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LOCKHEED

LOCKHEED GEORGIA COMPANY

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

REPORT NO.: LG1US55-1-1

DATED: 2-7-66

LOCKHEED-GEORGIA COMPANY

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

MARIETTA GEORGIA

TITLE

C-5A

ENVIRONMENTAL NOISE, VIBRATION,

AND SONIC FATIGUE PROGRAM REPORT

SUBMITTED UNDER

MODEL C-5A REFFRENCE MIL-A-8870/MIL-A-8806

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DATE	REV. BY	PAGES AFFECTED	REMARKS

GA FORM 402-6

SUMMARY

This report outlines the program proposed for meeting the noise and vibration requirements for the C-5A aircraft. Included are the analytical and test programs for noise prediction, environmental vibration, sonic fatigue, and soundproofing. It is concluded that this overall program is adequate to define the problem areas and provide analyses and tests to substantiate the aircraft for meeting the noise and vibration requirements of MIL-A-8870, MIL-A-8806, and the detailed requirements outlined in CP40002-1A, CP40002-2A, and SS40001A.

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1.0 REFERENCES

1. CP40002-1A, CEI C-5A Air Vehicle
2. CP40002-2A, CEI C-5A Air Vehicle, Airframe Subsystem
3. SS40001A, CEI General Specification, Performance and Design Requirements
4. MIL-A-8870, Military Specification, Airplane Strength and Rigidity, Vibration, Flutter, and Divergence
5. MIL-A-8806, Military Specification, General Specification for Acoustical Noise Level in Aircraft
6. ASD TN 61-141, Detail Requirements and Status, Air Force Structural Integrity Program, September, 1961

2.0 INTRODUCTION

The C-5A Sound and Vibration Program will derive design and test requirements to ensure that the aircraft structure and equipment are free from premature sonic fatigue and vibratory induced damage and to optimize vibration and noise environments, obtaining the required personnel comfort and equipment operating levels. Program goals will be achieved through four inter-related activities, which are:

a. Noise prediction and general acoustics

b. Environmental vibration

c. Sonic Fatigue

d. Soundproofing

Of fundamental importance to the evolution of vibration qualification levels, sonic fatigue criteria and soundproofing configurations is an accurate definition of the acoustic environment. Therefore, predicted noise levels, derived previously, will be refined with data obtained from analytical studies, acoustic model tests, and General Electric-Lockheed engine test stand programs. These data will be integrated into the environmental vibration, sonic fatigue and soundproofing activities. In addition, noise safety problems in the vicinity of the aircraft during ground operation and community noise levels during takeoffs and landings will be evaluated.

Environmental vibration levels have been predicted for the C-5A aircraft and equipment qualification requirements are established. These will be used for equipment design and test criteria during the development phase. In parallel, the vibration prediction techniques and environmental levels will be refined in conjunction with the acoustic and engine test stand programs. Adequate operation and design life of vibration sensitive equipment will be ensured by devising isolation systems or by defining mounting configurations which minimize response.

Premature structural damage due to excitation from all noise sources is the prime consideration of the sonic fatigue program. Analytical and test programs, which will define the effect of noise on the fatigue life of a

2.0 INTRODUCTION (CONT'D)

wide range of conventional, honeycomb, and laminated structures, will be performed to develop configurations for a wide spectrum of applications. Laboratory proof tests will verify the design life of basic wing, empennage and fuselage components and an accelerated life test of the nacelle, pylon, and a large wing segment, (with all basic components) will be performed on the Lockheed engine endurance test stand and in the RTD sonic fatigue test facility.

Stringent requirements for aircraft interior noise levels have led to the initiation of a comprehensive program of selecting soundproofing which will be satisfactory and be the lightest weight possible. This will require utilization of transmission loss data from C-141, C-130, JetStar, and other aircraft in conjunction with developmental tests of numerous specific soundproofing configurations. The resulting data will be combined with an analytical program, which will calculate the parameters necessary to define the optimum installation. A continual updating of the derived configurations will be accomplished with inputs from the acoustic prediction program and latest noise transmission loss test data.

The criteria developed during this program will be applied to the design of C-5A structural and equipment components to produce an operational aircraft which has satisfactory acoustic, vibration and sonic fatigue characteristics. A flight test program will be performed to demonstrate these qualities. Strain, vibration, and noise data will be measured at all significant points in the ground and air operating envelopes.

3.0 NOISE PREDICTION AND GENERAL ACOUSTICS

3.1 GENERAL

The objectives of this program are to predict and measure the noise environment of the airplane in order that sonic fatigue, vibration and soundproofing requirements can be accurately evaluated. The schedule of activities is shown on Pages 3.3 and 3.4.

3.2 ANALYTICAL NOISE PREDICTION

During the early design phase, propulsion system noise and aerodynamic noise will be determined analytically. Recently obtained C-141 inflight exterior noise data will be incorporated into the C-5A predictions. The noise predictions will be updated as more measured data becomes available from test programs described in applicable sections to follow.

3.3 ACOUSTIC MODEL TEST

The acoustic scale model is one of the most accurate methods of predicting the propulsion system acoustic environment, particularly when no full scale engine data is available. During the conceptual phase and PDP phase, acoustic models have been utilized to map jet noise on the aircraft structure. The model aircraft are 1/16 scale with model engines operating at the correct pressures, temperatures, and flow rates. The model will be updated for further tests to give a more accurate evaluation of the exhaust noise field over the aircraft.

Tests will consist of measuring noise levels at 100 locations on the fuselage and empennage, and 100 locations on the wing, flaps, aileron, and pylons by means of 1/4 inch diameter flushmounted microphones. The data will be taken on a 14 channel FM magnetic tape recorder. The raw data will be automatically analyzed in octave band form, digitized, and plotted as contours of equal noise intensity over the aircraft surface by an IBM 7094 computer-plotter program.

3.4 G.E. ENGINE TESTS

Noise measurements will be taken at G.E.'s engine test stand for the TF 39 demonstrator (2/3 scale) and full scale TF 39 engines. The measurements will be taken at simulated wing, pylon, and fuselage locations. The

3.4 G.E. ENGINE TESTS (CONT'D)

tests will be monitored by Lockheed personnel and the data will be incorporated in the aircraft noise environment predictions.

3.5 GELAC ENDURANCE TEST STAND

Noise measurements on the nacelle, pylon, and wing surfaces will be taken on the endurance test stand to further define the engine noise environment and provide correlation with vibration and strain measurements. Program details are contained in Section 7.1.

