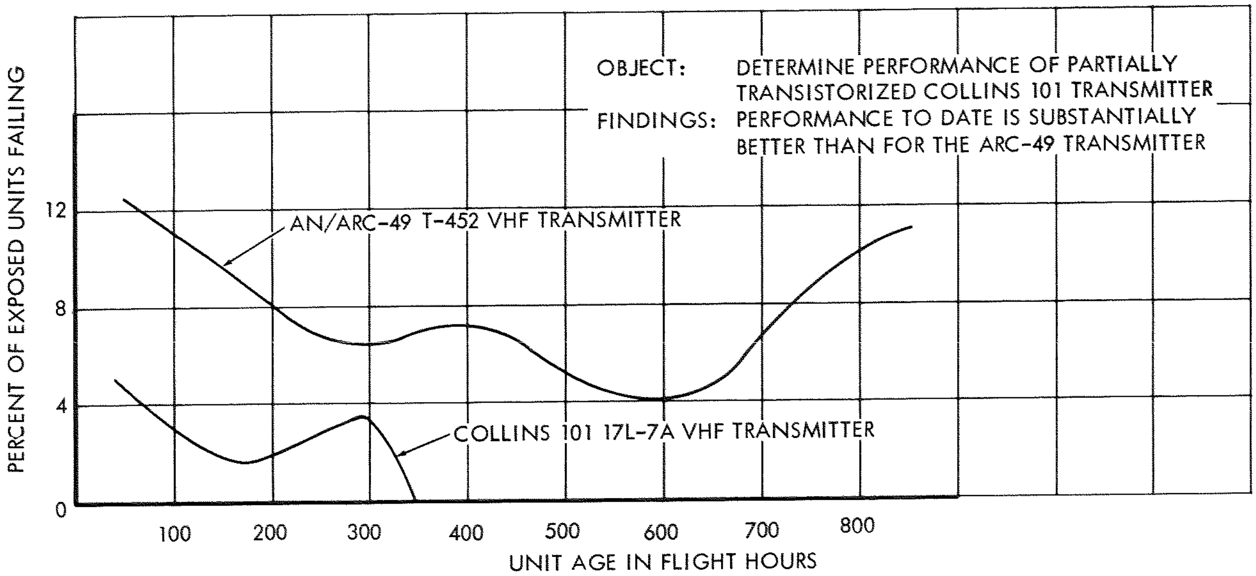


Figure 9-5—ACTUARIAL HISTORY OF TWO VHF TRANSMITTERS ON C-130 AIRCRAFT.

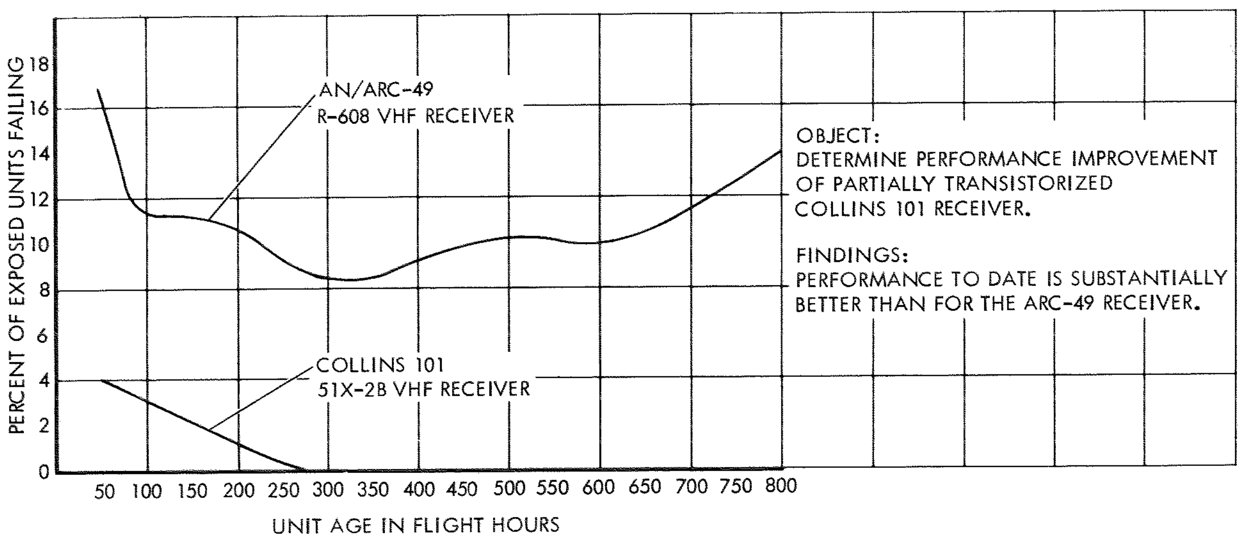


Figure 9-6—ACTUARIAL HISTORY OF TWO VHF RECEIVERS ON C-130 AIRCRAFT.

A mechanized actuarial for the ARC-34 transmitter-receiver described above is shown in Figure 9-10. The high infant failure pattern is characteristic of that found in virtually all electronic equipment using vacuum tubes and not specifically designed for high reliability.

The need for performance measurement was indicated early in the Lockheed reliability program. For example, a mean-time-to-failure of 500 hours may be good for one type of item, but extremely poor for another. Likewise, a mean-time-to-failure of 500 hours may be good for an entire system, but extremely poor for a component of a system. Recognizing the need for additional data and the recent availability of commercial aircraft records, failure data are now being exchanged with leading airlines. Figure 9-11, an excerpt taken from a recent Military-Airline Failure Data Comparison compiled by the reliability data center, reflects the type of summary data provided to staff and project engineers to assist in evaluating component and system operational performance. Upon specific request, Reliability Engineering conducts more detailed studies to provide additional information on failure causes, failure trends, or other related data in support of design considerations. Technical data exchanges with all major airlines are an integral part of the Lockheed reliability program.

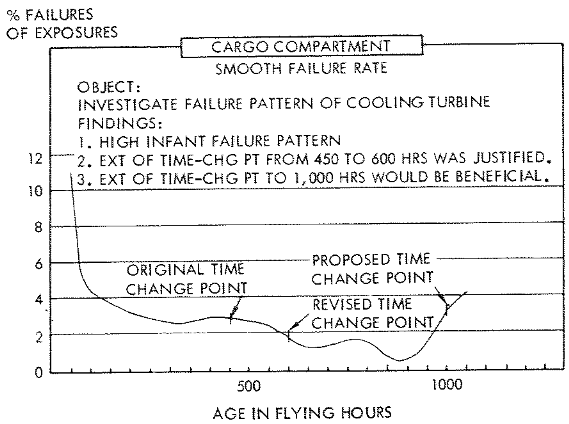


Figure 9-7—COOLING TURBINE ACTUARIAL CHART.

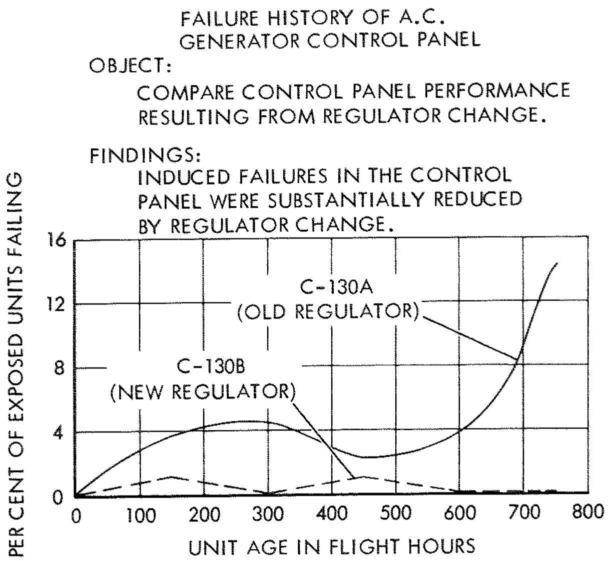


Figure 9-8—FAILURE HISTORY OF AC GENERATOR CONTROL PANEL.

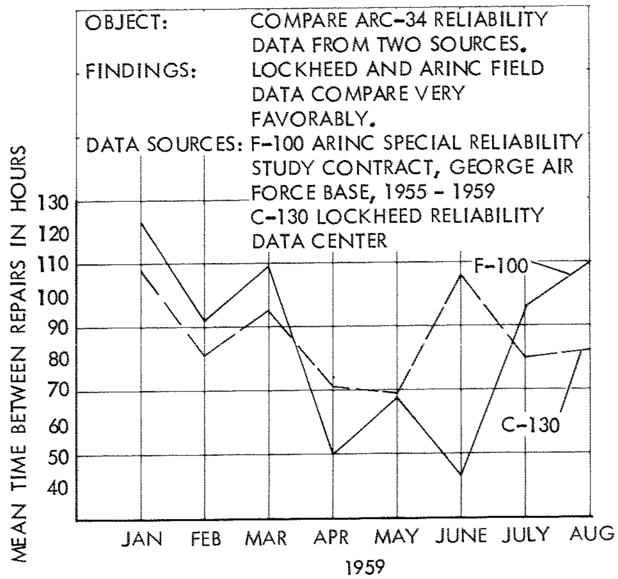


Figure 9-9—ARC-34 UHF RADIO TRANSMITTER.

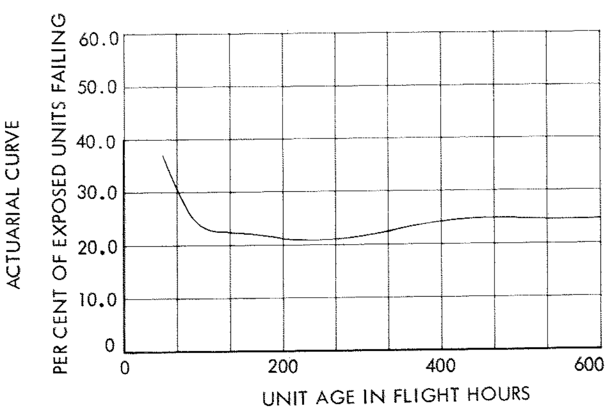


Figure 9-10—ARC-34 ACTUARIAL CHART.

Measurement and Evaluation of Achieved Reliability

Measurement and evaluation of achieved reliability is provided through the use of field failure data which allow high confidence level calculations for actual operating conditions and sufficient exposure time. Specific calendar-time points after the delivery of the first operational aircraft are established for measurement and evaluation of operational reliability.

Reliability measurement is made from the field data obtained through the feedback system. Such data includes all pertinent aircraft success and failure data for computing overall quantitative reliability. Since failures are assigned to specific cause items, reliability measurement is possible at each level of breakdown, including systems, subsystems, and major components. Achieved reliability is then computed at each level.

Achieved reliability is compared with the quantitative reliability goals established for operational use. Discrepant areas are detected by comparison at system and subsystem level. Further detailed analyses are conducted in the discrepant areas to determine the degree of reliability improvement required and to establish improvement action. Actuarial studies are used to examine failure trends and critical age points. Statistical analyses of failure types, times of failure, and similar field information provide indications of necessary action. Examination of the extensive historical data for similar or identical C-130 items also provides information as to possible improvement action. Valuable sources of information at this stage are the detailed data obtained from field teardown programs, which allow both quantitative and qualitative examination of specific failure causes and the circumstances surrounding the incidents.

When the reliability goal is achieved, field failure data continues as the basis of a continuing surveil-

LAC 5 DIGIT CODE	A.C./AIRLINE	NOMENCLATURE	UNITS PER AIRCRAFT	NO. UNSCHED. REPL.	UNIT UNSCHEDULED REPL. PER 1,000 FLT. HRS. C-130A (30 MOS.)	C-130B (12 MOS.)	DC-8 AIRLINE A 1960 (6 MOS.)	B-707 AIRLINE B 1959 (12 MOS.)	B-707 AIRLINE B 1960 (6 MOS.)
51342	C-130A	OIL TEMP. BULB	4	54	.080				
	C-130B	OIL TEMP. BULB	4	5		.087			
	AIRLINE A								
	AIRLINE B	TEMPERATURE BULB, OIL SYSTEM	4	9/8				.116	.068
51343	C-130A	OIL QUANTITY TRANSMITTER	4	132	.195				
	C-130B	OIL QUANTITY TRANSMITTER	4	46		.798			
	AIRLINE A								
	AIRLINE B	QUANTITY TANK UNIT	4	18/23				.232	.813
51344	C-130A	OIL QUANTITY INDICATOR	4	48	.071				
	C-130B	OIL QUANTITY INDICATOR	4	5		.087			
	AIRLINE A	INDICATOR OIL QUANTITY	4	37			.463		
	AIRLINE B	QUANTITY INDICATOR	4	72/78				.755	.534
51347	C-130A	OIL PRESS. TRANSMITTER ENG.	4	1,712	2.529				
	C-130B	OIL PRESS. TRANSMITTER ENG.	4	4		.069			
	AIRLINE A	TRANSMITTER OIL PRESS.	4	3			.038		
	AIRLINE B	PRESS. TRANSMITTER	4	110/66				1.419	2.333
51348	C-130A	OIL PRESS. INDICATOR	4	60	.089				
	C-130B	OIL PRESS. INDICATOR	4	0		0			
	AIRLINE A	INDICATOR OIL PRESSURE	4	6			.075		
	AIRLINE B	PRESS. INDICATOR	4	7/10				.090	.353
51361	C-130A	FUEL FLOW TRANSMITTER	4	1,225	1.810				
	C-130B	FUEL FLOW TRANSMITTER	4	26		.451			
	AIRLINE A	TRANSMITTER FUEL FLOW	4	116			1.451		
	AIRLINE B	TRANSMITTER	4	61/85				.640	.582
51362	C-130A	FUEL FLOW INDICATOR	4	113	.167				
	C-130B	FUEL FLOW INDICATOR	4	5		.087			
	AIRLINE A	INDICATOR FUEL FLOW	4	107			1.338		
	AIRLINE B	INDICATOR	4	77/222				.808	1.521
51465	C-130A	FUEL PRESSURE TRANSMITTER	1	50	.295				
	C-130B	FUEL PRESSURE TRANSMITTER	1	3		.208			
	AIRLINE A	TRANSMITTER FUEL PRESS.	4	36			.450		
	AIRLINE B	TRANSMITTER	4	79/31				1.019	1.096
51366	C-130A	FUEL PRESSURE INDICATOR	1	15	.089				
	C-130B	FUEL PRESSURE INDICATOR	1	1		.069			
	AIRLINE A	INDICATOR ENG. FUEL PRESS.	4	9			.113		
	AIRLINE B	INDICATOR	4	11/10				.117	.081

OBJECT: DETERMINE IF AIRLINE MAINTENANCE DATA CAN BE UTILIZED IN EVALUATING MILITARY COMPONENT PERFORMANCE.

FINDINGS:
1. AIRLINE DATA IS A GOOD YARDSTICK TO MILITARY PERFORMANCE
2. DIFFERENCES IN DAILY UTILIZATION NORMALLY IMPOSES NO SERIOUS PROBLEM.

Figure 9-11—MILITARY—AIRLINE DATA SUMMARY—EXCERPT.

lance program to provide further upgrading and to ensure maintenance of satisfactory aircraft reliability for those items which do not develop failure characteristics until after becoming operational. Periodic mechanized computation of field failure rates permits evaluation of aircraft performance and detection of potential reliability problems. Special surveillance is maintained for any items known to have marginal reliability and effort is directed toward upgrading such items.

Corrective Action

It is recognized that not every field problem warrants redesign or retrofit. Every field problem does, however, warrant investigation and analysis to determine degree of trouble, reason for trouble, and the most logical mode of corrective action.

Without thorough feedback data, changes could be erroneously or hastily made, based on isolated instances or unsupported desires for change. Such alterations are costly in engineering time, retrofit materials, installation costs, and aircraft down-time. GL 207-45 systems are designed for maximum performance with minimum maintenance by normally available field skill levels. In reviewing corrective action requirements, this same philosophy is considered. However, if failure analysis shows conclusively that the problem is in field maintenance techniques rather than in basic design, efforts are made through changes in maintenance handbooks to improve maintenance. Results of analytic findings are also provided to field personnel.