3.6 GELAC PERFORMANCE TEST STAND NOISE TESTS

Near-field sound measurements will be obtained on a 50' radius forward of the engine inlet at 8 locations. This will be accomplished with bellmouth and with airframe nacelle inlet to evaluate the acoustical attenuation of the airframe-supplied inlet. Measurements will be repeated to determine any differences in noise output of the X, Y, and TF versions of the engine.

3.7 FLIGHT TEST PROGRAM

The acoustical environmental predictions will be substantiated during the ground and flight test program using aircraft 7004. Section 7.2.2 describes the test conditions and instrumentation.

3.8 AUXILIARY POWER UNIT NOISE PROGRAM

A design study will be performed for the APU installation, which must not exceed an overall sound pressure level of 100 db at a distance of 20 ft. Methods of exhaust and intake silencing will be analytically evaluated. A noise survey to substantiate the design will be performed on the Environmental Subsystem Simulator and compliance will be demonstrated with an aircraft noise survey.

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NOISE PREDICTION & GENERAL ACOUSTICS

ACTIVITY	1965	1966	1967	1968	1969	1970	1971	1972
I ANALYSIS								
(a) Noise Prediction and General Support								
(b) Substantiation								
II G.E. PROTOTYPE ENG. NOISE TESTS								
III ACOUSTIC MODEL TEST								
IV PERFORMANCE TEST STAND								
NOISE MEASUREMENT								
TEST PLANNING								
X ENGINE								
Y ENGINE								
TF ENGINE								
V ENDURANCE TEST STAND								
NOISE MEASUREMENT								
(a) Preproduction Test								
( ) Test Planning								
Test								
Data Red. And Anal.								

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NOISE PREDICTION & GENERAL ACOUSTICS

ACTIVITY	1965	1966	1967	1968	1969	1970	1971	1972
(b) Production Test								
Test Planning		▬	▬					
Test				▬				
Data Reduction & Anal				▬				
VI AIRCRAFT FLIGHT TEST								
TEST PLANNING			▬	▬				
TEST					▬			
DATA REDUCTION & ANAL					▬			
VII REPORTS								
(a) LG1S38-1-1, Prel.Anal.		●						
(b) LG1US58-1-1 Final Anal.				●				
(c) LG1UT78-1-1 Final Test Report					●			

4.0 ENVIRONMENTAL VIBRATION

4.1 GENERAL

Environmental vibration levels have been predicted for the C-5A aircraft and equipment qualification requirements are established. A continuing effort to update the prediction techniques and improve the environmental definition will include engine test stand and flight test program results. Adequate operation and design life of vibration sensitive equipment will be ensured by defining isolation systems, where necessary. A flight vibration survey of structural, crew and equipment areas will be performed to demonstrate compliance with MIL-A-8870 (ASG). A schedule of activities is shown on Pages 4.4 and 4.5.

4.2 ANALYSIS

4.2.1 Noise Induced Vibration

The most wide spread source of structural and equipment vibration in this aircraft is the acoustic field, which engulfs the entire outer surface. Structural response is primarily random in nature and its characteristics depend on the local structural configuration. The amplitude and frequency characteristics can be predicted with an experimentally derived empirical relationship between noise levels and structural response. Analysis of this relationship will be performed and values updated, if necessary, based on state of the art changes and test data. Revised noise levels will be used to update the predicted vibration levels, as necessary.

4.2.2 Mechanically Induced Vibration

Vibration at discrete frequencies is produced by engines, APU, pumps, and fans and thus is confined to local areas. Analysis of test cell or other operating data from these components will be used to update predicted vibration levels. Qualification and design requirements will be revised, if necessary.

4.3 DESIGN SUPPORT

4.3.1 Isolation Systems and Configuration Studies

Predicted vibration levels will be evaluated in conjunction with equipment design and qualification criteria to determine those components requiring isolation systems for protection. In addition, strong rotating (or alternating) vibratory sources, such as the APU, will be considered for isolation to protect adjacent mounting structure and equipment. Analytical studies and, if necessary, test programs will be performed to define the necessary isolation systems or, if subcontracted, the vendor program will be monitored and technical assistance rendered where necessary.

Gelac and vendor design groups will be assisted in defining stiffness and mass parameters for non-isolated items which are inherently affected by vibration such as probes and antennas. Configurations will be devised to satisfy design life requirements without undue penalties in weight and size.

4.3.2 Equipment Qualification Program

Vibration qualification criteria are established and will be applied to the design and test requirements for equipment developed for C-5A aircraft. Vendor proposals to implement this criteria will be evaluated and surveillance of the qualification test programs will be maintained, where necessary, in order that deficiencies can be corrected promptly. Final test reports will be reviewed for compliance.

4.4 CRITERIA TESTING

4.4.1 Engine Test Stands

The vibration qualification and design criteria are derived from the empirical relationship between ambient noise levels and random structural vibration in conjunction with continuous vibration produced by strong local sources such as the power plants. A program of vibration and noise measurements will be performed during the powerplant test stands and flight test program to improve the existing predictions.

4.4.1 Engine Test Stands (Cont'd)

These programs are outlined as follows:

(a) Endurance Test Stand - Accelerometers will be mounted on the engine, accessories, nacelle, pylon, and adjacent wing sections. Vibration data will be obtained throughout the available operating envelope as described in Section 7.1.

(b) Performance Test Stand - The performance stand will operate with the X, Y, and production engine configurations over an extended period. Vibration pickups will be located at selected engine locations and will be monitored as necessary throughout the program. Acceptable vibration levels for the engine installation will be determined statistically from the data obtained.

4.5 FLIGHT TEST PROGRAM

In order to demonstrate compliance with MIL-A-8870 (ASG) a flight program will be performed which will define the vibratory environment of the aircraft at all significant operating conditions. In general, vibration levels will be measured throughout the primary structure of the fuselage, wings, empennage, pods, nacelles, pylons, and in equipment and crew areas. Vibration measurements will be obtained at all significant ground and flight operating conditions. Test program details are described in Section 7.2.

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ENVIRONMENTAL VIBRATION

ACTIVITY	1965	1966	1967	1968	1969	1970	1971	1972
I. ANALYSIS								
(a) Design Support & Anal								
(b) Substantiation								
II. EQUIP. SPEC. REVIEW								
III. QUAL. TEST SURVEILLANCE								
IV. QUAL. TEST REVIEW & DEFICIENCIES								
V. PERFORMANCE TEST STAND								
VIBRATION MEASUREMENT								
TEST PLANNING								
X ENGINE								
Y ENGINE								
TF ENGINE								
VI. ENDURANCE TEST STAND								
VIBRATION MEASUREMENT								
(a) Preproduction Test								
Test Planning								

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ENVIRONMENTAL VIBRATION

ACTIVITY	1965	1966	1967	1968	1969	1970	1971	1972
Test			━					
Data Reduction & Anal.			━					
(b) Production Test								
Test Planning	━	━	━					
Test			━	━				
Data Red. & Anal.				━				
VII AIRCRAFT FLIGHT TEST								
TEST PLANNING			━	━				
TEST				━	━			
DATA RED. & ANAL.					━			
VIII REPORTS								
(a) LG1S38-2-1 Prel.Anal.		●						
(b) LG1US57-1-1 Prel. Design Reqmts.		●						
(c) LG1US58-1-1 Final Analysis				●				
(d) LG1US59-1-1 Final Design Reqmts.				●				
(e) LG1UT78-1-1 Final Test Report					●			

5.0 SONIC FATIGUE

5.1 GENERAL

In the past few years aircraft designers have had to cope with a relatively new fatigue phenomena, sonic fatigue. This damage to vehicle structure is caused by the resultant of numerous noise sources, such as, propulsion system exhaust noise, pseudo-noise in turbulent and separated air flow, and that resulting from operation of equipment items. This structural fatigue or damage is common in lightweight structure and can jeopardize the integrity of primary load carrying structural members if not accounted for during the design effort.

This section is intended to outline the methods and tests, from preliminary analytical work through strain measurements on a full-scale vehicle, for prevention of sonic fatigue damage to the aircraft structure, as required in MIL-A-8870 and as outlined in ASD TN 61-141. The flow diagram on Page 5.6 depicts the overall program for sonic fatigue prevention to be followed in the C-5A development. The schedule of activities is shown on Pages 5.8 and 5.9.

5.2 DESIGN CRITERIA

Sonic fatigue analyses and tests are to be based on a required service life of 30,000 hours with 12,000 takeoffs and landings.

The effect of combined environments will also be accounted for as necessary since in some instances, these analyses are not only dependent on the acoustic environment, but a combination of sound pressure levels, low frequency vibration, elevated temperatures, and pressure cycling. If any one or more of these environmental conditions is not considered during design in combination with the acoustic environment, the resulting loads could result in premature damage in service.

5.3 ANALYTICAL PROGRAM

The starting point for all analytical work in designing the C-5A

5.3 ANALYTICAL PROGRAM (CONT'D)

structure for resistance to sonic fatigue damage is, of course, dependent on the predicted near field acoustic environment, as shown in the flow diagram on Page 5.6. To date, these analyses have been primarily based on data from 1/16 scale acoustic model test programs which was conducted during Phase IB and IC of the C-5A development program. This work is continuing, as discussed in Section 3.0.

From the near field noise predictions, the C-5A will be divided into noise intensity zones with a view toward relative sonic fatigue damage. In those areas where the noise environment is relatively severe (the nacelles and pylons, and portions of the wing trailing edge structure) and the structure is very susceptable to sonic fatigue damage, close attention will be given to the development of structural configurations that will have a satisfactory service life. In those other areas of the aircraft where the noise environment is moderate to severe, details of the structural configurations shall be monitored, especially in light weight fairings and secondary structure, to assure that good design practices are followed and resistance to sonic fatigue damage is built-in each design.

As shown on Page 5.6, structural design for resistance to sonic fatigue damage and fatigue analyses and design studies are the next major milestones in the analytical program. These efforts are based on current state-of-the-art methods of analysis, case studies of similar operational aircraft, and test data available from previous component and full scale sonic fatigue tests.

The results of these fatigue analyses will be input to the structural design effort through a design improvement stage as shown on Page 5.6 to assure a satisfactory service life.

5.4 LABORATORY TESTS

5.4.1 High Intensity Sound System Tests

Since sonic fatigue analysis is not an exact science and many structural configurations do not lend themselves readily to analyses, laboratory component tests are necessary to complement the analytical program. To support the detailed design activities and to satisfy the requirements of MIL-A-8870 and ASD TN 61-141, a three phase laboratory sonic fatigue test program is scheduled to be run in the Lockheed sonic fatigue facility. This facility is a modern, fully equipped test lab with capabilities for random or discrete frequency testing using a high intensity sound system.

5.4.1.1 Development Tests

The first phase of this program is to test a series of development panels to evaluate new materials and evaluate design concepts for which no test data is available and which are not amenable to analysis; all of which are to provide data for minimum weight structure which has adequate sonic fatigue resistance. The results of these tests are to be input to the design effort through a design improvement cycle and at an early date to preclude possible costly redesigns and is to be available prior to final drawing release to manufacturing.

The table on Page 5.7 is a listing and description of development tests now in progress or planned for this phase of testing. It should be noted that other configurations may be required as the design develops.

5.4.1.2 Production Tests

As the various areas of structural design becomes more complete and during the early manufacturing effort the second phase of the laboratory sonic fatigue program is to be conducted. This consists of tests to failure of several panels of various production configurations. The test panels are to be built to production drawings, tolerances, and specifications and inspected by production quality control prior to test. It is proposed to show, from these tests, any deficiencies in the

5.4.1.2 Production Tests (Cont'd)

production configurations and items not uncovered during analyses and to keep retrofit to a minimum through timely feedback of test data through a design improvement cycle.

Structural configurations to be tested during this phase of the program are as follows:

1. Empennage
   a) four elevator panels
   b) four rudder panels
   c) four horizontal stabilizer panels
   d) four vertical stabilizer panels
   e) four fairing panels
2. Fuselage
   a) four fuselage side wall panels
   b) four MLG pod panels
   c) four aft cargo door panels
3. Wing
   a) twenty miscellaneous panels to be determined

5.4.1.3 Fix cycle Tests

Provision has been made for sonic fatigue tests that are not foreseeable at the present; therefore, there is a third phase of the laboratory sonic fatigue test program. This could include tests of service repairs for various configurations, evaluation of any redesigns due to service damage, or evaluation of cost reduction proposals through structural redesign.

5.4.2 General Design Support Tests

Laboratory tests as necessary shall be conducted to support design analyses. These may include response tests of structural configurations to measure strain and damping, response of hydraulic or fuel plumbing and its impact on clips and brackets, and preliminary investigations of materials and composite structures. These tests will be scheduled as

5.4.2 General Design Support Tests (Cont'd)

the need arises.