A very high percentage of field problems involve functional components. Since virtually all components are produced by suppliers to Lockheed, effective corrective action is dependent upon an effective vendor reliability control program. A free interchange of success and failure data is maintained and extensive efforts are made to provide vendors with a clear understanding of requirements and objectives. One of the benefits of a successful vendor selection program is that Lockheed is dealing with suppliers who fully recognize the need for reliability and have demonstrated their willingness and capability to resolve problems in a timely and acceptable manner. This direct approach to corrective action in the C-130 program has provided substantial reliability growth.

Recognition is given to the fact that many discrepancies are a result of basic operating concepts and procedures. Failure to correct these concepts and procedures means that, at best, only temporary corrective action is achieved. Diligent efforts are made to determine the basic causes of problems. Once determined, necessary changes are initiated, followed by periodic monitoring to assess the value of such changes. Application of the foregoing concepts result in compounded growth in operational reliability.

When design changes are necessary, incorporation of such changes into future production or into retrofits demand a trade-off evaluation of cost, schedule, effect on spares, effect on aircraft utilization and other operating considerations. Reliability Engineering provides information which assists in evaluating these various items and participates in design change board and enginering change proposal meetings considering these changes.

RELIABILITY MONITORING PROGRAM

General

The proposed monitoring program establishes specific points for formal review of the continuous reliability program conducted by Reliability Engineering. Each monitoring point represents a milestone in the overall reliability effort. At each point, a report is prepared summarizing the activities to that time, the results of a quantitative reliability evaluation, and the planned future activities. This report includes data collection procedures, analytic methods, and detailed test plans and specifications when applicable. When corrective action is necessary, the report also includes the specific actions taken, description of the studies conducted to develop these actions, and the expected results in reliability improvement.

The monitoring program provides periodic formal review and assessment of reliability achievements. Progressive quantitative reliability requirements are established for successive monitoring points, as derived from a projected reliability growth curve. Such a growth curve is shown in Figure 9-12 for GL 207-45, with numerical reliability goals given for each phase of the monitoring program. This growth curve is derived from current Lockheed concepts and C-130 experience. Specific values for the System 476L are subject to mutually acceptable definitions developed through contractual negotiations. At each point, the achieved and predicted reliabilities are computed from data accumulated to that time, and compared with the corresponding requirements to evaluate the degree to which satisfactory reliability is attained.

The data from which reliability measurements and predictions are made at each stage include all data accumulated from all sources, with proper screening and evaluation to verify validity. These data vary successively from experience data on C-130 and commercial aircraft, vendor data, test data obtained from all phases of the test program, and finally operational data obtained from Air Force use of the GL 207-45.

Maximum use is made of C-130 data for similar or identical GL 207-45 components and subsystems permitting reduction in the overall reliability test program. Such data also supplements test data in areas where sufficient sample sizes and test durations are not economically feasible, and provides a valid base for comparisons to measure reliability improvement or degradation early in the Support System 467L program. Such comparisons allow projection of expected operational reliability in terms of that achieved by the C-130. Since achieved operational reliability can be validly measured from operational data only, the proposed monitoring program includes points in the operational phase of the aircraft. Operational surveillance allows effective product improvement as necessary and insures proper growth of operational reliability.

Monitoring Points

Tentative monitoring points for the System 476L reliability program are outlined below, with the general time phasing of these points shown in Figure 9-12.

Effectiveness study and Initial Design Analysis

Upon completion of the effectiveness study and Air Force approval of the resulting operational reliability goal for the support system, including AGE, quantitative reliability requirements are established at major subsystem level. Concurrently, a reliability analysis of the initial design is conducted to predict expected operational reliability for the complete support system using a mathematical probability model. Quantitative evaluation is based upon these computations. Projected growth curves are then developed to describe the progressive reliability achievements expected at each stage prior to attainment of the operational reliability objective.

Basic Design Analysis

This point is identified as release of 90% of Engineering, as noted in Figure 9-12. A reliability design analysis is conducted, and predicted operational reliability for the almost-completed design is computed using a mathematical probability model. Evaluation is provided through comparison with the quantitative operational reliability requirements.

Contractor Technical Compliance Inspection

A reliability demonstration is conducted in conjunction with the CTCI to assess the system reliability readiness for operational production. The

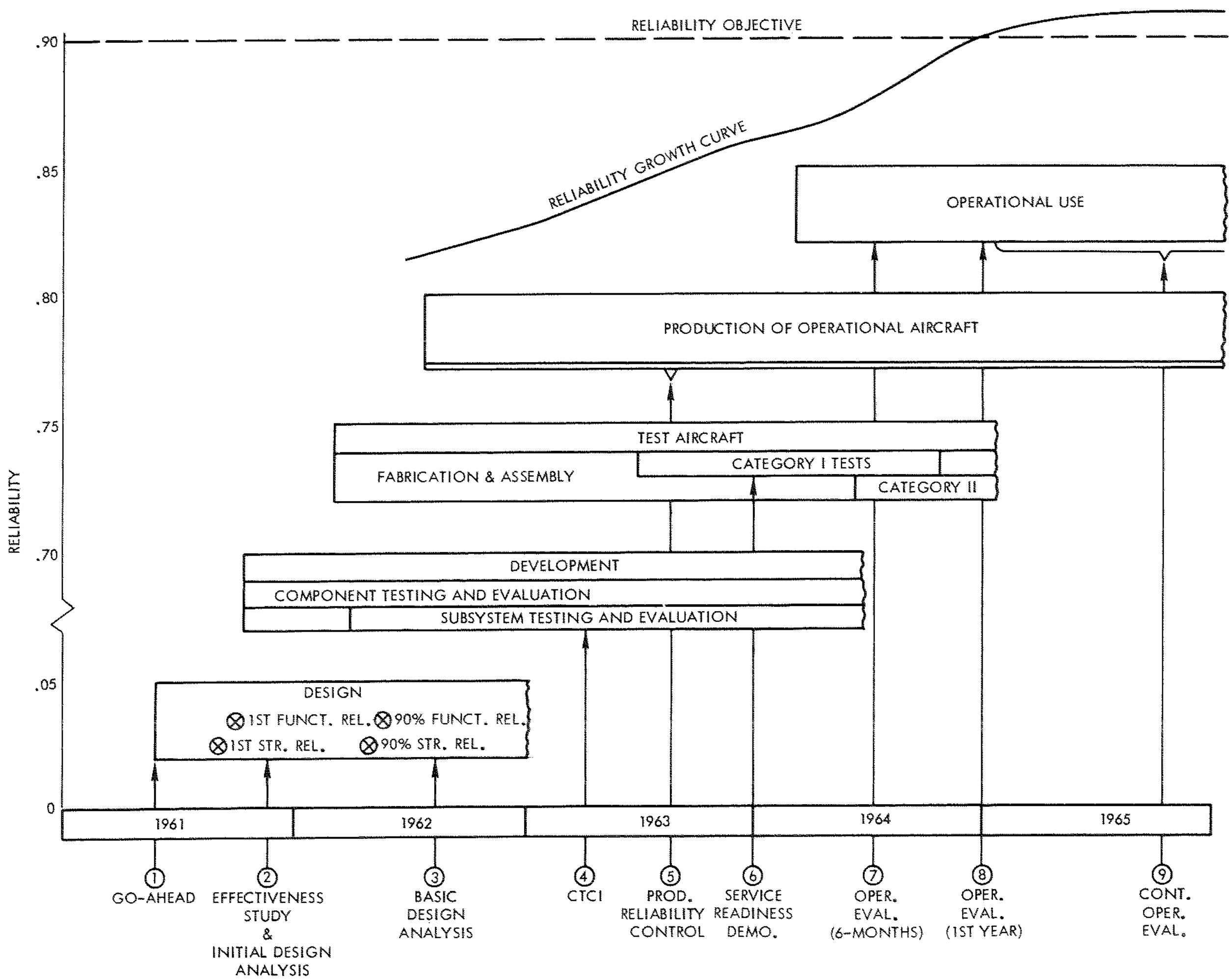


Figure 9-12—RELIABILITY GROWTH CURVE AND MONITORING POINTS.

demonstration includes physical operation of subsystems to prove functional capability, a formal presentation of reliability achievements to that time, and planned activities to assure continued reliability growth. Considerable component testing and some mock-up testing have been accomplished at this time and these data are available for evaluating achieved reliability.

Production Reliability Control

Production reliability control is a continuous process to minimize reliability degradation resulting from manufacture and is provided through the quality control program, production test program, and manufacturing reliability control program. Data accumulated through these programs are periodically surveyed by Reliability Engineering to evaluate possible effects of production discrepancies upon operational reliability. Quality control reports and special reliability reports are prepared as required.

Service Readiness Demonstration

A formal demonstration of support system reliability-readiness for operational use is made following completion of the first half of Category I testing and corresponds approximately to delivery of the first operational aircraft. This demonstration consists of a report detailing test results and achieved reliabilities with complete quantitative evaluation and reliability growth expectations.

Operational Evaluation (Six Months)

At the end of the first six months of Air Force use of operational aircraft, reliability evaluation is conducted with data accumulated through the feedback system, including Category I, II, and III test data. A report is submitted to the Air Force listing achieved reliability and the degree to which the reliability goal has been attained with expected improvements shown.

Operational Evaluation (One Year)

A similar evaluation is conducted at the end of the first year of field operation and a report is submitted. It is anticipated that the operational reliability objective will be achieved at this point.

Continuous Operational Evaluation

Operational surveillance and reliability evaluation continues beyond the first year, with continuous monitoring of field performance. Reports in summary form are prepared periodically to assess reliability achievement and product improvements. This is a normal reliability function now being conducted on C-130 aircraft. Reports are completely mechanized and are routinely produced on a scheduled basis from latest operational data.

MATHEMATICAL AND STATISTICAL ANALYSIS

General

Mathematical analytic methods are extensively applied in support of the reliability program. This allows quantitative standards and measurements as a basis for reliability evaluation and control, and a statistical analysis of data provides guidelines for corrective action.

Quantitative Reliability Requirements

Quantitative reliability requirements are established as standards by which reliability achievement can be evaluated and by which attention can be focused on areas where improvement is required. The method used is an adaptation of the method recommended by Task Group One, AGREE Airborne system requirements are established at successive levels of major and minor subsystems and components. The total aircraft reliability goal is thus allocated to individual items, allowing early evaluation of such items before assembly into a complete system.

Requirement figures are in the form of mean-time-to-failure (MTF). A basic assumption in the requirement process is that failure rates are constant with respect to operating time. Analysis of C-130 data disclosed that this assumption is not completely valid for many individual items. However, the assumption does provide a valid basis for the establishment of reliability requirements for fleet operation of a large number of aircraft over an extended period of time. MTF then becomes the average operating time between failures for many identical items over a long period of time, and this is the numerical standard by which reliability is evaluated. With a constant failure rate, mathematical reliability computations are expressed by the exponential equation $R = e \frac{-t}{m}$, where t is the time of operation and m is MTF. The time of operation used in the requirements process is the expected time of flight of a typical aircraft mission, which is taken to be five hours for the GL 207-45.

An overall aircraft reliability requirement is established by an Air Force specification or derived from a system effectiveness study. This probability requirement is transformed into an allowable number of failures per million aircraft hours (fpmh) as a standard for fleet operation. The allowable fpmh is computed by substituting required reliability and expected time per flight into the exponential reliability equation, and by solving for m = mean time to failure (MTF). When the required value of m is obtained, the fpmh is computed by the relation $\text{fpmh} = \frac{1{,}000{,}000}{m}$

The allowable failures are then allocated successively to sublevels of major subsystems, minor subsystems, and major components. This is accomplished through assignment of comparative risk to each item at successive sublevels through the use of complexity and importance factors. It is assumed that the rate of failure of an item is proportional to its complexity and that the allowable failure rate is limited by the importance of the item to mission success.

A comparative numerical complexity factor is assigned to each item as its proportion of the total complexity of the given sublevel. This is based on an analysis of design and function with consideration being given to the number of parts or components present, unusual environmental conditions, etc. Importance factors are computed quantitatively from C-130 data, as the ratio of inflight aborts to the total number of inflight discrepancies of an item. This objective approach has been adopted to minimize reliance on judgment and to reduce errors. In the few cases in which an item of GL 207-45 equipment is completely different from any C-130 item, importance factors are assigned following analysis of failure effects of the item. Subsequently they are converted to "unimportance" since failures are actually allocated on the basis of relative unimportance.

When complexity and unimportance factors are assigned to all items, the allowable aircraft failures (fpmh) are divided into two categories: failures allowable due to complexity and failures allowable due to unimportance.

For the GL 207-45, this division was accomplished as a 75:25 ratio of complexity to unimportance. The failures in each category are then simply allocated to the first sublevel on the basis of the proportional factors for the related items. The total fpmh figure assigned to each major subsystem is then converted to MTF through use of the exponential equation, and the required MTF is established. This process continues through each sublevel down to the component level.

The allocation of failures to sublevels within the two categories is on a direct proportional basis when items within the sublevel are all in reliability series; i.e., all items are required to operate properly for the complete flight. Analysis includes the construction of reliability block diagrams of the complete aircraft and all systems and subsystems down to component level, displaying the relationships of all items and the contribution of each to the total operation.

When a reliability parallel exists, i.e., redundant items perform the same function; failure of an individual item does not result in loss of the given function. Thus, the total number of failures of the individual items may be greater than the resulting number of function failures. When this occurs, failures are allocated to the function rather than the individual items by the same process described above. Probability equations which express function reliability in terms of the reliabilities of the redundant items are then solved, using the assigned complexity and unimportance factors for the individual items to determine the requirement for each item. As an illustration, consider the following example:

Suppose that two items are completely redundant for the performance of a given function. The function reliability is given by the equation $R = 1 - Q_1 \cdot Q_2$, where $Q_1 =$ unreliability of the first item and $Q_2 =$ unreliability of the second item. Failures are initially allocated to the function as fpmh for complexity and fpmh for unimportance, and each is converted to a reliability figure. Suppose that the two items have comparative complexity factors in the ratio 70:30, complexity failures are then allocated to the redundant items as follows. Let $R_c =$ function complexity reliability, $Q_{1c} =$ complexity unreliability for the first item, and $Q_{2c} =$ complexity unreliability for the second item. Next, let $Q_{1c} = 0.7x$ and $Q_{2c} = 0.3x$. Then $R_c = 1 - (0.7x)(0.3x) = 1 - 0.21x^2$. Since R_c is known, this equation is solved for X, and in turn, Q_{1c} and Q_{2c} are computed. The complexity MTF's for the items are then obtained by solving the equations $Q_{1c} = 1 - e^{\frac{-t}{m_1}}$ and $Q_{2c} = 1 - e^{\frac{-t}{m_2}}$ for m_1 and m_2. These are converted to complexity fpmh, which are added to the allowable unimportance fpmh computed in a similar manner to solve for the total allowable fpmh for each redundant item.

This technique is applied in all cases of redundancy, with the equations altered as dictated by the number of items, the degree of redundancy, etc. This approach may result in the allocation of more total failures to the individual redundant items than are allowed a function. Due to the redundance, however, all item failures do not constitute function failures, and total allowable failures remain the same. If the complexity factors or the unimportance factors are identical for redundant items, they may be ignored in solving the probability equations.

The establishment of quantitative reliability requirements for all levels of a complete airborne system is a recent innovation to aircraft reliability control applied to the C-130A and C-130B aircraft. Initial figures may require revision when data becomes available to support reliability evaluation, as some items will prove to be better than expected and others not as good as expected. When data become available, the requirements are re-examined and trade-offs are made, to give a more realistic allocation of allowable failures. This updating of requirements is a continuing process and provides current standards closely correlated with actual performance. In this updating, the overall aircraft reliability requirement remains the same; only the allocation among the various sublevels is modified. GFE receives the same reliability evaluation as contractor-furnished equipment, and Lockheed cooperates closely with the Air Force in upgrading any items which may be marginal. An example in this area is the AN/APN-59 Search Radar System, which initially experienced an excessive failure rate in the C-130 aircraft. Substantial improvements were incorporated as the result of negotiations between the Air Force, Lockheed and the manufacturer.

Reliability requirements are phased with the reliability monitoring program, and progressive requirement figures are established for each monitoring point, as determined by the projected reliability growth curves for the GL 207-45.