5.5 ENGINE TEST STAND ENDURANCE TESTS

In compliance with the requirements of MIL-A-8870 and ASD TN 61-141, a full scale sonic fatigue proof test of critically located structure is scheduled for the C-5A engine test stand. It is necessary to extend the results of sonic fatigue analyses and component tests to full scale hardware since structural edge conditions, structural coupling, and flexibility of support structure are difficult to account for in analysis and component tests. A two part 450 hour endurance test is scheduled; a 150 hour preproduction test and a 300 hour production test. This program is described in Section 7.1.

5.6 RTD Sonic Fatigue Test

At the conclusion of the 300 hour sonic fatigue endurance test at the engine test stand, the production test hardware is to be transferred to Wright Patterson Air Force Base and tested in the RTD sonic fatigue test facility. The hardware will be subjected to an accelerated life test to simulate the 30,000 hour aircraft service life. This is to be a full scale proof test and the hardware and instrumentation assemblies are to be tested as on the engine test stand except that 160 additional strain gages will be installed on the wing segment. Combined environments of sound, heat, and low frequency vibration will be studied during the detailed planning for the RTD test and will be dependent on the results of engine test stand program. Any unusual combinations of temperature or low frequency buffet loads will be simulated or accounted for in this program.

5.7 FLIGHT TEST PROGRAM

To further substantiate the analytical results and component test program, a production aircraft will be instrumented with strain gages and data recorded both onground and inflight. This program shall provide documentation of operating strain on all major structural assemblies where sonic fatigue failures could occur. Program details are outlined in Section 7.2.4.

Page 5.6
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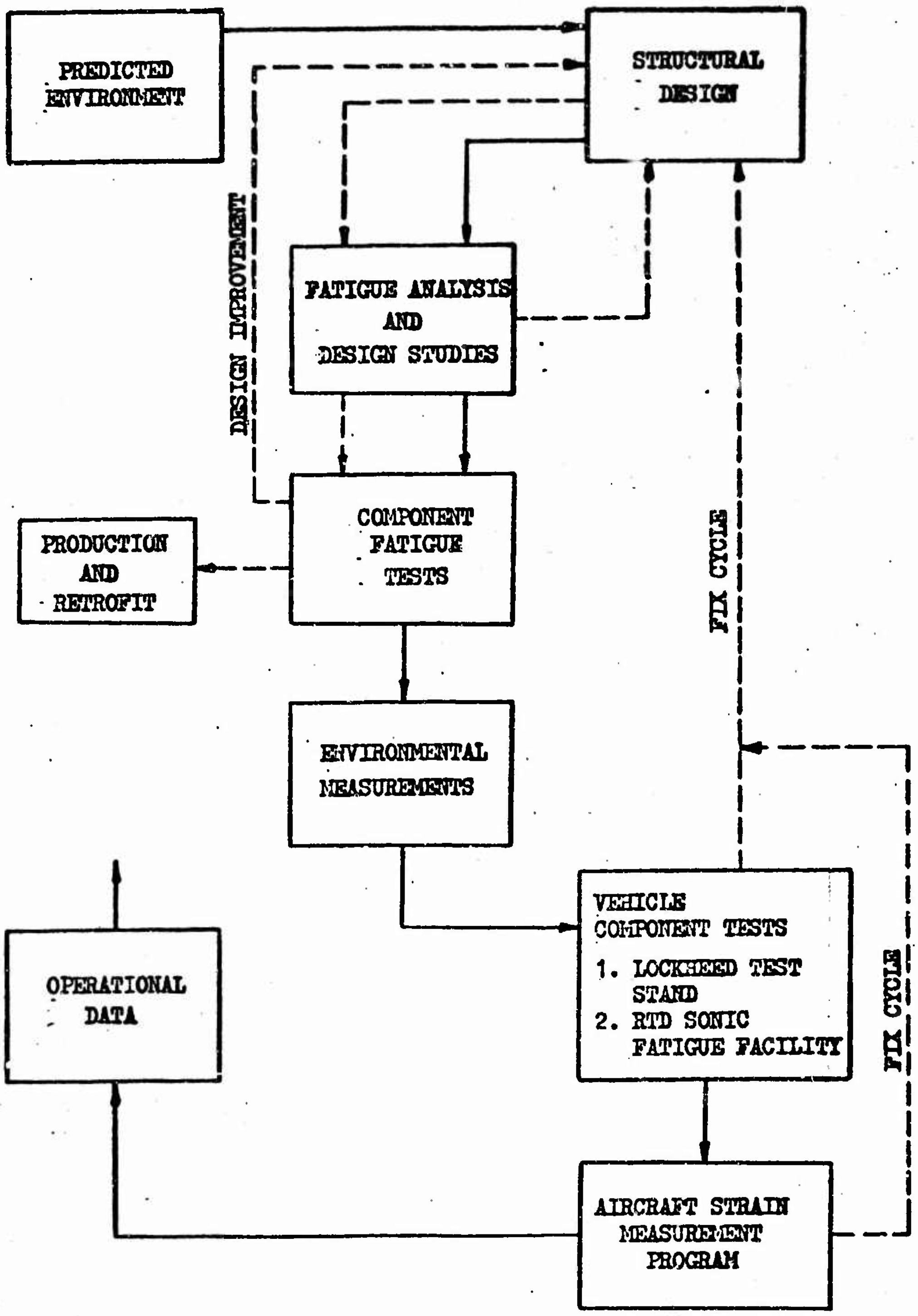
FLOW DIAGRAM FOR SONIC FATIGUE PREVENTION



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SONIC FATIGUE DEVELOPMENT TESTS

	Panel Configuration	No. of Specimens	Remarks
1.	Titanium Skin-Stringer	12	Six panels have titanium skins with aluminum stringers and six have titanium skins and stringers.
2.	Welded stainless steel and titanium honeycomb sandwich panels	6	Panels are all welded, commercially available honeycomb sandwich for high temperature applications.
3.	Honeycomb sandwich panel with fiberglas face sheets	6	All panels have fiberglas face sheets and aluminum core.
4.	Fiberglas bonded-beaded panels	6	All panels have flat fiberglas outer face sheet and beaded fiberglas inner face sheet, bonded together.
5.	Honeycomb sandwich panels with low density core	9	Standard aluminum sandwich panels with 2.3 to 2.8 lb/ft^3 honeycomb core.
6.	Large honeycomb sandwich panels	3	Standard aluminum sandwich panels approximately 40" x 60" in size.
7.	Other	As Necessary	Test panels to be defined as the design progresses; this will include more fiberglas evaluation, new methods of attaching sandwich panels to support structure, and welded titanium and steel.