Predictions and Measurements

Quantitative predictions and measurements of achieved reliability are computed from available success and failure data at each major stage in the development, manufacture, and operation of the airborne system. Efficient application of prediction methods is made possible by a complete mechanization of the processes. These calculations, when combined with the quantitative requirements, provide the basis for reliability evaluation of the complete aircraft and all sublevels. Measurement of achieved reliability determines the extent to which goals have been achieved.

Reliability predictions for the complete airborne system are computed at certain specified intervals to facilitate periodic reliability evaluation. All predictions are directed toward operational reliability under field conditions. Precise definitions of success and failure, which can be correlated with actual performance data, are necessary. Lockheed has chosen to define reliability as the probability of 100% successful mission accomplishment, with failure defined as any malfunction which could degrade mission success. This strict requirement results in conservative reliability measurement and provides a broad base for reliability evaluation, resulting in a reliability figure which is actually an effectiveness index. These failure criteria allow detection of discrepant areas which would not be possible with more limited approaches such as abort criteria. Abort criteria are so limited in their objective that they do not serve to point out areas in need of corrective action. The C-130 airplane, for example, has achieved operational reliability in excess of 97% based on unedited recorded abort data.

Reliability measurement and prediction also requires precise definition of operating times and operating conditions. Operating time is defined in terms of flight time for a given mission, which for general studies is taken as a normal flight profile, with necessary alterations for special missions or aircraft configurations. The estimated flight time for the GL 207-45 for a normal mission of a 2250-nautical-mile range at 450 knots average speed is 5.0 hours, and this figure is used in all preliminary reliability calculations. This average flight time is taken as the operating time for all items, disregarding actual energized time of components and subsystems which do not operate continually on the entire flight. This equates all calculations to the same base and allows use of aircraft flight time for computations of actual operational reliabilities. True measures of the performance of individual items require recognition of energized time, which is unknown for the majority of items under field conditions. However, since both requirement and predictions figures from field data are based on the same criteria, comparisons for evaluation purposes are valid.

Operating conditions are disregarded when computing actual achieved aircraft reliability from operational data, since the failure data reflects the effect of the operational evironment. For predictions from experience data for the C-130, airline data, test data, and data from other sources, the actual environmental conditions under which the data were collected are specified. These are compared with the environmental conditions expected for like items for the GL 207-45, to determine the degree to which reliability predictions should be upgraded or downgraded. Environmental effects are derived from environmental tests and instrumented flight tests.

The prediction and measurement techniques used are varied, as necessary, to provide the most valid results depending upon the quantity, source, and type of data available. The reliability measure used is mean-time-to-failure (MTF), which is defined as the arithmetic mean of the experienced failure times for a given item. In practice, the best estimate of MTF is computed from incomplete life data as the ratio of the total flight hours to total failures. The corresponding reliability is computed from the exponential survival function, $R = e \frac{-t}{m}$. Use of the exponential presupposes a constant failure rate, which is not a valid assumption for all aircraft components. Extensive C-130 data show that no single theoretical mathematical model suitably describes all failure patterns. The exponential equation, however, provides a valid basis for evaluating the performance of a number of identical aircraft for extended periods of time and is equivalent to using comparative failure rates as a reliability measure. MTF then is used for all calculations from operational experience data. This approach is also used for test data when it is sufficient to establish valid MTF measures.

When the quantity of test data is limited, or the test time span is insufficient to allow true life measures, then more discerning methods are used. These include methods discrete calculations of reliability from attribute data (go, no-go) as the ratio of successes to total trials, and calculations from variable data using tabulated distributions of pertinent parameters. From variable data, mean values and standard deviations are computed. Reliability is then determined through comparison of distribution limits with specified operating requirements, including performance parameters, environmental levels, and stress levels. Actuarial studies are used to detect failure trends and project expected failure rates to extended intervals.

Computer programming is used to provide mechanical computation of reliability values. Computation of achieved operational reliability for the C-130 aircraft is presently accomplished quarterly as a part of the operational reliability and maintenance report produced by the IBM 705 computer. This report lists achieved MTF's at subsystem level, with mechanical comparisons of achieved levels with corresponding requirements. For the GL 207-45, computer programming includes a mathematical reliability model consisting of probability equations, which express complete system reliability, as the proper combination of subsystem and component reliabilities. Mechanical computation of predicted system reliability is provided by input of failure data from the reliability data center.

Failure Data Analysis

Techniques

Failure data analysis provides a valid basis for reliability surveillance and improvement action throughout the GL 207-45 program. During design stages, the extensive data available in the reliability data center permits detailed analyses of possible component and subsystem configurations, and guides design decisions. Analysis of feedback data for the GL 207-45 permits detection of marginal and unsatisfactory items and timely corrective action. Analysis of operational data also aids in the development of optimum maintenance programs and overhaul periods.

Relative failure frequencies and failure probabilities are computed from failure data for evaluation of achieved reliabilities. When improvement is necessary, guides to corrective action are developed through analysis of recurring failure types, failure modes, and failure conditions. Complete historical data are analyzed to determine failure trends and project expected future performance. Component interactions and induced failures are evaluated collation of data for complete systems and subsystems to establish the time sequence of malfunctions. Environmental effects are examined by comparison of success and failure data accumulated under varied environmental conditions.

Failure records identify all discrepancies and malfunctions to specific items, and aircraft serial accountability is maintained for operational data. Such information provides for comparative studies of the performance of differenct production lots, and close surveillance of suspected items. Similarly, comparisons are possible for given groups of aircraft, which allows analysis of the effects of varying geographical locations and operating conditions. This information also permits quantitative evaluation of the effects of configuration modifications, changes in production processes, and the performance of different vendors.

In all data analyses, both mathematical and engineering approaches are used to give thorough coverage of all reliability considerations. Mathematical analysts and reliability engineers collaborate in teams with mathematical treatment of failure data and reliability parameters combined with the application of appropriate statistical methods to provide for quantitative evaluations to guide engineering. Qualitative engineering analyses relate statistical results to physical situations and equipment design. Engineering analysis of data obtained through the proposed teardown program assists in the determination of corrective actions.

Mechanization

Data analysis is facilitated and supported by the completely mechanized processing of data. Data processing equipment within the reliability data center is used to provide listings in any format desired, and correlated data from different sources are immediately available for specialized studies. Mechanized processing actually becomes a part of the analysis procedures in that entries are automatically tabulated from masses of data during the sorting process. Several computer programs for data summaries and analyses which are directly applicable to the GL 207-45 are currently in use. These programs include the Operational Reliability and Maintenance Summary Report, Failure Mode Analysis Report, Inspection Evaluation Report, Reliability Actuarial Analysis Report, and standard statistical analyses programs such as regression analysis and analysis of variance.

The Operational Reliability and Maintenance Summary Report is produced quarterly for both the C-130A and C-130B with data extracted directly from the master tape files for these aircraft. The report lists all significant maintenance actions by type, for each component, with the following computed reliability measures: mean-time-to-maintenance-action (MTMA), mean-time-to-replacement (MT to Repl.), and MTF. At subsystem level, this report lists the required MTF and gives a comparison of the achieved MTF to the required MTF in terms of percentage. The computer program for the Summary Report makes production of the above information possible for the entire fleet of aircraft, each Air Force base, or any selected group of aircraft. An excerpt from a C-130 Summary Report appears in Figure 9-13 which shows a complete maintenance summary for the C-130A High Frequency Communication System as of September 1, 1960. It is noted that the operational MTF achieved by the subsystem substantially exceeds the requirement initially established for the C-130A.

The Failure Mode Analysis Report lists the type of malfunction reported for each component for each 50-hour log time interval, with totals for each component, major subsystem, and minor subsystem. This report provides for immediate detection of predominant failure types and their relative frequency. The log time basis provides for evaluation of the effects of aircraft age on the type of failures experienced.

Reliability Actuarial Analysis Report

The actuarial analysis is a major analytical tool in reliability evaluation and extensive application of this technique has been achieved at Lockheed. The actuarial study, adapted from Air Force T.O. 00-25-128, has been mechanized and is currently applied at component level for the C-130A and C-130B aircraft. The actuarial computer program extracts data directly from the master tape file and produces a table of failure rates and a life curve. The actuarial life curve for a particular item gives the pattern of failures on an age basis, showing infant failure periods and wear-out failure periods.

An actuarial curve produced by the IBM 705 for a C-130 component appears in Figure 9-14; the corresponding actuarial table is shown in Figure 9-15.

OPR 62-381 C-130 A RELIABILITY DATA LISTING BY SYSTEM AND COMPONENT-SUMMARY PAGE NO 84 DATE 01-SEP-60

SYSTEM CODE	COMPONENT DESCRIPTION	UNSC-REPL FLT	UNSC-REPL TOTL	TIME REPL	REPR	ADJS	CHKS OK	SERV	OTHER MAINT	TOTAL	CURR MTMA	MT TO REPL	ACT MTF	REQD MTF	RATIO A/R
	HF COMMUNICATION SYSTEM														
	GENERAL														
	COLLINS 618S-1 LIA SYS														
61101	ANTENNA ASSEMBLY	30	98		29	27	3	6	132	289	1240	3656	11943		
61102	ANTENNA TUNER, 180L-3	43	143		45	16	1		62	267	1342	2506	8332		
61103	ANTENNA MAST	11	83		16	2	6		468	575	623	4317	32572		
61104	ANTENNA STRAIN INSULATOR	3	37		2	3				42	8531	9684	119432		
61105	ANTENNA TENSION TAKE-UP		7		2	1			7	17	21076	51185			
61106	RELAY	1	4		3	2	1		3	13	41342	134360	537442		
61107	TRANSCEIVER, 618S-1	255	614		157	88	84	26	234	1177	304	584	1405		
61108	CONTROL PANEL, 614C-2	3	10		17	17	1		13	58	6177	35829	119432		
61109	POWER SUPPLY, 416W-1	30	90		38	10	12		239	389	921	3981	11943		
61110	FUSE	11	41		10				2	53	13521	17478	65144		
61111	CIRCUIT BREAKER	2	84		6	4			2	96	11197	12796	537442		
61112	CRYSTAL	7	98		5	1	12		16	132	1357	1828	25592		
61113	GROUND STRAP		5			12			6	23	186936	859907			
61114	MAST BASE PLATE	1	2						6	8	44787	179147	358295		
	SUB-SYSTEM TOTAL, MINOR	397	1316		330	183	120	32	1190	3139	114	272	903	365	2.47
	COMPLETE														
61199	HF COMM SYS INSTN COMPL				3		12		2	17	10538				
	SUB-SYSTEM TOTAL, MINOR				3		12		2	17	10538				
	SUB-SYSTEM TOTAL, MAJOR	397	1316		333	183	132	32	1192	3156					
	SYSTEM TOTAL	397	1316		333	183	132	32	1192	3156					
	A/T OTHER MAINTENANCE BREAKDOWN														
	O REPAIR TO ATTACHING UNITS								23						
	F SEALS, GASKETS & PACKING								10						
	J PAINT								531						
	K ATTACHED ELECTRICAL CONNECTIONS								118						
	L REMVD FOR CANNIBAL								4						
	M ATTACHED TUBING CONNECTIONS								3						
	P TROUBLE SHOOT								11						
	Q REMOVE														
	R INSTALL								18						
	W REPLD AFTER CANNIBAL								5						
	MSP								17						
	SAFETY WIRING								69						

Figure 9-13—OPERATIONAL RELIABILITY AND MAINTENANCE SUMMARY—EXCERPT.

The table includes an age interval breakdown, the number of units exposed to each interval, the number of units which failed in each interval, and the raw "failure rate" or percent of exposures failing for each interval. Smooth failure rates obtained by applying a smoothing process to the raw rates, are also given and the computed mean actuarial life (MAL) is included for each interval. The MAL is the mean-time-to-unscheduled-replacement which would result if a time change were introduced at the end of the given age interval, as computed from actuarial failure rates. For purposes of clearer illustration, lines have been added to the graph in Figure 9-14 joining the points produced by the computer. The dotted line represents the raw failure rates and the solid line indicates smooth failure rates. Also added to the graph, is information extracted from the table: current and optimum mean-time-to-unscheduled-replacement, the recommended time-change point, and the area where exposure data are limited. The life curve obtained for this component is typical of many, with a high initial or infant failure rate decreasing into a period of random failures, with wearout apparently beginning in the neighborhood of 1,100 hours.

Actuarial studies have several important applications in a reliability control program. Probably most important is the fact that an actuarial study provides a more valid measurement of achieved reliability than MTF measurements from incomplete life data. MTF figures are subject to wide fluctuations until the exposure time of individual units is sufficiently high. This is a serious shortcoming when measuring from early operational data, since aircraft exposure is a limiting factor. Actuarials, however, are completely valid for the age periods covered by the data. Early portions of life curves can thus be used to detect trends in failure patterns and to project these patterns to extended age periods based on past experience with similar components.

Another important use of actuarials is for use in determining optimum scheduled overhaul periods. Optimum points for scheduled replacement and overhaul depend upon failure patterns. MTF is not a valid basis for determining such points, as illustrated in Figure 9-16 which shows actuarial curves and MTF's with optimum time-change points indicated for two different components. The actuarial computer program includes formulas developed by Lockheed Reliability Engineering, to compute the optimum overhaul period.

Actuarial curves also point out critical age points where failure rates increase to unacceptable levels. Analysis of such peaks and types of failures aids

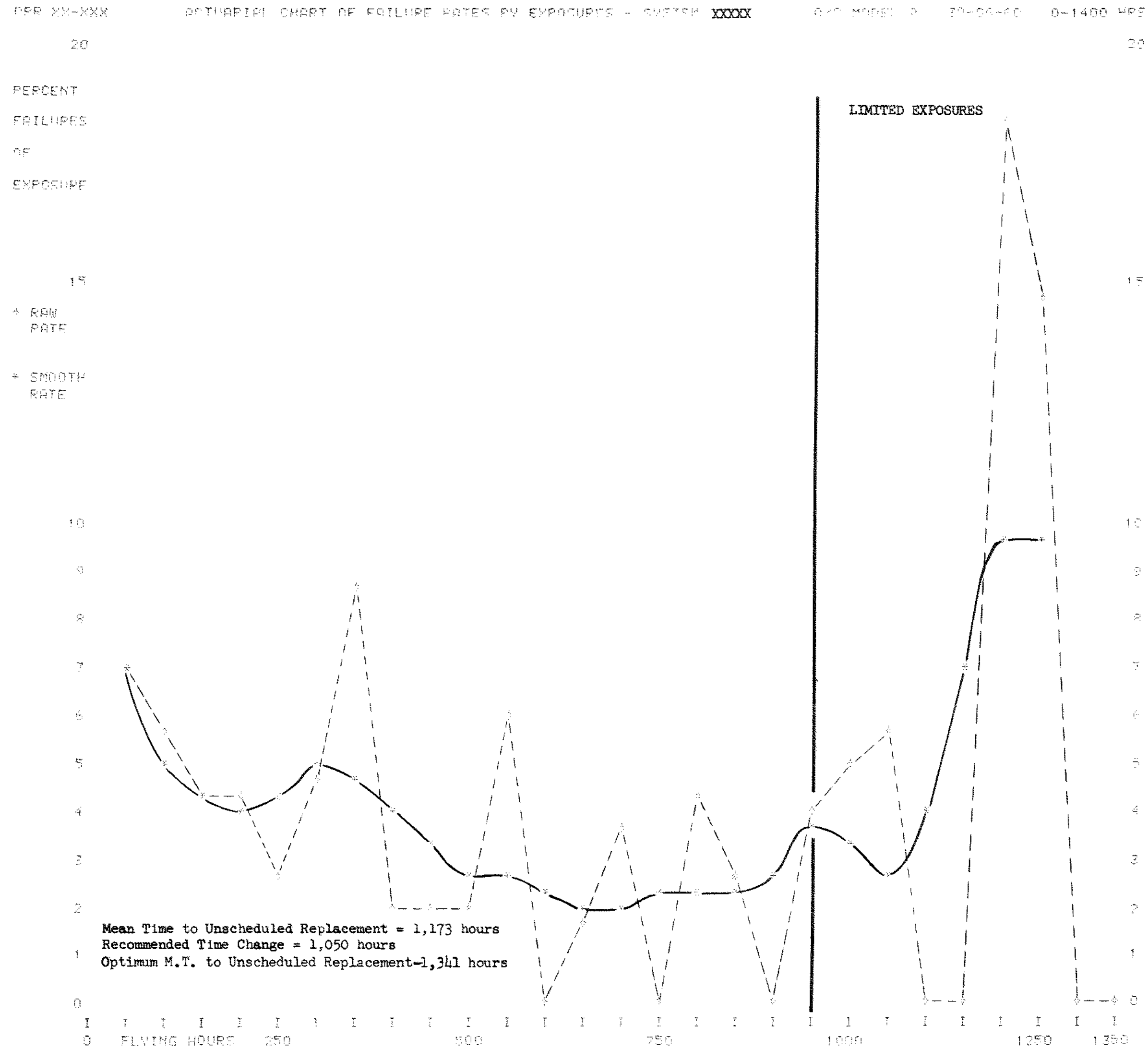


Figure 9-14—MACHINE DERIVED ACTUARIAL GRAPH.

in developing appropriate corrective actions. Analysis of failure types on an age basis permits detailed evaluation of design for possible weaknesses which develop at extended ages. Techniques are being developed for application at subsystem and system levels to point out weaknesses due to component interactions and to detect critical age points. A similar approach is being developed to establish optimum maintenance cycles.