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SONIC FATIGUE

ACTIVITY	1965	1966	1967	1968	1969	1970	1971	1972
I ANALYSIS AND DESIGN SUPPORT								
(a) Prelim. Sonic Fatigue Anal								
(b) Final Sonic Fatigue Anal								
(c) Substantiation								
II LABORATORY TESTS								
(a) High Intensity Sound System Tests								
Development Tests								
Production Tests								
Fix-Cycle Tests								
(b) Gen. Design Support Tests								
(c) Subsystem Tests								
III ENGINE TEST STAND ENDURANCE TESTS								
(a) Preproduction Test								
Test Planning								
Test								

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SONIC FATIGUE

ACTIVITY	1965	1966	1967	1968	1969	1970	1971	1972
Data Reduction & Analysis								
(b) Production Test								
Test Planning								
Test								
Data Reduction & Analysis								
IV RTD SONIC FATIGUE TEST								
(a) Test Planning								
(b) Test								
(c) Data Red. & Analy.								
V AIRCRAFT FLIGHT TEST								
(a) Test Planning								
(b) Test								
(c) Data Red. & Analy.								
VI REPORTS								
(a) LG1S38-3-1 Prel.Anal.								
(b) LG1US58-1-1 Final Anal.								
(c) LG1UT78-1-1 Final Test Report								

6.0 SOUNDPROOFING

6.1 GENERAL

The lightest weight soundproofing configuration which will be sufficient for obtaining the specified noise levels given on Page 6.4 will be determined. The program outline is shown by a block diagram on Page 6.5 and the work schedule is shown on Page 6.7.

6.2 ANALYTICAL PROGRAM

An existing computer program will be updated for calculation of interior noise levels, optimum soundproofing configuration, and maximum allowable internal noise sources in an occupied area. Noise levels will be predicted for take-off, maximum continuous power, and normal cruise conditions, as defined in MIL-A-8806 for each of the following areas.

a. Flight station area
b. Crew rest area
c. Forward troop area
d. Aft troop area
e. Cargo area

These areas are shown pictorially on Page 6.6. Input data for the computer program will be obtained from the following sources.

a. Data obtained from existing airplanes
b. Fuselage transmission loss tests
c. Interior partition transmission loss tests
d. Interior absorptivity tests
e. Internal equipment noise data
f. Predicted external noise levels

The optimum soundproofing configuration will be determined by alternatively performing analyses and tests.

6.3 DEVELOPMENT TESTS

These tests are necessary to develop more effective soundproofing techniques and to obtain data for the computer program. The development test program will be divided into the following categories.

a. Fuselage wall transmission loss
b. Internal partition transmission loss

6.3 DEVELOPMENT TESTS (CONT'D)

c. Interior absorptivity

d. Internal equipment noise

6.3.1 Fuselage Wall Transmission Loss Tests

Panels which simulate four foot by seven foot sections of the C-5A fuselage will be fabricated for these tests and will be tested with various soundproofing insulation configurations. Approximately the following number of transmission loss tests will be performed.

Panels	Number of Tests
Aft fuselage - Cargo area, 1 Ea.	20
Forward fuselage - Cargo Area, 1 Ea.	20
Upper fuselage - Crew & Troop Area, 1 Ea.	20

6.3.2 Interior Partition Transmission Loss Tests

Noise reduction capabilities shall be demonstrated on panels which simulate the internal partitions which separate areas of high internal noise equipment and occupied areas of the aircraft such as:

a. Environmental Equipment area

b. Hydraulic pump areas

c. Avionics area

6.3.3 Interior Absorptivity

Absorption measurements will be performed on new acoustical materials and/or modified configurations of trim cloth and liners. Absorption coefficients will be determined from reverberation time measurements with and without the sample placed in the reverberation chamber.

6.3.4 Internal Equipment Noise Tests

6.3.4.1 Air Conditioning System

a. Air Conditioning Ducts - Flow rates, duct sizes, weight, and attenuation properties are to be studied.

b. Mufflers - Insertion loss will be measured for various muffler configurations.

c. Air Conditioning Plenum Chamber - Attenuation will be measured between intake and exhaust openings.

6.3.4.2 Miscellaneous Noise Sources

Noise measuring tests will be performed to determine the overall sound power levels and spectrum shapes of the following equipment items which are potential noise sources.

a. Blowers
b. Recirculating fans
c. Hydraulic pumps
d. Turbine compressors
e. Outflow valves
f. Rectifiers

6.4 FLIGHT TEST PROGRAM

To verify that the interior noise levels do not exceed the specification levels for each area of the airplane, acoustic instrumentation will be installed in aircraft number 7004 and noise levels recorded as outlined in Section 7.2.2.4.

INTERIOR NOISE LEVEL REQUIREMENTS

Frequency Band, CPS	TAKEOFF Cargo Comp. Aft Troop, Fwd. Troop, Crew Bunk, Crew Rest, Flt. Sta. Table II from MIL-A-8806 (ASG)	MAX. CONT. POWER Cargo Comp. Aft. Troop, Fwd. Troop, Crew Bunk, Crew Rest, Flt. Sta. Table I from MIL-A-8806 (ASG)
Overall	120 db	113 db
37.5 - 75	118	111
75 - 150	118	111
150 - 300	118	111
300 - 600	112	105
600 - 1200	106	99
1200 - 2400	100	93
2400 - 4800	94	87
4800 - 9600	94	87

NORMAL CRUISE POWER

Frequency Band, CPS	Cargo Comp	Aft Troop Area	Fwd Troop Area	Crew Rest and Bunk Areas	Flight Stations
Overall	106db	106db	106db	106db	106db
37.5-75	96	98	98	91	88
75-150	101	103	103	93	89
150-300	103	100	100	95	89
300-600	96	83	83	83	83
600-1200	88	82	(Arithmetic ave. of these	(Arithmetic ave. of these	(Arithmetic ave. of these
1200-2400	86	81	three bands not to exceed	three bands not to exceed	three bands not to exceed
2400-4800	82	81	75db)	65db)	70db)
4800-9600	82	80	75	65	70

(db reference 0.0002 Dynes/CM^2)

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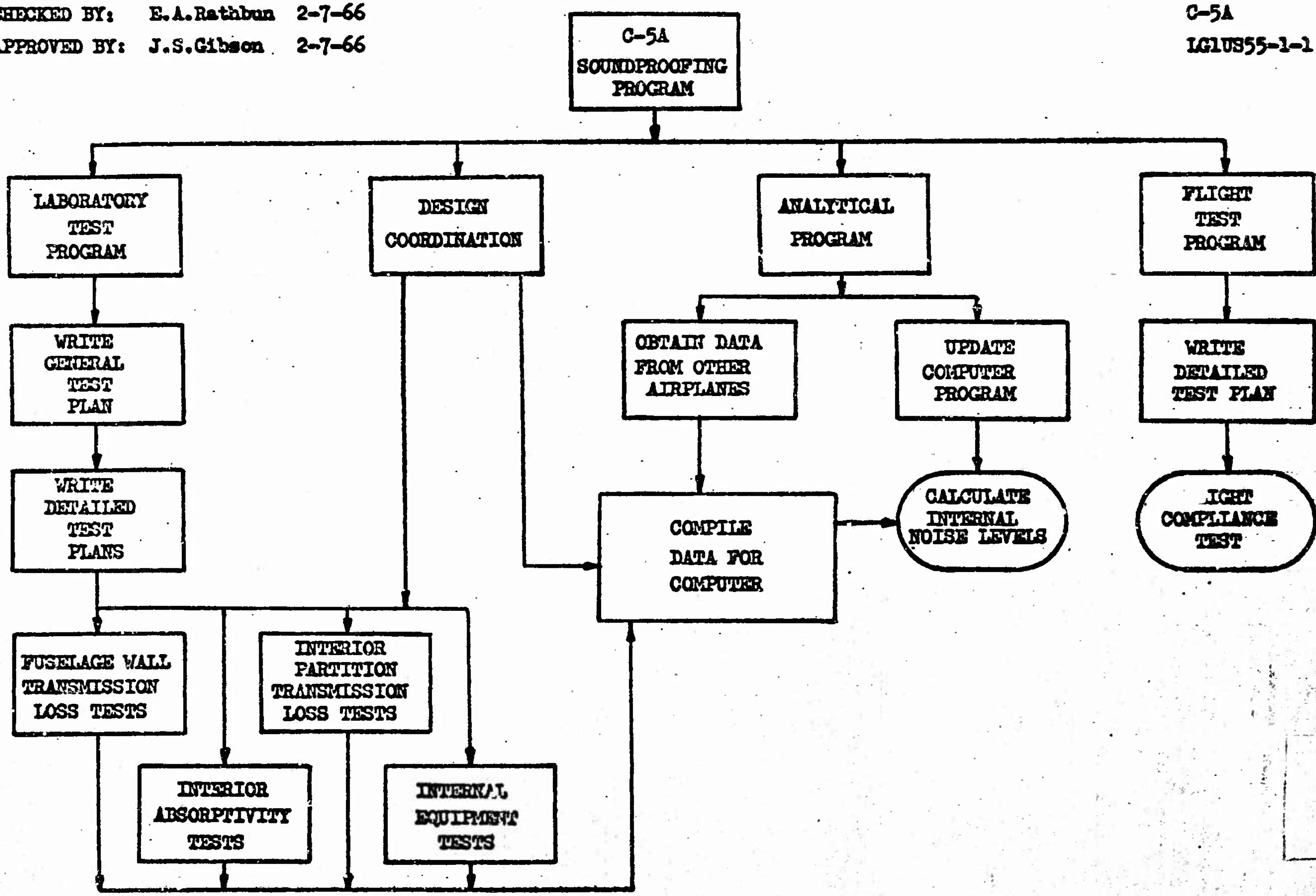
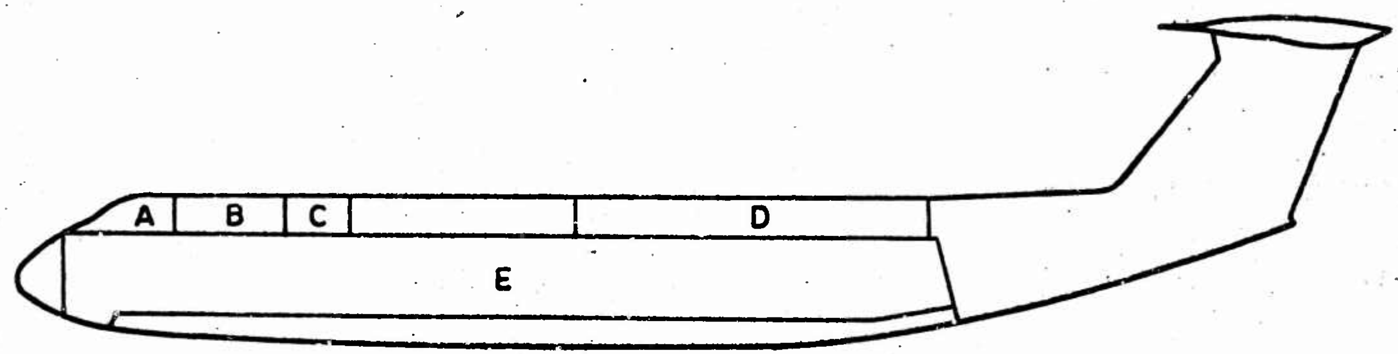