Mechanized actuarials have been produced for all items that can be individually identified. Appropriate procedures have been established for the GL 207-45 to provide complete actuarial coverage. The available C-130 actuarials provide a valuable aid in the GL 207-45 reliability program, since many components on the two aircraft are identical or similar.

Maintenance and Logistic Support

Maintenance requirements are a major consideration in overall reliability evaluation and are included in the extensive C-130 data available. A similar maintenance operational data collection system is proposed for the GL 207-45. Analysis of maintenance requirements are performed as a part of the evaluation of specific items: Mean-time-to-maintenance-action (MTMA) and mean-time-for-repair (MTR) are measurements used in these evaluations. Analysis of maintenance data also aids in developing optimum inspection periods and in establishing overhaul periods for specific items of equipment.

The mechanized Inspection Evaluation Report is designed to evaluate the effectiveness of scheduled inspections. This report lists the number of discrepancies discovered during each scheduled inspection at component level by 50-hour log-time intervals. Each inspection category is shown, including the manhours required to conduct the inspection and to correct the discrepancies. Also shown is the

DPR XX-XXX ACTUARIAL STUDY - SYSTEM XXXXX A/C MODEL A 30-06-60

FLYING HOURS	EXPOSURES	FAILURES	RAW FR	SMOOTH FR	MAL
- 50	262.01	18	.0686	.0696	703.9
50 - 100	217.13	12	.0552	.0514	803.9
100 - 150	181.72	8	.0440	.0438	891.9
150 - 200	162.83	7	.0429	.0408	939.6
200 - 250	144.84	4	.0276	.0444	965.3
250 - 300	131.18	6	.0457	.0490	969.7
300 - 350	116.24	10	.0860	.0466	978.8
350 - 400	103.42	2	.0193	.0401	999.7
400 - 450	98.09	2	.0203	.0327	1031.7
450 - 500	92.44	2	.0216	.0264	1071.2
500 - 550	83.99	5	.0595	.0256	1107.8
550 - 600	72.08		.0000	.0239	1143.5
600 - 650	65.83	1	.0151	.0191	1184.6
650 - 700	55.43	2	.0360	.0195	1222.0
700 - 750	48.50		.0000	.0224	1251.7
750 - 800	45.10	2	.0443	.0237	1276.7
800 - 850	36.58	1	.0273	.0218	1302.8
850 - 900	28.76		.0000	.0268	1319.5
900 - 950	25.54	1	.0391	.0355	1322.0
950 - 1000	20.14	1	.0496	.0320	1329.9
1000 - 1050	18.00	1	.0555	.0273	1341.3
1050 - 1100	16.81		.0000	.0407	1336.3
1100 - 1150	12.49		.0000	.0711	1298.8
1150 - 1200	10.82	2	.1848	.0976	1243.7
1200 - 1250	6.84	1	.1461	.0954	1201.6
1250 - 1300	4.78		.0000		
1300 - 1350	2.64		.0000		
1350 - 1400	.70		.0000		
TOTAL	2064.92	88			

OPTIMUM MEAN ACTUARIAL LIFE

FLYING HOURS	MAL
1010	1321.4
1020	1334.0
1030	1336.6
1040	1339.1
1050	1341.3
1060	1340.4
1070	1339.6
1080	1338.7
1090	1337.9

A/C INVOLVED IN THIS SYSTEM 150
A/C WITH NO ACTIVITY THIS SYSTEM 45
MEAN TIME TO UNSCHED REPL 11[illegible]

TABLE 2

Figure 9-15—MACHINE DERIVED ACTUARIAL CHART.

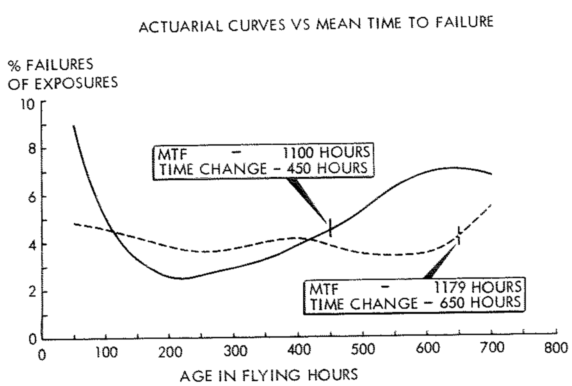


Figure 9-16—MEAN-TIME-TO-FAILURE VERSUS ACTUARIAL LIFE CHART.

number of discrepancies discovered between scheduled inspections, with manhours necessary to effect correction. The above figures are totaled at subsystem level. This listing permits evaluation of scheduled inspections in terms of manhours consumed as compared to percentage of total discrepancies discovered. This information, available for the C-130, is utilized to establish recommended inspection cycles for the GL 207-45.

Operational maintenance data are also used by Reliability Engineering to provide logistic support recommendations. Reliability Engineering currently provides replacement-rate figures at component level for C-130 spares determination. Existing C-130 data provides valuable information for computing spares requirements for the System 476L until operational data are developed for that system. Spares procurement based on detailed and complete experience data can result in substantial reduction of logistical expenditures. The variety of aircraft configurations, geographical locations, and mission assignments which are identified for C-130 data provide for differentiation of spares requirements for any of these criteria. The same basic approach is applied to determine fly-away kit composition for specific aircraft and operations.

THE RELIABILITY DATA CENTER

To provide a completely integrated approach to the collection and utilization of reliability data, Lockheed has centralized all reliability records in the reliability data center as shown in Figure 9-17. Experience has shown that there are a number of advantages to such an approach. All data are processed immediately, completely coordinated, and processed more efficiently. The centralized handling of data permits complete mechanization, provides for greatly accelerated development of data reduction techniques, and provides a central source of information.

Information Sources

Data are received from numerous sources and may be generally broken into four categories: manufacturing discrepancy data, test data, incoming quality data, and operational data. A brief description of each follows:

1 A report of every discrepancy occurring in the Georgia Division is maintained in the data center. These data include operational discrepancies during functional test of components and a report of all non-conforming parts processes, tool designs, drawing procedures, or techniques.

2 Test data are obtained both by variables and attributes on all tests conducted by vendors and subcontractors as well as tests conducted in-plant. Included are detailed data on design development, qualification, functional, acceptance, production, reliability, and system mock-up tests.

3 Incoming quality records are obtained on all material received from sources outside of the Georgia Division.

4 Operational data are obtained both from in-plant operation such as engineering and production flight testing and from military and commercial customers. Operational data from in-plant operation are obtained through flight reports and discrepancy reports.

   Operational data on military aircraft are obtained directly from operational maintenance forms such as Air Force 781A and the 26 series forms and Navy FUR and EFUR forms. These forms, which are reproduced and transmitted to the data center for processing, provide complete coverage of all operational experience.

Supporting data are obtained from service trouble reports on problems considered worthy of special attention, and from field service spotlight reports covering surveys requested by in-plant organizations. Air Force unsatisfactory reports are given priority handling.

Operational data on commercial aircraft are obtained from several sources. On Georgia Division aircraft, maintenance data are obtained from forms furnished to the customer which provide complete coverage of significant maintenance, and from ATA and FAA sources. In addition, the Georgia Division, by reciprocal agreement, obtains maintenance reports on aircraft comparable to the C-130 and GL 207-45 from a number of airlines. These data are particularly significant from the standpoint of furnishing information on components common to the C-130 and GL 207-45 under conditions which are similar to MATS operation. It also furnishes data including rate information on components and system configurations which may be considered for use in the GL 207-45 aircraft.

Data Processing

All data on Georgia Division products are coded and placed on punched cards. After processing, the original documents are filed by ship serial and by date for ready reference.

Supporting documents such as service trouble reports, unsatisfactory reports, and spotlight reports are filed under a component code number by date. All supporting data which cover multiple items and cannot be filed by component code are easily located

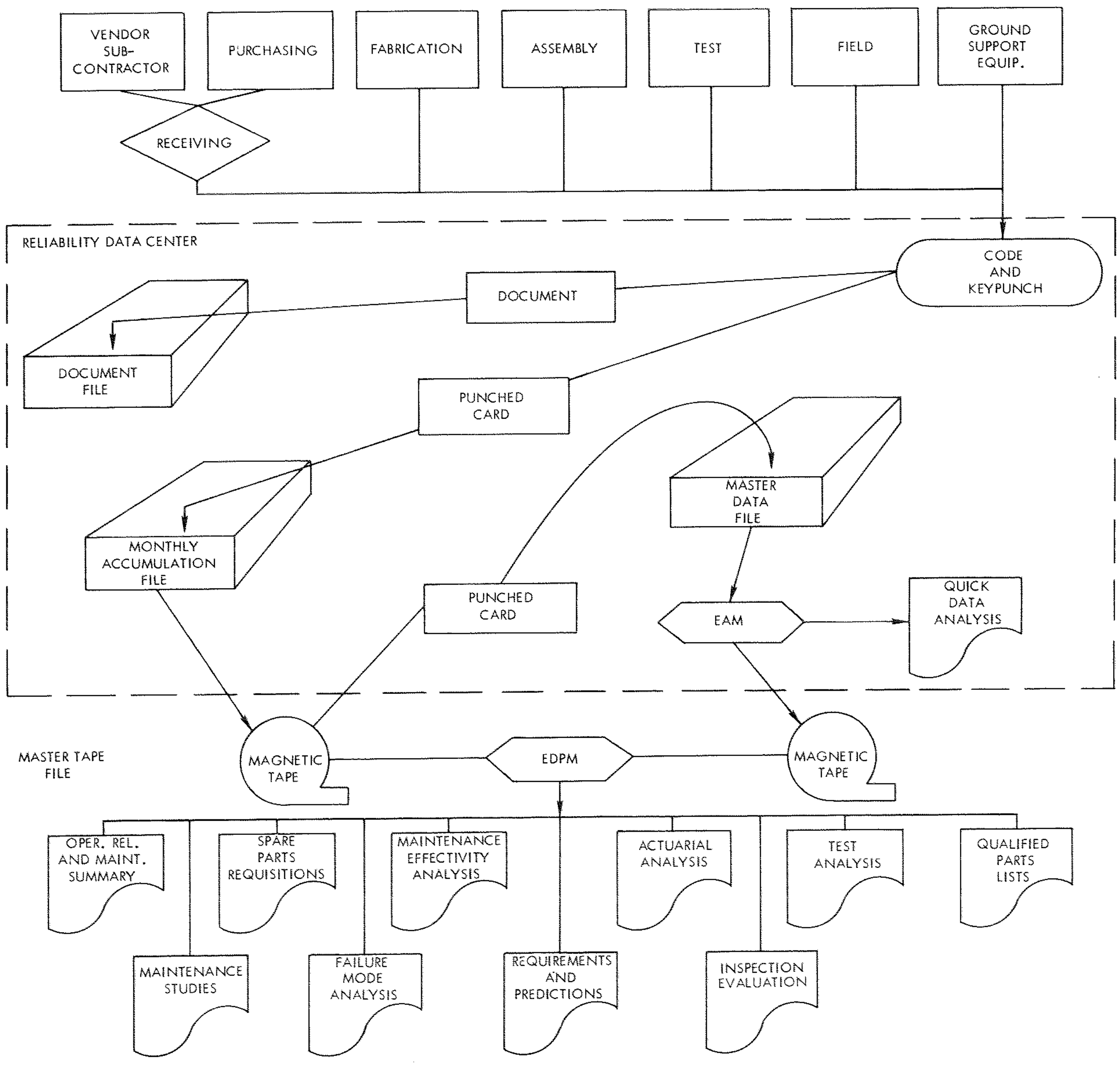


Figure 9-17—RELIABILITY DATA FLOW DIAGRAM.

by a mechanized data retrieval system. The retrieval system cards are filed by component code, and multiple cards are generated by documents covering multiple components.

Coding of the data is accomplished by former flight line supervisory personnel with both Lockheed and Air Force experience.

The data are coded in sufficient detail to permit all information to be extracted for analysis. Data are analyzed by sequence of occurrence of discrepancies, operating base frequency, variation of configuration within a model, aircraft area, malfunction type and similar criteria. All data processing follows the procedures of AFM 66-1, T.O. 00-20A-1, T.O. 00-35D-54.

Coded data are subject to several audits before being transcribed to master tape records. The majority of the audits are mechanized and exception lists are compiled from those reports in which incompatible information is contained. These exception lists define the incompatible information and permit rapid correction of the data.

The data center records currently contain a record of three years operational history on C-130 series aircraft and a one year history of all in-plant discrepancy documents.

Data Reduction

Reduction of data is accomplished both by simple programs for EAM equipment and by IBM 7090 and 705 computers. The major requirement of the data center equipment is its use as an analysis tool. It is used to segregate data into various statistically significant formats and to provide printed listings for detailed analyses. All phases of new computer programs are worked out originally using the departmental equipment. This practice has considerably decreased computer programming time.

Reliability data center personnel have been responsible for the initial development of a number of computer programs now in use and have assisted in their programming.

Typical computer programs are derived from a single master tape. Additional reports, equivalent in usefulness, may be derived from the master tape by simple patch programming. Several additional computer programs, including mechanization of requirements and prediction analyses, are presently under study and will be programmed in the near future.

Utilization of Data

Considerable emphasis is placed on the use of the data to define potential problem areas prior to trouble developing. Where the data have become available too late to be used as a preventive means, they are used to determine practical, economical corrective action. Emphasis is placed on the use of the data to support design so as to ensure maximum practical reliability, maintainability, supportability and economy.

RELIABILITY CALCULATIONS

A preliminary reliability design evaluation has been conducted for the GL 207-45 based on the proposed design. This evaluation consists of three phases: (1) assignment of quantitative reliability requirements to the subsystem level; (2) prediction of expected operational reliability from subsystem level up, based on C-130 historical failure data available for items similar to those of the GL 207-45 aircraft; and (3) comparison of required and predicted values at subsystem level to detect potential reliability problems.

The results of the analyses' requirements, and prediction calculations are shown for the hydraulic power supply system. The analyses of this system meet the requirements of Paragraph 5.1.5.7.1 of the Statement of Work.

For the sample analyses, the hydraulic system consists of the components necessary for supplying hydraulic power and does not include components which are limited to other functional areas. Classification of such components into subsystems for reliability analyses are based on an applicability rule: "A system or subsystem is comprised of all items which would otherwise not exist if there were no requirement for the function performed by that system or subsystem." Thus, hydraulic components limited in application are assigned to the subsystems in which they function and are included in the reliability analyses of those areas.

RELIABILITY REQUIREMENTS

A quantitative reliability requirement for the complete airborne system is assigned to successively lower levels down to subsystem level on the basis of comparative complexity and importance. Lockheed has initially established an airborne system requirement of 90 percent reliability for operational GL 207-45 aircraft. This quality level is based on past experience and a quality concept described in the proposal. The required MTF's resulting from assigning of this system requirement are shown in Figures 9-18, 9-19, 9-20, 9-21, 9-22 down to minor subsystem level. The illustration which follows shows the actual calculations performed in assigning a quantitative requirement to the hydraulic power supply system.

Airborne System Requirement

The reliability requirement of 90% for the complete airborne system is converted to an allowable number

AIRBORNE SYSTEM — M_R 47, M_P 40; R = 88%

- **AIRCRAFT BASIC** — M_R 183, M_P 134; R = 96.33%
- **POWER PLANT** — M_R 230, M_P 386; R = 98.71%
- **UTILITIES** — M_R 396, M_P 267; R = 98.13%
- **COMMUNI-CATIONS** — M_R 318, M_P 303; R = 98.36%
- **NAVIGATION** — M_R 178, M_P 124; R = 96.05%

M_R = REQUIRED MEAN-TIME-TO-FAILURE NECESSARY TO REACH AIRBORNE SYSTEM REQUIREMENT OF 90%

M_P = PREDICTED MEAN-TIME-TO-FAILURE HOURS, BASED ON C-130 FAILURE EXPERIENCE

R = PREDICTED RELIABILITY FOR A 5-HOUR MISSION FOR THE MAJOR SYSTEMS AND THE AIRBORNE SYSTEM

Figure 9-18—AIRBORNE SYSTEM REQUIRED AND PREDICTED VALUES.

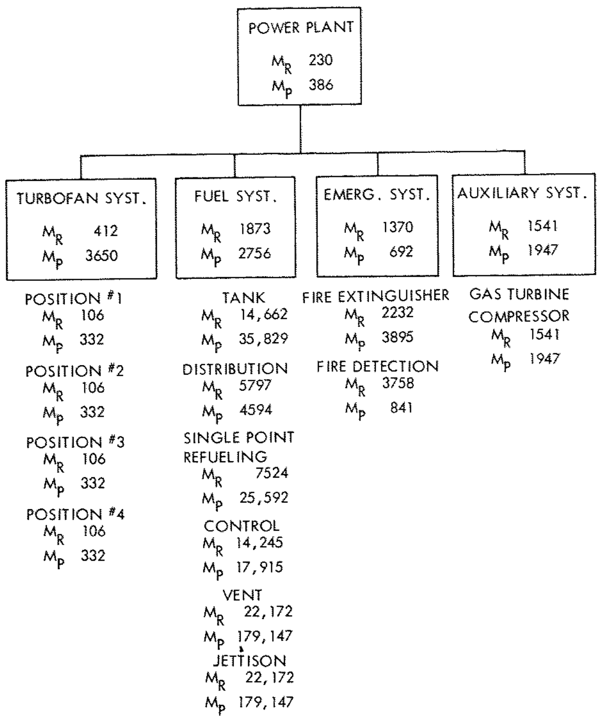
AIRCRAFT BASIC — M_R 183, M_P 134

- **AIRFRAME** — M_R 1224, M_P 618
  - PERSONNEL WARNING — M_R 58,824, M_P 179,147
  - EVACUATION & SURVIVAL — M_R 58,824, M_P 179,147
  - PYROTECHNICS — M_R 58,824, M_P 179,147
  - WINDSHIELDS & WINDOWS — M_R 4219, M_P 1810
  - HYDRAULIC DOORS — M_R 16,393, M_P 8143
  - MECHANICAL DOORS — M_R 16,129, M_P 8143
  - EMERGENCY DOORS — M_R 40,000, M_P 35,829
  - ELECTRICAL DOORS — M_R 18,519, M_P 8143
  - FUS., WINGS, PYLON EMP. — M_R 43,478, M_P 18,469
  - ANTI-ICING, DE-ICING — M_R 4739, M_P 2268
  - FURN., CARGO, FLT. DK, FUS. — M_R 13,333, M_P 6177
  - LOOSE EQUIPMENT — M_R 55,556, M_P 179,147
- **LANDING GEAR** — M_R 729, M_P 656
  - LANDING GEAR DOORS — M_R 10,000, M_P 16,286
  - MAIN GEAR — M_R 4219, M_P 2431
  - NOSE GEAR — M_R 5435, M_P 2631
  - CONTROLS — M_R 6410, M_P 179,147
  - BRAKES, ANTI-SKID — M_R 3719, M_P 2913
  - STEERING — M_R 6369, M_P 11,943
  - EXT. - RETRACTION — M_R 12,500, M_P 41,667
  - EMERG. EQUIP. — M_R 5319, M_P 15,625
- **FLIGHT CONTROLS** — M_R 306, M_P 233
  - AILERON CONTROL — M_R 7519, M_P 25,592
  - AILERON TRIM TAB — M_R 13,333, M_P 29,858
  - RUDDER CONTROL — M_R 3585, M_P 17,915
  - RUDDER TRIM TAB — M_R 8850, M_P 9529
  - ELEVATOR CONTROL — M_R 14,286, M_P 179,147
  - ELEVATOR TRIM TAB — M_R 7299, M_P 8332
  - WING FLAPS — M_R 4310, M_P 14,447
  - FLIGHT INSTRUMENTATION — M_R 1287, M_P 340
  - AUTOPILOT — M_R 2151, M_P 1066

M_R = REQUIRED MEAN-TIME-TO-FAILURE NECESSARY TO REACH AIRBORNE SYSTEM REQUIREMENT OF 90%

M_P = PREDICTED MEAN-TIME-TO-FAILURE HOURS, BASED ON C-130 FAILURE EXPERIENCE

Figure 9-19—AIRCRAFT—BASIC—REQUIRED AND PREDICTED VALUES.



M_R = REQUIRED MEAN-TIME-TO-FAILURE NECESSARY TO REACH AIRBORNE SYSTEM REQUIREMENT OF 90%

M_P = PREDICTED MEAN-TIME-TO-FAILURE HOURS, BASED ON C-130 FAILURE EXPERIENCE

Figure 9-20—POWER PLANT—REQUIRED AND PREDICTED VALUES.

of system failures per million hours (fpmh) through use of the exponential equation as follows:

$$\text{Reliability} = R = e^{\frac{-t}{m}} = 0.90$$

$$t = \text{mission time} = 5 \text{ hours}$$

$$m = \text{MTF}$$

$$m = \frac{t}{-\ln R} = \frac{5}{-\ln 0.90} = 47.45 \text{ hours}$$

$$f = \text{fpmh} = \frac{1{,}000{,}000}{m} = \frac{1{,}000{,}000}{47.45} = 21{,}075$$

The 21,075 allowable fpmh are divided into two groups—failures due to complexity and failures allowable on the basis of unimportance. An arbitrary ratio of 75:25 for complexity to unimportance is used based on experience and engineering judgment.

$$\text{Complexity failures} = f \times CR = 21{,}075 \times 0.75 = 15{,}806 \text{ fpmh}$$

$$\text{Unimportance failures} = f \times IR = 21{,}075 \times 0.25 = 5{,}269 \text{ fpmh}$$

Major System Requirements

The total airborne system consists of five major systems: aircraft basic, power plant, utilities, communications, and navigation. Allowable failures are allocated to these major systems on the basis of relative complexity and unimportance within the major system level.

A complexity ratio (CR) is assigned to each major system as the proportion of allowable complexity failures for the airborne system which are due to each major system. The complexity ratios assigned to the major systems total to 1.0 and represent 100% of the complexity failures. Importance ratios (IR) are determined objectively from historical data obtained from C-130 operation as the ratio of flight aborts to total in-flight discovered discrepancies for each system. The resulting numerical values are as follows:

Major System	C.R.	I.R.
Aircraft Basic	0.31	0.271
Powerplant	0.24	0.275
Utilities	0.10	0.160
Communications	0.10	0.096
Navigation	0.25	0.090
	1.00	0.892

Since failures are actually allocated on the basis of unimportance, the importance ratios are next converted to unimportance ratios (UR) simply by taking the reciprocals of the values given. To allocate the unimportance failures among the major systems, it is necessary to express relative unimportance as proportions which total to 1.0 or unity. This is accomplished by totaling the existing unimportance ratios and dividing this total into each ratio to give a relative unimportance ratio (RUR). The resulting numerical values are as follows:

Major System	C.R.	I.R.	U.R.	R.U.R.
Aircraft Basic	0.31	0.271	3.690	0.105
Powerplant	0.24	0.275	3.636	0.104
Utilities	0.10	0.160	6.250	0.179
Communications	0.10	0.096	10.416	0.296
Navigation	0.25	0.090	11.111	0.316
	1.00	0.892	35.103	1.000

Since all of the major systems are in series, the allowable complexity failures previously computed for the airborne system are now allocated to the major systems on a direct proportional basis given by the complexity ratios. The allowable unimportance failures are similarly allocated proportionally to the unimportance ratios. Since the concern here is with eventual allocation to the hydraulic power supply, the calculations are shown for the utilities system only.

Subsystem	M_R	M_P
UTILITIES	396	267
PNEUMATIC	2874	3039
AIR COND-FLT DECK +CARGO COMPT	3559	100,000)
PRESSURIZATION	8130	1,190,476
BLEED AIR	32,258	8143
ANTI-ICING, DE-ICING	11,062	5118
ELECTRICAL DC	2232	2013
POWER SOURCE	2801	5429
POWER CONTROL	3802	3257
POWER DISTRIB	7353	179,147
INSTRUMENTS FOR DC	5917	179,147
ELECTRICAL AC	1348	706
POWER SOURCE	2841	1597
POWER CONTROL	3922	1404
POWER DISTRIB	7463	179,147
INSTRUMENTS FOR AC	6024	12,796
LIGHTING	1812	953
EXTERIOR	4329	2804
INTERIOR	4464	2059
CONTROLS	7194	4842
HYDRAULIC POWER	7576	8065
BOOST POWER SUPPLY	1406	1445
UTILITY POWER SUPPLY	1370	1445
AUXILIARY POWER SUPPLY	1942	1982
LIQUID OXYGEN	3311	2294
FIXED	5814	2294
PORTABLE	7692	179,147

M_R = REQUIRED MEAN-TIME-TO-FAILURE NECESSARY TO REACH AIRBORNE SYSTEM REQUIREMENT OF 90%

M_P = PREDICTED MEAN-TIME-TO-FAILURE HOURS, BASED ON C-130 FAILURE EXPERIENCE

Figure 9-21—UTILITIES—REQUIRED AND PREDICTED VALUES.

Subsystem	M_R	M_P
COMMUNICATIONS	318	303
VHF COMM (2)	1642	64,935
UHF COMM (2)	1590	88,235
HF COMM (2)	2114	280,898
INTERPHONE	1325	326
PASSENGER ADDRESS	1678	14,929
SELECT CALL	2525	14,929
AUTOMATIC COMM	1634	14,929

Subsystem	M_R	M_P
NAVIGATION	178	124
WEATHER RADAR	1465	286
DOPPLER NAV & COMPUTER	3185	5598
LOW ALT RADAR ALTIMETER	2915	1493
MARKER BEACON	4676	8143
IFF COMM	2950	1493
ASTRO TRACKER	4255	3981
GLIDE SCOPE (2)	4697	996,016
ADF (DIR FIND) (2)	5405	179,147
TACAN (2)	4014	3,125,000
VOR(OMNI RANGE)(2)	2375	312,500
GYRO COMPASS (2)	3185	666,666
INERTIAL NAVIGATION	2833	1828
FLIGHT DIRECTOR	5288	11,943
NAV INSTRUM	6098	3199
RADIO COMPASS	1852	753
EMERG RADIO	5647	179,147
AUXILIARY SYS	6944	12,796
LORAN	3623	3257

M_R = REQUIRED MEAN-TIME-TO-FAILURE NECESSARY TO REACH AIRBORNE SYSTEM REQUIREMENT OF 90%

M_P = PREDICTED MEAN-TIME-TO-FAILURE HOURS, BASED ON C-130 FAILURE EXPERIENCE

Figure 9-22—COMMUNICATIONS AND NAVIGATION—REQUIRED AND PREDICTED VALUES.

Utilities complexity failures

= airborne system complexity failures × CR
= 15,806 × 0.10
= 1,581 fpmh

Utilities unimportance failures

= airborne system unimportance failures × RUR
= 5,269 × 0.179
= 943 fpmh.

Total allowable failures are thus allocated to the utilities system, and the required MTF for this system is computed as follows:

$$m = \frac{1{,}000{,}000}{\text{total fpmh}} = \frac{1{,}000{,}000}{(1{,}581 + 943)} = 396 \text{ hours}$$

The utilities system is now broken down into its constituent major subsystems, and the allocation process continues.

Major Subsystem Requirements

All of the major subsystems comprising the utilities system are in series. Complexity and unimportance factors have been assigned at this level as shown below.

Major Subsystem	C.R.	I.R.	R.U.R.
Pneumatics	0.08	0.103	0.234
Electrical, DC	0.14	0.100	0.241
Electrical, AC	0.40	0.209	0.116
Lighting	0.25	0.146	0.166
Hydraulic power supply	0.04	0.333	0.073
Oxygen	0.09	0.143	0.170
	1.00	1.034	1.000

Complexity and unimportance failures are then allocated to the hydraulic power supply as follows:

Hydraulic complexity failures

= utilities system complexity failures × CR
= 1,581 × 0.04
= 63 fpmh

Hydraulic unimportance failures

= utilities system unimportance failures × RUR
= 943 × 0.073
= 69 fpmh.

The required MTF for the hydraulic power supply is now computed.

$$m = \frac{1{,}000{,}000}{(63 + 69)} = 7{,}576 \text{ hours.}$$

Minor Subsystem Requirements

The hydraulic power supply consists of three minor subsystems: utility, auxiliary, and boost subsystems. By a similar process allowable failures are allocated to each of these subsystems. In this case, there is redundancy present, which is examined in detail in the following prediction analysis. Through the use of probability equations which describe the reliability parallels, the following MTF requirements are established for the three hydraulic subsystems.

Minor Subsystem	fpmh	MTF
Utility	660	1,370 hours
Auxiliary	515	1,942 hours
Boost	711	1,406 hours

Reliability Predictions

Preliminary reliability productions have been computed for the GL 207-45, using an appropriate mathematical model developed from a preliminary design analysis. Mathematical probability equations were derived to express reliability at successively higher levels as combinations of subsystem and component reliability values, with proper mathematical description of parallels and series present at each level. Component and subsystem failure rates were compiled from experience data available in the reliability data center, primarily C-130 operational data. Failure rates for GL 207-45 items were assigned on the basis of similarity to comparable equipment of known reliability. Component and subsystem reliabilities were computed from these failure rates by use of the exponential reliability equation, with a flight-time requirement of five hours.

With this technique, a predicted reliability of 88% is obtained for the overall GL 207-45. This predicted reliability is the probability of 100% successful mission accomplishment with no degradation for five hour flights of operational aircraft, based on C-130 experience. The results of the prediction calculations down to the subsystem level are shown as MTF's in Figures 9-18 thru 9-22, based on the assumption of production quality, personnel skills, and maintenance support levels comparable to those obtained for the C-130.

The predicted reliability of 88% developed within the framework of definitions and ground rules used by Lockheed is a very conservative measure with respect to aircraft capability. A major factor contributing to this conservatism is the definition of failure as any discrepancy which could result in mission degradation. This approach provides a broad base for reliability evaluation with proper consideration for total maintenance as well as mission effectiveness. Such a stringent definition, however, results in reliability values which do not include the capability of successful mission completion under degraded conditions.

Conservatism is also introduced through the criterion established for compiling failure rates from operational maintenance data. Component failure rates in the C-130 data are based on all replacements which result from discrepancies discovered while aircraft are in flight status, including those discovered during pre-flight inspections. This criterion is obviously conservative with respect to mission accomplishment. Approximately 30% of replacements are made as a result of incorrect troubleshooting or minor malfunctions not traced to the proper source. Of those replacements which represent true component failures, many are items which in no way affect mission accomplishment and are of a nuisance nature only. The degree of mission degradation resulting from the remaining component failures vary from minor to serious.

A specific example of the prediction techniques used with actual computations is given below for the hydraulic power supply system. Reliability equations for this system were derived from the reliability block diagram shown in Figure 9-23, which displays the functional relationships of the various components and minor subsystems, including series and parallel combinations.