C-5A SOUNDPROOFING AREAS



A - FLIGHT STATION
B - CREW REST
C - FORWARD TROOP
D - AFT TROOP
E - CARGO

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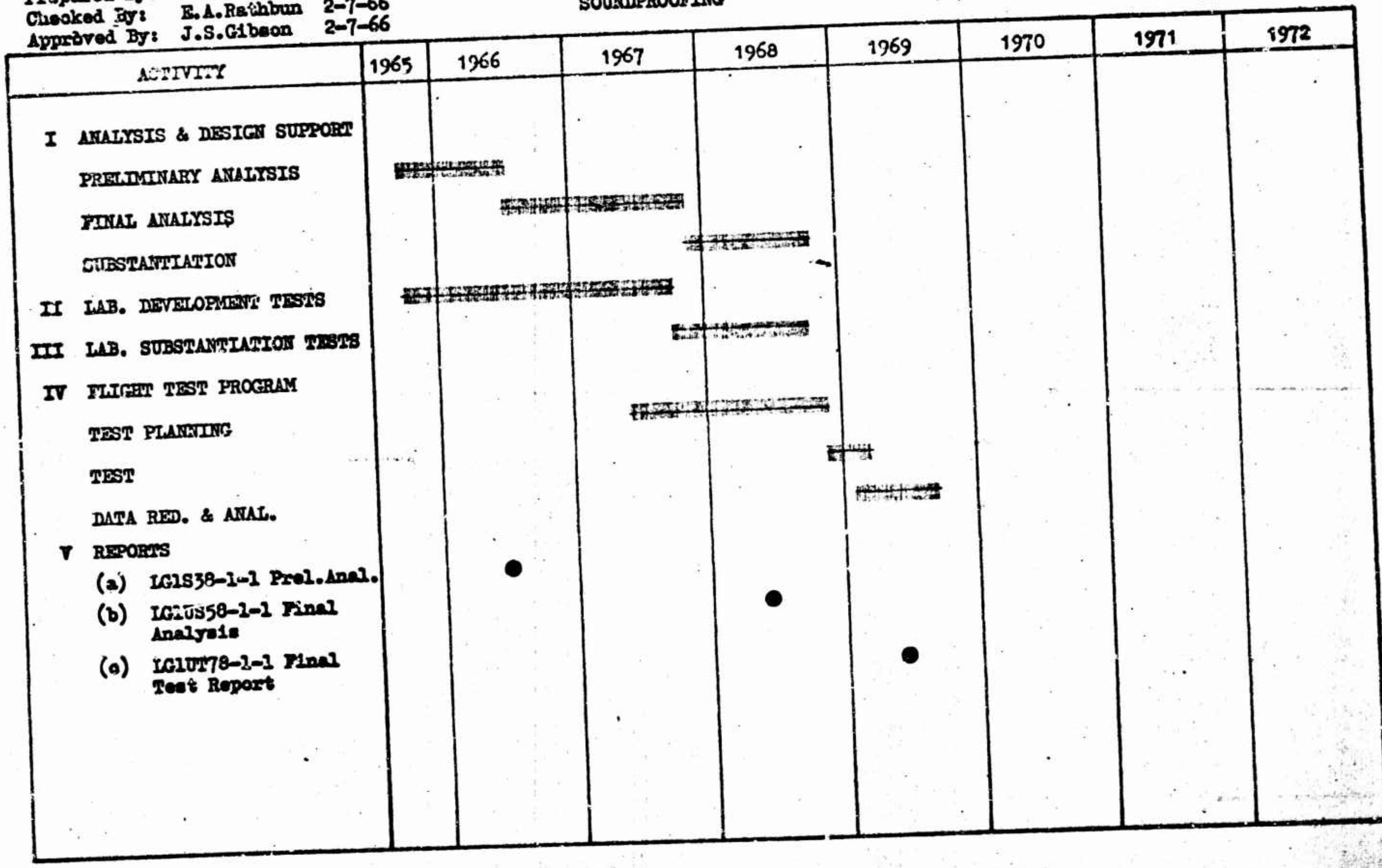
SOUNDPROOFING



7.0 MAJOR TEST PROGRAMS

7.1 ENDURANCE TEST STAND PROGRAM

7.1.1 Preproduction Tests

Since the flaps, nacelles, and pylons are exposed to the more severe acoustic environments on the aircraft, it is desirable to have test data as early as possible.

The hardware required for this test is as follows:

1. preproduction, flight-weight nacelle
2. preproduction pylon
3. Engine
4. preproduction outboard flap
5. preproduction outboard vanes
6. preproduction outboard cove doors
7. preproduction flap hinge system and fairings
8. preproduction flap actuators
9. preproduction vane and cove door actuators and hinge system

A dummy wing box segment will be provided to support the engine and the sonic fatigue test hardware. The installation will simulate an outboard engine position in the takeoff configuration. The flap, vanes, and cove doors will be operable. Magnetic tape will be utilized to record vibration, strain, and noise from the following transducers.

a. Sound-level surveys on external surfaces of structure will utilize 30 microphone locations.
b. Internal fan duct noise surveys will utilize 10 microphones.
c. Structural vibratory strain surveys will require 115 uni-axial strain gages.
d. Structural vibratory measurements will utilize 45 uni-axial vibration accelerometers.
e. Structural temperature surveys will require 90 thermocouples.
f. Vibration measurements on the basic engine will require 8 vibration accelerometers with an additional 15 for engine accessories.

7.1.1 Preproduction Tests (Cont'd)

The test will be conducted with the engine at power settings to simulate typical mission profiles from takeoff through cruise and back to landing with thrust reverse. Also, there will be a total of 110 thrust reverser cycles during this test. The total engine operation time during the test will correspond to approximately 1500 service hours.

7.1.2 Production Tests

At the conclusion of the 150 hour preproduction sonic fatigue endurance test the test hardware will be removed from the test stand and replaced with a production outboard wing segment and a 300 hour endurance test will be run. In addition to the wing segment, a production side aft cargo door is to be tested. The test is to run concurrently with the 150 hour production nacelle endurance test and the hardware is to be installed for the 250 thrust reverser cycles to be run at the conclusion of the 150 hour production nacelle endurance test. At the conclusion of the above testing, an additional 150 hours is to be accumulated for a total of 300 hours.

The production hardware required for this test is as follows:

1. Complete nacelle
2. Complete pylon
3. Engine
4. Outboard flap
5. Outboard Cove doors
6. Outboard flap vanes
7. Flap torque tube assembly
8. Flap actuator assembly
9. Flap brake assembly
10. Flap hinge system and fairings
11. Cove door actuators and hinge system
12. Vane hinges, actuators, and support structure
13. Outboard spoiler

7.1.2 Production Tests (Cont'd)

14. Complete spoiler actuator system
15. Outer wing box beam segment - that portion of the wing box from the production break outboard to the tip, completely stuffed with wire harnesses, hydraulic and fuel plumbing, control cables, and associated brackets
16. Fixed wing trailing edge structure - includes fixed panels, wiring, tubing, cables, and associated brackets
17. Wing leading edge structure - includes an operable anti-icing system, wiring, tubing, ducting, controls systems, and fixed leading edge support structure
18. Wing leading edge slats and actuators
19. Aft side cargo door and actuators

The wing segment is to be attached to supporting structure with aircraft splice plates and cantilevered as on the aircraft. The number 4 engine position is to be simulated with the hardware in the takeoff position during the test. The flap, vanes, cove doors, spoilers, leading edge slats, anti-icing system, and aft cargo door shall all be operable.

The side aft cargo door shall be positioned aft of the wing segment and in the same geometric relationship to the test stand engine as it would be to an inboard, or number 3 engine, when installed on the aircraft. Aircraft structure surrounding the door shall be simulated with a 3 - 4 foot wide boiler plate design.