A prediction analysis is the reverse of the requirements allocation process, in that reliabilities are first computed at the lowest level possible. These are combined mathematically to produce the reliability at the next higher level. The process continues upward to the complete airborne system level. This process began at component level for the hydraulic power supply and is illustrated for the boost minor subsystem.

Component Reliabilities

Redundancy is present within the boost subsystem in that there are two engine driven pumps which perform the same function, and either of these pumps is sufficient for successful operation. The two pumps with associated components provide two identical "pump groups" which are in parallel.

Each of the pump groups is composed of the six series components listed below, with predicted MTF's compiled from C-130 failure data. Also shown for each component is the resulting component reliability computed by the exponential equation with a mission time of five hours.

Components	Predicted MTF (hrs.)	Predicted Reliability
Relief Valve	33,030	$R_{RV} = 0.99985$
Engine driven pump	8,258	$R_P = 0.99939$
Filter	16,515	$R_F = 0.99969$
Pressure shut-off valve	33,030	$R_{PSV} = 0.99985$
Firewall shut-off valve	33,030	$R_{FSV} = 0.99985$
Check Valve	33,030	$R_{CV} = 0.99985$

The reliability of a single pump group is now obtained by multiplying the component reliabilities, since all components are in series.

$$\begin{aligned} R_G &= \text{reliability of pump group} \\ &= R_{RV} \cdot R_P \cdot R_F \cdot R_{PSV} \cdot R_{CV} \\ &= (0.99985)\ (0.99939)\ (0.99969)\ (0.99985) \\ &\quad (0.99985)\ (0.99985) = 0.99848 \end{aligned}$$

The reliability of the two pump groups in parallel combination is now given by the following equation:

$$\begin{aligned} R_C &= 1 - (Q_G)^2 \\ \text{where } Q_G &= 1 - R_G = 0.00152. \\ R_C &= 1 - (0.00152)^2 \\ &= 1 - 0.000002 \\ &= 0.99999 \end{aligned}$$

All of the remaining components of the boost subsystem are in series with the parallel pump combination. These components are shown below with predicted MTF's and reliabilities.

Component	Predicted MTF	Predicted Reliability
Suction pump	6,606	$R_1 = .999244$
Filter, return line (2)	27,525	$R_2 = .999819$
Accumulator	16,515	$R_3 = .999698$
Reservoir and vent	7,180	$R_4 = .999304$
Pressure relief valve	16,515	$R_5 = .999698$
Check valve	16,515	$R_6 = .999698$
Pressure transmitter and snubber	11,796	$R_7 = .999577$
Plumbing	16,515	$R_8 = .999698$

Minor Subsystem Reliabilities

The reliability of the total boost subsystem is now given by the following equation:

$$\begin{aligned} R_B &= R_C \cdot R_1 \cdot R_2{}^2 \cdot R_3 \cdot R_4 \cdot R_5 \cdot R_6 \cdot R_7 \cdot R_8 \\ &= 0.99654. \end{aligned}$$

This predicted reliability is converted to MTF as shown below:

$$\begin{aligned} MTF &= \frac{t}{-\ln R} \\ &= \frac{5}{-\ln 0.99654} = \frac{5}{0.00346} \\ &= 1{,}445 \end{aligned}$$

Similar calculations are performed for the utility and auxiliary subsystems of the hydraulic power supply. The final prediction results at minor subsystem levels are given below:

Minor Subsystem	Predicted Reliability	Predicted MTF (hrs.)
Boost	0.99654	1,445
Utility	0.99654	1,445
Auxiliary	0.99748	1,982

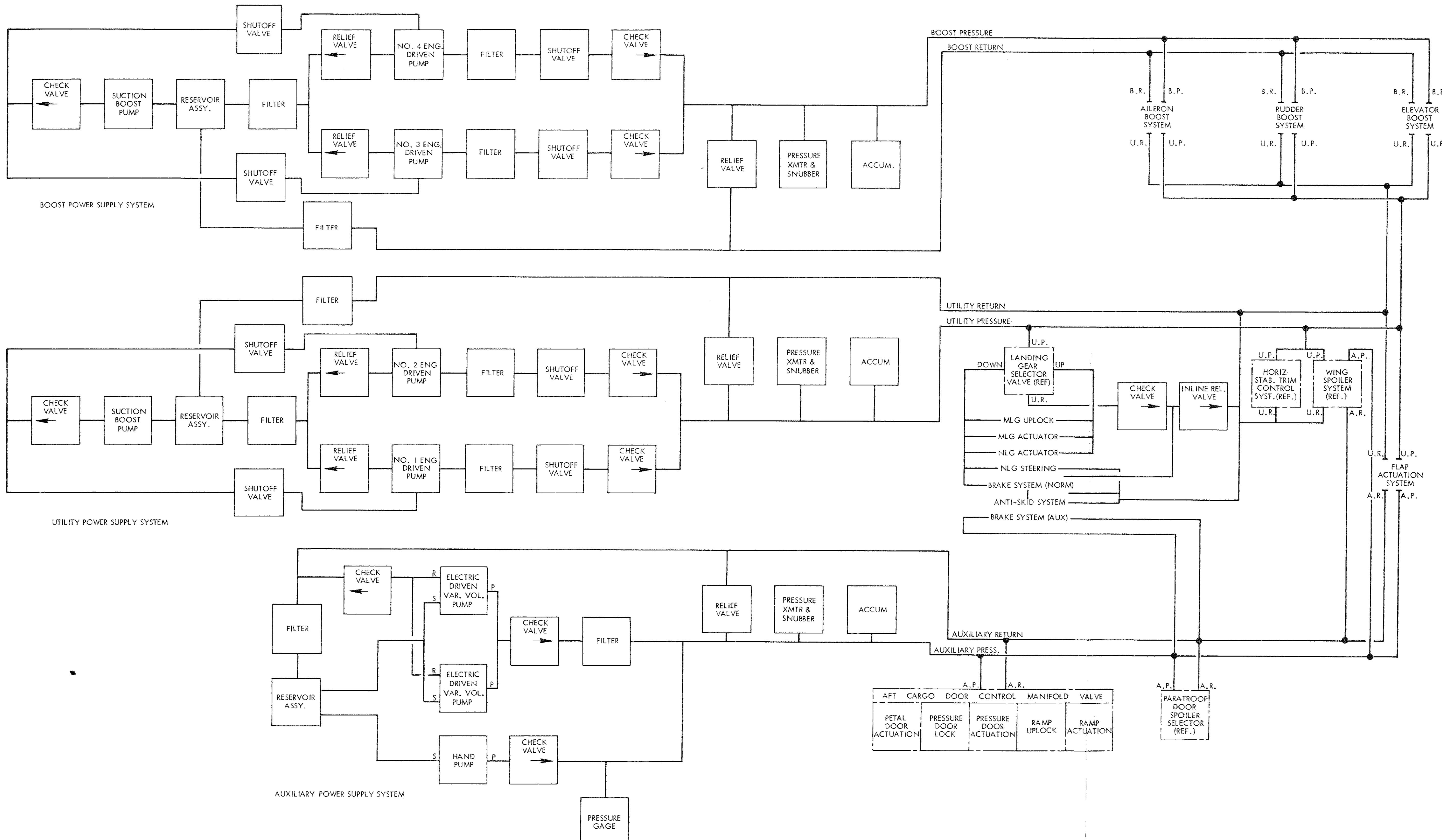


Figure 9-23—RELIABILITY BLOCK DIAGRAM—HYDRAULIC POWER SUPPLY SYSTEM.

Complete Hydraulic Power Supply Reliability

The predicted reliability of the complete hydraulic power supply system is computed as a combination of the reliabilities of the three subsystems. Redundancy is present among the subsystems to the extent that approximately 90% of the functions of the utility subsystem can be performed adequately by the boost and auxiliary subsystems in combination.

Conversely, the utility subsystem can adequately perform all of the functions of the boost subsystem and approximately 90% of the functions of the auxiliary subsystem. On this basis, it is determined that 10% of the failures attributable to the utility subsystem and 10% of the failures attributable to the auxiliary subsystem will constitute aircraft failure within the definition previously stated. These failures are mathematically equivalent to failures of a series subsystem. On the other hand, the remaining 90% of the failures attributable to these two subsystems are equivalent to failures of parallel subsystems. This determination is influenced by the fact that the essential functions of the hydraulic power supply system can be performed mechanically by back-up systems, which are not included in this example.

With this determination of the reliability relationships existent among the three subsystems, the complete system reliability is expressed by the equation given below:

$$R_S = [1 - (1 - R_{AP} \cdot R_B)(1 - R_{UP})] \cdot R_{AS} \cdot R_{US}$$

where R_S = reliability of the complete hydraulic power supply system.

R_{AP} = reliability of the auxiliary subsystem for functions paralleled by the utility subsystem.
= 0.99773

R_{AS} = reliability of the auxiliary subsystem for series functions.
= 0.99975

R_{UP} = reliability of the utility subsystem for functions paralleled by the auxiliary and boost subsystems in combinaion.
= 0.99688

R_{US} = reliability of the utility subsystem for series functions.
= 0.99965

R_B = reliability of the boost subsystem.
= 0.99654

Substitution of the given values in the equation above results in the following predicted reliability for the complete hydraulic power supply system:

$$R_S = 0.99938$$

This reliability is converted to MTF:

$$MTF = \frac{5}{-\ln 0.99938} = \frac{5}{0.00062} = 8{,}065 \text{ hours}$$

Comparison of Required and Preducted Values

Required and predicted MTF's for the hydraulic system are shown below for comparison purposes.

	Required MTF (hrs.)	Predicted MTF (hrs.)
Hydraulic power supply	7,576	8,065
Boost subsystem	1,406	1,445
Utility subsystem	1,370	1,445
Auxiliary subsystem	1,942	1,982

From this comparison it is seen that the required values are exceeded at all levels. The conclusion drawn from this preliminary evaluation of the hydraulic system is that this system, as designed, is expected to achieve satisfactory operational reliability with normal reliability control.

RELIABILITY IMPROVEMENT

The initial reliability prediction of 88 per cent for the GL 207-45 airborne system does not meet the preliminary requirement of 90% previously established. Comparison of predicted MTF's with corresponding requirements given in Figures 9-18 thru 9-22 points out those areas where attention must be concentrated. This preliminary reliability evaluation indicated that maximum benefit could be realized in achieving future increments of reliability if efforts were directed primarily toward these specific areas:

Aircraft Basic

1 Windshield and windows
2 Airframe anti-icing and de-icing
3 Main landing gear
4 Nose landing gear
5 Flight instrumentation
6 Autopilot

Powerplant

1 Fire detection

Utilities

1 AC electrical power source and control
2 Exterior lighting
3 Fixed oxygen

Communications

1 Interphone

Navigation

1 Radio compass
2 Weather radar
3 Radar altimeter
4 Inertial navigation
5 Navigation instruments

Conclusions

It must be emphasized that the above subsystems were isolated through an initial requirements and predictions analysis of a preliminary design. The design is not fixed at this stage, and the analysis was of necessity limited in detail. In many cases it was not possible to make the detailed engineering comparison analysis necessary to assign valid failure rates on the basis of C-130 experience. Also the requirements allocation should be examined in the light of predicted values, with trade-offs of allowable failures to give closer correlation in areas where the requirements appear unrealistic.

This analysis, however, is considered to be sufficiently valid to warrant special attention in the areas listed above, along with other areas where marginal reliabilities are indicated. A major advantage of this preliminary analysis is that detailed design is not complete, and necessary reliability improvements can be incorporated with minimum effort and cost. The results of this analysis have been provided to Engineering, and individuals with design responsibility in the various subsystem areas are aware of the reliability considerations necessary in developing the detail designs. Upon receipt of program go-ahead, reliability engineers will cooperate closely with the design engineers in studies of historical data and application of reliability design principles to the final design. Concurrently, detailed requirements and prediction analyses are begun to direct major control efforts as the reliability program progresses.

Some of the areas listed above have been previously recognized as problem areas for the C-130 and corrective features have been incorporated into the present GL 207-45 design. The main landing gear, for example, has been redesigned and is expected to be satisfactory. Recent improvements in the C-130B fire detection system appear to have a marked effect on achieved reliability, but enough data have not been accumulated to reflect this improvement in the predicted values.

Several of the areas listed above, such as electrically heated windows, are universal problem items. Substantial improvements of such equipment might well require major new developments and a general advance in the state-of-the-art beyond the intended scope of the System 476L program. Further studies may establish reliability trade-offs, with the possibility of concentrated efforts in other areas compensating for these inadequacies. Cost considerations might also prove a determining factor.

It is impossible at this time to properly examine the degree to which government-furnished equipment will affect the reliability. If the effects of such equipment are significant, substantial reliability improvement might result from close cooperation between Lockheed and the Air Force, as has existed for the C-130 and Air Force requirements become the major factor in such cases. It is recognized that justification of expenditures to incorporate improvements is influenced by the application of the equipment in question to airborne systems other than the GL 207-45 so that reliability trade-offs are investigated and acceptable courses of action are developed through negotiation.

EFFECTIVENESS ANALYSIS

Effectiveness studies for the GL 207-45 are initiated upon receipt of contractual go-ahead. In analyzing the effectiveness of an airborne system, problems arise in formulating a model which accurately describes the operation, and defines the characteristics of the system, in terms which permit quantitative measurement of the system's effectiveness. The most important elements in this analysis are those related to the reliability and the maintainability of the aircraft system. Defined characteristics of reliability and maintainability, injected into the operational model, will allow the assessment of other factors of importance to the efficient operation of the aircraft, such as—support availability, turn-around time, transportability, and vulnerability. The data which Lockheed has collected on the C-130 aircraft, provide a valuable basis for estimating quantitative relationships that make this effectiveness analysis feasible, practical and meaningful. Familiarity with the operation of MATS aircraft and the assigned airlift tasks further facilitates the formulation of realistic operational models.

OPERATIONAL MODEL

The GL 207-45 is designed to be used by the Military Air Transport Service in the performance of its airlift tasks. It is appropriate, therefore, that some of these tasks be examined in order to formulate realistic operational models.

Peacetime

Channel Traffic

The air transportation of Department of Defense passengers and cargo between ports in the United States and overseas on a regularly scheduled basis is known in MATS as "channel traffic." This portion of the peacetime task is performed by the Common User Fleet and by commercial carriers under contract with MATS. A large portion of the flying time of the GL 207-45 aircraft will be devoted to performing routine operations in the Common User Fleet.

The routine structure for channel traffic is shown in Figure 9-24. WESTAF is responsible for the Pacific and the Far East, terminating at Dhrahan. EASTAF is responsible for Central and South America, Europe and Africa. Dhrahan is the eastern terminus of the EASTAF routes. An example of current MATS operations is the daily cargo flights that are flown from McGuire Air Force Base to Frankfurt, Germany, with stops at Harmon Air Force Base and

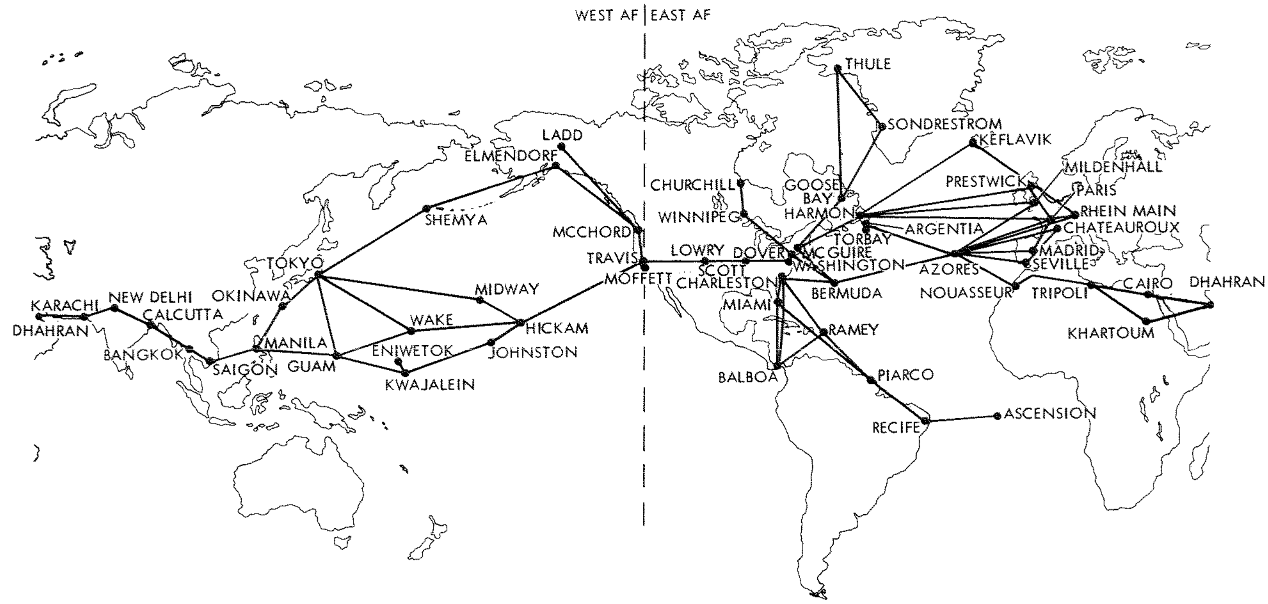


Figure 9-24—MATS ROUTE STRUCTURES.

Lages Field in the Azores, using the C-118. Availability of an aircraft with a longer range than the C-118 might eliminate one or two of the intermediate stops. A typical route for the operations under the jurisdiction of WESTAF is one from Travis Air Force Base to Tachikawa, Japan, with an intermediate stop at Hickam Air Force Base.

Special Missions

While the routine channel traffic of the Military Air Transport Service has remained relatively stable during the past few years, the demand for special missions has increased. These special missions include transporting of priority personnel and deployment of the Tactical Air Command and Strategic Army Corps strike forces during training exercises. A typical mission in support of one of these training exercises would require the airplane to leave its operational base, proceed to an airfield near the TAC or STRAC strike force, load cargo and supplies, and then proceed directly to the area for training exercises. In major airlift exercises lasting for several days, aircraft may be required to make several round trips in delivering troops and supplies. At the completion of the exercise, the airplane would conduct the operation in reverse terminating at its operational base. On these special missions, the aircraft would, in general originate from a major operational base, operate for one or more cycles between a base of moderate facilities and one of marginal repair facilities, and finally terminate at its operational base.

Limited War

Channel Traffic

During periods of limited war, aircraft would be diverted from MATS' channel traffic routes to implement the airlift requirements of tactical and strategic strike forces. In addition, the amount of channel traffic in the direction of the war would probably increase. The increased traffic, as well as the reduction of aircraft available for use in the channel traffic, would require increased utilization of MATS aircraft. The routes flown during periods of limited war would remain similar to those of a peacetime operation.

Strike Force Deployment

The operation of aircraft for the deployment of strike forces in limited war would be similar to the training exercises conducted during peacetime. The urgency of the operation and the quantity of the material to be transported would be different since the terminal airfields would probably have few facilities.

General War

Strategic Air Command Support

Operation of MATS aircraft in a period of general war is difficult to define since each operation would involve different requirements. Quick reaction time, high speed in transit, and rapid turnaround would be most important. The primary missions would probably be transportation of critical material or weapons to Strategic Air Command bases.

Strike Force Deployment

It appears that the need for the deployment of strike forces that exist during a limited war would be similar during a general war. After the first strategic attack, delivery and support of these forces would probably be a major requirement.

Operational Model Formulation

An examination of the missions of MATS in which the GL 207-45 would be used indicates that the missions might be categorized by the type of bases used by the aircraft. Because the level of maintenance support would vary at the different bases, an operational model is developed to explain the plan of action.

The bases are divided into the following six categories according to the level of support facilities available.

I Depot—Complete support facilities.
II Operational—Support exclusive of major overhaul.
III Intermediate base, Military—Bases which receive similar type of aircraft, but have none based there.
IV Intermediate bases, Commercial—Bases from which similar commercial aircraft operate.
V Advanced bases—Low level of maintenance capability.
VI Landing strip—Requires the airplane to be completely self-supporting.

Schematic descriptions of the various types of missions are shown in Figure 9-25. Mission A would be representative of scheduled operation in transporting channel traffic with the airplane traveling the circuit on a scheduled basis. In a single shot mission it would also be representative of a SAC support mission in which the airplane left its operational base and proceeded to a military base for a critical airlift. Missions B and C would be representative of deployment missions in which the aircraft would proceed to the base of the strike force and then proceed to an advanced base in the theater of operations. Peacetime exercises would probably permit selection of bases where some support was available. Wartime operations would introduce the possibility of no support at the advanced base.

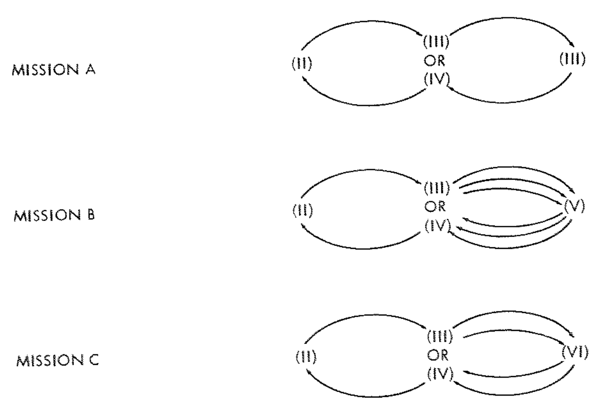


Figure 9-25—SCHEMATIC DESCRIPTION OF TYPES OF MISSIONS.

Each leg of the mission would be further classified with respect to the flight phases and the time spent in each phase. The flight phases which appear to be pertinent to reliability assessment are: preflight, take-off and climb, cruise, descent and landing, post-flight, and maintenance action.

AIRBORNE SYSTEM DEFINITION

It is necessary to describe the airborne system in terms of its subsystems and their characteristics which influence the analysis of the system's effectiveness. For the first phase of this analysis, it is assumed that the aircraft is defined down to the minor subsystem level. The breakdown of the complete system into minor subsystems is similar to that used in the C-130 reliability program. Approximately 300 minor subsystems are used to describe the C-130B. A similar number should describe the GL 207-45. To define the entire airborne system, however, aerospace ground equipment subsystems should also be included in the analysis.

Mean-Time-to-Failure

The criteria which would affect the reliability of the airborne system is the mean-time-to-failure (MTF) of a subsystem while the airplane is in flight status. Data collected on the C-130 is used in estimating the MTF of the subsystems of the GL 207-45, and the portion of the flight in which they are most likely to occur. Failures discovered during preflight, flight, and post flight are identified. Where possible, components used only during specific portions of the flight are identified in order that the probable time of failure occurrence may be determined.

In estimating MTF for most of the subsystems a uniform time distribution of the failure is used. A constant failure rate allows the use of the decreasing exponential for estimating reliability distribution. Allowance for wearout is provided by including an estimated time for replacement. A record in terms of logged flight time is maintained for each component on the aircraft. It is then possible to institute maintenance action at the nearest overhaul period for components reaching the wearout period.

Mean-Time-to-Maintenance-Action

The total maintenance problem of the airplane must consider the mean time to maintenance action (MTMA) which includes failures discovered during flight status, out-of-flight status, and other maintenance action which may not be related to specific system failure. C-130 reliability data is used in estimating the total maintenance requirement.

FAILURE CLASSIFICATION

A failure analysis is required to classify identified failures with respect to their effect upon the remaining portion of the flight. The effects are categorized by the urgency of the mission as well as by the phase of the flight in which failures occur. Actions taken as a result of failures are defined by their effect upon the flight and upon maintenance.

The most critical failures are those which would cause an immediate abort of the flight. Even in this instance, however, a portion of the aircraft's mission might still be accomplished if, when the failures occur, the closest airfield is one at which the aircraft is scheduled to land. A second type of failure is one which cancels the mission, if discovered during the pre-flight phase. The same failure may not be considered reason for abort if the airplane is already in flight. A third type is one which requires the aircraft to return to its take-off point provided it has not reached the midpoint of its flight.

The performance of some of the subsystems are related to that of other subsystems. Failure of one of the subsystems might not be serious, whereas, failure of two or more related subsystems may be. Thus, the failure of a given subsystem must be considered with respect to possible additional failures of related systems.

The less serious failures of subsystems may be classified as those which do not prevent the airplane from completing its mission, or at least one leg of the mission, or repair of which can be postponed.

MAINTENANCE REQUIREMENTS

Manhours

The data which have been collected in the C-130 reliability program include the maintenance manhours applied to specific maintenance work. Analysis of these data permits estimates to be made of manhours required for maintenance of individual GL 207-45 subsystems. As these subsystems are designed for the GL 207-45 and maintenance activity is better defined, these estimates will be revised.

Elapsed Time

The total elapsed time is significantly important in establishing turnaround time and total cycle time of the aircraft. The crew size that can be effectively assigned to the repair of the subsystems is also determined. By comparing crew availability at the base, with the manhours required, total time necessary for repair or replacement is estimated.

Crew Skill Level

Estimates are made of the maintenance crew skill levels required in handling each of the subsystems. These estimates provide the basis for assignment of specific skills to the various bases.

Spare Parts Category

The quantity and type of spare parts stocked at each base depends upon the classification of the base. The type of base at which it is possible to obtain the required spare parts will be identified for each of the subsystems.

Mathematical Model

The description of the operational model and the description of the airborne system provides input to the system effectiveness analysis which is programmed on the IBM 7090 computer. A flow diagram of the analysis is described in Figure 9-26. The operational model description includes specifications of a network of bases; the time and distance between bases; and the category of skills, equipment, and spare parts available at each of the bases. For a specific analysis the times and routes are fixed input. The distribution of skills and equipment may be fixed, or determined through random selection procedures.

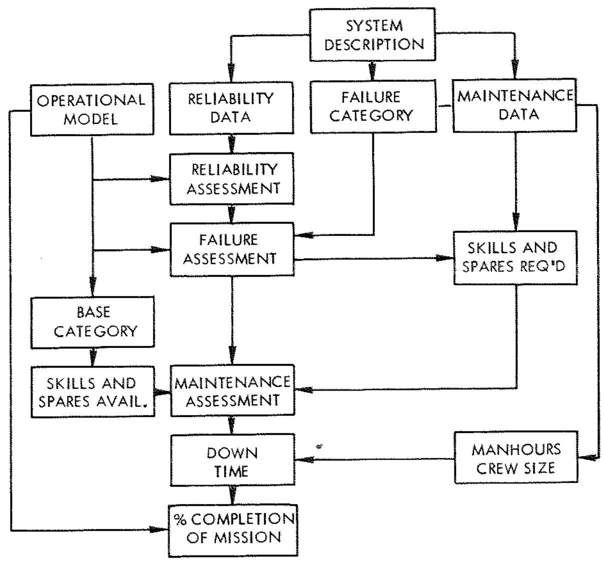


Figure 9-26—MATHEMATICAL MODEL OF EFFECTIVENESS ANALYSIS.

The reliability data for each subsystem are integrated in the computer with the appropriate operational data to determine the probabilities of failure at successive stages of the mission. The completion of the mission and the time required is a function of the distribution of skills and equipment at the various bases and the nature of the failure. To determine the effect of the failure, when the flight is aborted, continued to the next base or to completion, the computer receives information pertaining to the subsequent flight status in the event of a system failure.

The computational requirements may be handled with the aid of random number generation. The performance of each subsystem is simulated as the mission progresses. The computer routine considers the probability that the failure of one subsystem will induce failure in another. The exact mathematical model depends on the number and complexity of such relationships.

At each time stage of the mission the operation of all subsystems is tested, using failure rate inputs and random selections. In the event of a failure, the effect on the flight is evaluated from input failure data. Where maintenance is required at the next base, or subsequent bases, the statistical distribution of man-hours for maintenance is consulted (again using random numbers), and the cost and time delay of maintenance actions are noted. Following this simulation procedure, the cost and time requirements to reach any stage of the mission are determined for a typical run. Many runs are made to establish the probability distribution function for costs and times at various stages of mission completion.

Printed output consists of tabular data representing cost and time distribution as a function of percent or stage of mission completion. The specific mission network (routes) and distribution of skills and equipment for maintenance at the various bases are also printed.

Mission accomplishment will probably be measured by the relative quantities of aircraft which complete the mission without encountering enroute delays due to subsystem failure. Aircraft which complete the circuit without failure; failures not requiring immediate corrective action, or failures which can be repaired within normal ground servicing time, are considered to have 100% mission accomplishment. Aircraft delayed due to enroute failure, but which still complete the full circuit, will be penalized proportionally to the total enroute delay and will show less than 100% mission accomplishment. The third category of aircraft are those which encounter failures aborting the mission, or requiring maintenance not consistent with the available spare parts or skill level of the enroute bases. This latter category is credited with only that cargo delivered prior to failure. An aircraft aborting prior to reaching any of its destinations is credited with zero accomplishment.

Calculations are performed for each of several distributions of maintenance capabilities, or for the optimum distribution of maintenance capabilities for each input set of mission specifications.

APPLICATION

The initial output of the computer program is based on the preliminary predicted reliability of the GL 207-45 airplane. This reliability is used to establish the total cost of maintaining the required airlift capability. Trade-off analyses are conducted between maintainability and reliability to identify the proper relationships for minimum cost. Critical systems which need increased reliability or reduced maintenance are examined and the effects of design changes are evaluated. The effects of adding redundancies to obtain higher reliability at the expense of increased maintenance are determined. The final results of the effectiveness analysis define an optimum relationship between reliability, maintainability, cost, and other significant parameters. The system reliability level, thus derived, becomes the quantative reliability objective for the GL 207-45.

Examination of the routes which apply to "channel traffic" should give valuable guidance to the stocking of parts or to the assignment of maintenance personnel at bases along MATS scheduled routes.

It is possible to examine vulnerability by assessing increased component failure rate during specific portions of the mission when a threat such as ground fire exists.

One of the more important aspects of this type of analysis in the capability to determine average turn-around times, making it possible to estimate realistic fleet sizes for defined military missions where the cycle time is an important factor. Availability of actual data obtained from the C-130 reliability program, makes this type of analysis possible.

RELIABILITY REPORTS

All reports required by this program are prepared and submitted in accordance with MIL-D-9310 as required by MIL-R-26674 and the Statement of Work. These reports are prepared by the Reliability Engineering Department and incorporate the applicable information from other sources. Mechanized reports are used where applicable.

PRICING INFORMATION
RELIABILITY PROGRAM (5.4.8)

	Hours[1]	Rate	No Year Qty 5 Contractor's Proposal Amount[1]
Engineering			
D.L.—Basic	218	$4.24	$ 924
D.L.—Sustaining	21	4.23	89
Overhead		69.55% DL	705
Material & Direct Charges		.56	134
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$1,852
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			
Overhead			
Material & Direct Charges			
Purchased Equipment			
Subcontracting			
Total Manufacturing			
Quality Assurance			
D.L.—Basic	3	$3.37	$ 10
D.L.—Sustaining	—0—		—0—
Overhead		115.40% DL	12
Material & Direct Charges			300
Total Quality Assurance			$ 322
G & A Expense		23.97% DL	$ 245
Total Cost			$2,419
Profit		8%	194
Price			**$2,613**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
RELIABILITY PROGRAM (5.4.8)

	Hours[1]	FY 63 Contractor's Rate	Qty 31 Proposal Amount[1]
Engineering			
D.L.—Basic			—0—
D.L.—Sustaining	68	$4.47	$304
Overhead		70.50% DL	214
Material & Direct Charges		.56	38
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$556
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			
Overhead			
Material & Direct Charges			
Purchased Equipment			
Subcontracting			
Total Manufacturing			
Quality Assurance			
D.L.—Basic	—0—		—0—
D.L.—Sustaining	1	$3.59	$ 4
Overhead		109.10% DL	4
Material & Direct Charges			—0—
Total Quality Assurance			$ 8
G & A Expense		22.88% DL	$ 70
Total Cost			$634
Profit		8%	51
Price			**$685**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
RELIABILITY PROGRAM (5.4.8)

	Hours[1]	FY 64 Contractor's Rate	Qty 48 Proposal Amount[1]
Engineering			
D.L.—Basic			—0—
D.L.—Sustaining	71	$4.64	$329
Overhead		72.76% DL	239
Material & Direct Charges		.56	40
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$608
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			
Overhead			
Material & Direct Charges			
Purchased Equipment			
Subcontracting			
Total Manufacturing			
Quality Assurance			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Total Quality Assurance			
G & A Expense		28.16% DL	$ 93
Total Cost			$701
Profit		8%	56
Price			**$757**

[1]Thousands

FORMAT "A"

PRICING INFORMATION

RELIABILITY PROGRAM (5.4.8)

	Hours[1]	FY 65 Contractor's Rate	Qty 48 Proposal Amount[1]
Engineering			
D.L.—Basic			—0—
D.L.—Sustaining	67	$4.82	$323
Overhead		72.76% DL	235
Material & Direct Charges		.56	38
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$596
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			
Overhead			
Material & Direct Charges			
Purchased Equipment			
Subcontracting			
Total Manufacturing			
Quality Assurance			
D.L.—Basic			
D.L.—Sustaining			
Overhead			
Material & Direct Charges			
Total Quality Assurance			
G & A Expense		28.16% DL	$ 91
Total Cost			$687
Profit		8%	55
Price			**$742**

[1]Thousands

FORMAT "A"

PRICING INFORMATION
RELIABILITY PROGRAM (5.4.8)

	Hours[1]	Rate	Amount[1]
		PROPOSAL SUMMARY Contractor's Proposal	
Engineering			
D.L.—Basic	218	$4.24	$ 924
D.L.—Sustaining	227	4.60	1,045
Overhead		70.75% DL	1,393
Material & Direct Charges		.56	250
Technical Data & Handbooks			—0—
Subcontracting			—0—
Total Engineering			$3,612
Tooling			
D.L. Planning—Basic			
D.L. Planning—Sustaining			
D.L. Tool Design—Basic			
D.L. Tool Design—Sustaining			
D.L. Tool Mfg.—Basic			
D.L. Tool Mfg.—Sustaining			
Overhead			
Material & Direct Charges			
Subcontract Tooling			
Total Tooling			
Manufacturing—(Production)			
Direct Labor			
Overhead			
Material & Direct Charges			
Purchased Equipment			
Subcontracting			
Total Manufacturing			
Quality Assurance			
D.L.—Basic	3	$3.33	$ 10
D.L.—Sustaining	1	4.00	4
Overhead		114.29% DL	16
Material & Direct Charges			300
Total Quality Assurance			$ 330
G & A Expense		25.16%	$ 499
Total Cost			$4,441
Profit		8%	356
Price			**$4,797**

[1]Thousands

FORMAT "A"

SUPER HERCULES · GL207-45

section 10

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 1 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS
A - AIRLIFTING (All New Parts)													
(Flight Controls)													
Rigging Kit													
Spares 15%						($881)							
Operational Sqdr.													
Consolidated Maint.	8		$ 734			$5,872							
Depot		2	$ 734							$1,468			
										($220)			
(Flight Controls)													
Test Jig Aileron													
Spares 15%													
Operational Sqdr.													
Consolidated Maint.													
Depot		2	$2,669							$5,338			
										($801)			
(Flight Controls)													
Test Jig Elevator													
Spares 15%													
Operational Sqdr.													
Consolidated Maint.													
Depot		2	$3,014							$6,028			
										($904)			

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 2 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS
A - AIRLIFTING (All New Parts)													
(Flight Controls)													
Test Jig Rudder													
Spares 15%													
Operational Sqdr.													
Consolidated Maint.													
Depot		2	$2,669							$5,338			
										($801)			
(Flight Controls)													
Hoist													
Spares 15%						($308)							
Operational Sqdr	1		$2,050			$2,050							
Consolidated Maint.	8		$2,050			$16,400							
Depot						(2,460)							
(Flight Controls)													
Sling - Rudder													
Spares 15%						(28)							
Operational Sqdr.	1		$184			$184							
Consolidated Maint.	4		$184			$736							
Depot		4	$184			($110)				$736			
										($110)			

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 — WEAPON SYSTEM NUMBER: 476L — DATE: — PAGE 3 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
A - AIRLIFTING (All New Parts)													
(Flight Controls)													
Sling - Gen. Purp.													
Spares 15%						($138)							
Operational Sqdr.	1		$ 919			$919							
Consolidated Maint.	4		$ 919			$3,676							
Depot		4	$ 919			($551)				$3,676			
										($551)			
(Flight Controls)													
Sling - Stab.													
Spares 15%													
Operational Sqdr.													
Consolidated Maint.													
Depot		2	$ 789							$1,578			
										($237)			
(Fire Warning Syst.)													
Tester													
Spares 15%						($268)							
Operational Sqdr.	1		$1,788			$1,788							
Consolidated Maint.	8		$1,788			$14,304							
Depot		2	$1,788			($2,146)				$3,576			
										($536)			

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 — WEAPON SYSTEM NUMBER: 476L — DATE: — PAGE 4 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
A - AIRLIFTING (All New Parts)													
(Fuselage)													
Hoist & Sling													
Spares 15%						($108)							
Oper. Sqdr.	1		$720			$720							
Consolidated Maint.	8		$720			$5,760							
Depot		4	$720			($864)				$2,880			
										($432)			
(Fuselage)													
Fitting - Jack													
Spares 15%						($49)							
Oper. Sqdr.	4		$81			$324							
Consolidated Maint.	32		$81			$2,592							
Depot		8	$81			($389)				$648			
										($97)			
(Fuselage)													
Fitting - Jack													
Spares 15%						($41)							
Oper. Sqdr.	4		$69			$276							
Consolidated Maint.	32		$69			$2,208							
Depot		8	$69			($331)				$552			
										($83)			

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

			REPORTS CONTROL SYMBOL
WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I			
TYPE, MODEL, AND SERIES: CARGO, GL 207-45	WEAPON SYSTEM NUMBER: 476L	DATE	PAGE 5 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PROCURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
A-AIRLIFTING (All New Parts)													
(Fuselage)													
Dolly													
Spares 15%						($201)							
Oper. Sqdr.	1		$1,339			$1,339							
Consolidated Maint.	4		$1,339			$5,356							
Depot		2	$1,339			($803)				$2,678			
										($402)			
(Fuselage)													
Dolly													
Spares 15%						($110)							
Oper. Sqdr.	1		$732			$732							
Consolidated Maint.	4		$732			$2,928							
Depot		2	$732			($439)				$1,464			
										($220)			
(Fuselage)													
Adapter Kit													
Spares 15%						($754)							
Oper. Sqdr.													
Consolidated Maint.	4		$1,257			$5,028							
Depot		4	$1,257							$5,028			
										($754)			

AMC FORM APR 59 217 REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

			REPORTS CONTROL SYMBOL
WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I			
TYPE, MODEL, AND SERIES: CARGO, GL 207-45	WEAPON SYSTEM NUMBER: 476L	DATE	PAGE 6 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PROCURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
A - AIRLIFTING (All New Parts)													
(Wing)													
Fitting - Jack													
Spares 15%						($37)							
Oper. Sqdr.	4		$62			$248							
Consolidated Maint.	32		$62			$1,984							
Depot		8	$62			($298)				$496			
										($74)			
(Wing)													
Condensate Drain													
Spares 15%						($502)							
Oper. Sqdr.	16		$209			$3,344							
Consolidated Maint.													
Depot		4	$209							$836			
										($125)			

AMC FORM APR 59 217 REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 7 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PROCURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
B - ALIGHTING (All New Parts)													
(Landing Gear)													
Hoist													
Spares 15%						($93)							
Oper. Sqdr.	1		$618			$618							
Cons. Maint.	8		$618			$4,944							
Depot		4	$618			($742)				$2,472			
										($371)			
(Landing Gear)													
Lock													
Spares 15%						(~~$456~~)							
Oper. Sqdr.	16		$190			~~$3040~~							
Cons. Maint.													
Depot		4	$190							$760			
										($114)			
(Landing Gear)													
Lock													
Spares 15%						($1,733)							
Oper. Sqdr.	32		$361			$11,552							
Cons. Maint.													
Depot		8	$361							$2,888			
										($433)			

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 8 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PROCURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
B - ALIGHTING (All New Parts)													
(Landing Gear)													
Dolly													
Spares 15%						($136)							
Oper. Sqdr.	1		$905			$905							
Cons. Maint.	8		$905			$7,240							
Depot		4	$905			($1,086)				$3,620			
										($543)			
(Landing Gear)													
Dolly													
Spares 15%						($80)							
Oper. Sqdr.	1		$532			$532							
Cons. Maint.	8		$532			$4,256							
Depot		2	$532			($638)				$1,064			
										($160)			
(Landing Gear)													
Bridle Kit													
Spares 15%						($47)							
Oper. Sqdr.	1		$314			$314							
Cons. Maint.	4		$314			$1,256							
Depot						($188)							

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT – PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 9 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS
B - ALIGHTING (All New Parts)													
(Landing Gear)													
Bleeder Unit													
Spares 15%						($130)							
Oper. Sqdr.	1		$869			$869							
Cons. Maint.	8		$869			$6,952							
Depot		2	$869			($1,043)				$1,738			
										($261)			
(Landing Gear)													
Wrench													
Spares 15%						($44)							
Oper. Sqdr.	2		$147			$294							
Cons. Maint.	8		$147			$1,176							
Depot		4	$147			($176)				$588			
										($88)			
C - PROPULSION (All New Parts)													
(Engine)													
Hoist & Sling													
Spares 15%						($120)							
Oper. Sqdr.	1		$798			$798							
Cons. Maint.	8		$798			$6,384							
Depot						($958)							

AMC FORM APR 59 217 REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT – PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 10 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS
C - PROPULSION (All New Parts)													
(Engine)													
Sling													
Spares 15%													
Oper. Sqdr.													
Cons. Maint.													
Depot		8	$316							$2,528			
										($379)			
(Engine)													
Sling													
Spares 15%						($224)							
Oper. Sqdr.													
Cons. Maint.	4		$373			$1,492							
Depot													
(Engine)													
Adapter Remote Trimmer													
Spares 15%						($52)							
Oper. Sqdr.	1		$344			$344							
Cons. Maint.	8		$344			$2,752							
Depot		4	$344			($413)				$1,376			
										($206)			

AMC FORM APR 59 217 REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 11 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
D - ACTIVATION (All New Parts)													
(APU)													
Hoist													
Spares 15%						($63)							
Oper. Sqdr.	1		$421			$421							
Cons. Maint.	8		$421			$3,368							
Depot		2	$421			($505)				$842			
										($126)			
H - PROTECTION & SAFETYING (All New Parts)													
(Pneumatic Syst.)													
Safety Net Kit													
Spares 15%													
Oper. Sqdr.													
Cons. Maint.													
Depot		2	$2,909							$5,818			
										($873)			

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 12 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 MOS	GP 3 MOS	GP 4 MOS
H - PROTECTION & SAFETYING (All New Parts)													
(Doors)													
Lock Kit													
Spares 15%						($1,230)							
Oper. Sqdr.	4		$2,050			$8,200							
Cons. Maint.	32		$2,050			$65,600							
Depot		4	$2,050			($9,840)				$8,200			
										($1,230)			
(Engine)													
Plug Kit													
Spares 15%						($1,598)							
Oper. Sqdr.	16		$666			$10,656							
Cons. Maint.													
Depot		4	$666							$2,664			
										($400)			
(Engine)													
Screen													
Spares 15%						($753)							
Oper. Sqdr.	4		$1,255			$5,020							
Cons. Maint.	32		$1,255			$40,160							
Depot		4	$1,255			($6,024)				$5,020			
										($753)			

AMC FORM APR 59 217 — REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

WEAPON SYSTEM GROUND SUPPORT EQUIPMENT — PART I

REPORTS CONTROL SYMBOL

TYPE, MODEL, AND SERIES: CARGO, GL 207-45 | WEAPON SYSTEM NUMBER: 476L | DATE: | PAGE 13 OF 13 PAGES

ITEMS BY FUNCTIONAL CATEGORY A	NO. REQD OPER UNIT B	NO. REQD DEPOT OTHER C	UNIT COST D	FUNDS SERIES E	PRO-CURING ACTIVITY F	LEAD TIME – OPERATIONAL UNIT G: GP 1 18 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS	LEAD TIME – DEPOT/OTHER H: GP 1 24 MOS	GP 2 ... MOS	GP 3 ... MOS	GP 4 ... MOS
H - PROTECTION & SAFETYING (All New Parts)													
(Pneumatic Syst.)													
Plug Kit													
Spares 15%						($310)							
Oper. Sqdr.	16		$129			$2,064							
Cons. Maint.													
Depot		4	$129							$516			
										($77)			
(Landing Gear)													
Lock - Safety													
Spares 15%						($106)							
Oper. Sqdr.	2		$352			$704							
Cons. Maint.	16		$352			$5,632							
Depot		4	$352			($845)				$1,408			
										($211)			
(Landing Gear)													
Lock - Safety													
Spares 15%						($313)							
Oper. Sqdr.	4		$521			$2,084							
Cons. Maint.	32		$521			$16,672							
Depot		8	$521			($2,501)				$4,168			
										($625)			

AMC FORM APR 59 217 REPLACES AMC FORM 217, FEB 59, AMC FORM 504D, SEP 57, AND ASC FORM 89, AUG 58, (FORMERLY MCP FORM 118) WHICH ARE OBSOLETE

476L Lockheed

TIME PHASED PROCUREMENT PROJECT ____________ —PART II	REPORTS CONTROL SYMBOL
TYPE, MODEL AND SERIES: GL 207-45 · WEAPON SYSTEM NUMBER: 476 L · DATE:	PAGE 1 OF 2 PAGES

UNITS	CALENDAR YEAR 19 64												CALENDAR YEAR 19 65												CALENDAR YEAR 19 66												CALENDAR YEAR 19 67					
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
(WING.) NO. 1	X $ 1,788,825																																									
SQDN 1	X $ 388,875 ($58,331)																																									
SQDN 2						X $ 388,875 ($58,331)																																				
SQDN 3															X $ 388,875 ($58,331)																											
SQDN 4																		X $ 388,875 ($58,331)																								
EQUIPAGE DATE																																										
(WING, ETC.) NO. 2																		X $ 1,788,825																								
SQDN 1																		X $ 388,875 ($58,331)																								
SQDN 2																					X $ 388,875 ($58,331)																					
SQDN 3																								X $ 388,875 ($58,331)																		
SQDN 4																											X $ 388,875 ($58,331)															
EQUIPAGE DATE																																										
SQUADRON (WING, ETC.) NO. ____																																										
GROUP 1																																										
GROUP 2																																										
GROUP 3																																										
GROUP 4																																										
EQUIPAGE DATE																																										

FISCAL YR. 19 62	FISCAL YEAR 19 63	FISCAL YEAR 19 64	FISCAL YEAR 19 65
$ 105,310	$ 826,533	$ 1,084,143	$ 1,095,014

AMC FORM APR 59 217A PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

TIME PHASED PROCUREMENT PROJECT ____________ —PART II	REPORTS CONTROL SYMBOL
TYPE, MODEL AND SERIES: GL 207-45 · WEAPON SYSTEM NUMBER: 476 L · DATE:	PAGE 2 OF 2 PAGES

UNITS	CALENDAR YEAR 19 64												CALENDAR YEAR 19 65												CALENDAR YEAR 19 66												CALENDAR YEAR 19 67					
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
DEPOT NO. 1												X $ 2,152,000 ($322,800)																														
GROUP 1																																										
GROUP 2																																										
GROUP 3																																										
GROUP 4																																										
EQUIPAGE DATE																																										
DEPOT NO. 2																														X $ 2,152,000 ($322,800)												
GROUP 1																																										
GROUP 2																																										
GROUP 3																																										
GROUP 4																																										
EQUIPAGE DATE																																										
SQUADRON (WING, ETC.) NO. ____																																										
GROUP 1																																										
GROUP 2																																										
GROUP 3																																										
GROUP 4																																										
EQUIPAGE DATE																																										

FISCAL YR. 19 62	FISCAL YEAR 19 63	FISCAL YEAR 19 64	FISCAL YEAR 19 65
$ 145,690	$ 1,143,467	$ 1,499,857	$ 1,514,986

AMC FORM APR 59 217A PREVIOUS EDITION OF THIS FORM IS OBSOLETE.