As for the preproduction endurance test, mission profiles are to be simulated throughout the 300 hour production test. This consists of varying engine power setting from takeoff through cruise and landing with thrust reverse. Magnetic tape will be utilized to record vibration, strain, and noise from the following transducers:

7.1.2 Production Tests (Cont'd)

a. 70 external microphone locations

b. 10 internal fan duct noise survey microphones

c. 200 uni-axial strain gages

d. 80 uni-axial vibration accelerometers

e. 100 thermocouples

f. 23 vibration accelerometers on engine and accessories

7.2 FLIGHT TEST PROGRAM

7.2.1 General

The flight test program described herein will substantiate the acoustic, vibration, and sonic fatigue design and will demonstrate contractual compliance for these areas. Aircraft 7004 will be utilized for the program, as outlined in the following sections.

7.2.2 Noise Environment

7.2.2.1 Exterior Noise - Near Field

The basic exterior noise environment predicted for the C-5A air vehicle is the basis for the vibration, sonic fatigue, and soundproofing design studies. To ensure that the C-5A exterior noise environment has been accurately predicted, noise measurements will be made at 80 locations over the aircraft surface during onground engine operation. These data will be taken at the following conditions:

a. Takeoff power, takeoff flaps

b. Takeoff power, flaps retracted

c. Maximum reverse thrust, landing flaps

Exterior inflight noise measurements will be taken at 10 locations on the fuselage in compliance with MIL-A-8870.

7.2.2.2 Exterior Noise - Far Field

Static ground tests will be conducted at three engine power settings to obtain exterior far-field acoustical measurements. These noise measurements will be made at 5 locations on radii of 400 and 600 feet. In addition, measurements will be made at 3 locations 50 feet in front of the aircraft. These data will be utilized for evaluation of noise and safety

7.2.2.2 Exterior Noise - Far Field (Cont'd)

problems in the working vicinity of the aircraft in accordance with AFR 160-3A.

7.2.2.3 Community Noise Measurements

To evaluate the noise environment for communities adjacent to using-activity airfields, surveys of aircraft external noise will be made using ground-based instrumentation to establish noise-distance relationships for the C-5A airplane. Noise data from twenty takeoffs and landings will be recorded, at two ground stations, and analyzed to ensure good statistical averaging and to determine scatter limits due to variations in pilot technique and ambient conditions.

7.2.2.4 Interior Noise Environment

Interior environmental noise measurements will be made in all normally occupied areas of the aircraft to ensure that the C-5A design requirements are met. Measurements will be taken at approximately 36 locations and recorded on magnetic tape at the following operating conditions as defined in MIL-A-8806:

a. Take-off

b. Maximum continuous power at 22,000 feet

c. Normal cruise at 22,000 feet

7.2.3 <u>Vibration Environment</u>

The vibration measurement program will include both ground runs and flights. All data will be recorded on magnetic tape, using transducers to measure vibratory acceleration except for special instances where vibratory velocity or displacement is required. Transducers will be located approximately as follows:

Area	No. of Locations
a. Engine Cases	8
b. Engine Accessory Equipment	12
c. Avionics Equipment Racks	20
d. Fuselage	36
e. Wheel wells and pods	10
f. Wings	36

7.2.3 Vibration Environment (Cont'd)

g. Nacelles and pylons 10

h. Empennage 12

All transducers will be unidirectional except those on the engine case which will be radial.

In addition, crew station environmental vibration levels will be measured in flight at approximately 18 locations including the cargo and flight station floors, crew seats a tables, cockpit flight controls, and instrument panels in accordance with the test conditions and vibration limits of Paragraph 3.1.3 of MIL-A-8870.

7.2.3.1 Ground Tests

Vibration data from all transducers will be recorded during the following conditions:

a. Continuous power sweep through engine startup to takeoff power
b. Flap extension and retraction while at takeoff power
c. Continuous power sweep from takeoff power through engine shutdown.

7.2.3.2 Flight Tests

All transducers will be recorded during takeoff and one cruise condition. Selected transducers will be recorded during the remaining flight conditions. Test conditions will be as follows:

a. From just prior to brake release through takeoff and normal climb to 5,000 feet terrain clearance at approximately maximum takeoff gross weight.
b. Four airspeed-altitude combinations, including V_H at low altitude
c. Descent at constant airspeed
d. Acceleration from 1.2 V_S to V_H at constant altitude
e. Simulated wave-off, applying maximum power with landing flaps
f. Landing, from approach with landing flaps through touchdown, reverse thrust, braking, and back to idle

7.2.4 Sonic Fatigue

This program will provide measurements to verify structural designs for resistance to sonic fatigue damage. A flight test airplane will be instrumented with 300 uniaxial strain gages and data taken at various thrust settings and flight conditions in order to establish the magnitude of vibratory stresses throughout the aircraft. Strain measurements will be taken on the flaps, aileron, wing leading edge, pylon, nacelle, empennage, main landing gear pods, aft cargo doors, and fuselage. The flight test program for sonic fatigue will include both ground tests and flights.

7.2.4.1 Ground Tests

A comparative study has shown that most of the sonic fatigue damage to aircraft structure will occur during engine operations at high thrust settings. Therefore, the major portion of the program will be the engine ground runs for strain measurements. It will be necessary, however, to supplement these tests with flight data to obtain a complete documentation of vibratory stresses. Magnetic tape recordings of strain will be made for the following ground test conditions:

a. Continuous power sweep from idle to takeoff
b. Takeoff power, flaps retracted
c. Takeoff power, takeoff flaps
d. Normal engine reverse thrust, landing flaps

7.2.4.2 Flight Tests

The flight tests will consist of inflight strain measurements at critical locations determined by sonic fatigue analysis and ground test results. Magnetic tape recordings of strain data will be taken during the following test conditions:

a. From just prior to brake release through takeoff and normal climb to 5,000 feet terrain clearance at approximately maximum takeoff gross weight.
b. Four airspeed-altitude combinations which will provide data at maximum dynamic pressure, maximum Mach number, maximum cruise speed, and during inflight thrust reverse.

7.2.4.2 Flight Tests (Cont'd)

c. In the landing configuration, just prior to touchdown, power will be increased from flight idle to takeoff to simulate a wave-off condition. The run will continue until approximately 10 seconds after normal retraction of gear and flaps. This test will be conducted at about the maximum landing weight.

d. From just prior to touchdown through maximum reverse thrust after touchdown and back to forward idle power. Touchdown speed will be as required for maximum landing weight.

e. In the airdrop configuration, at heavy gross weight, maximum permissible true airspeed, and approximately 1,500 feet of altitude.

8.0 CONCLUSIONS

It is concluded that the program described herein is adequate to define the problem areas and provide analyses and tests to substantiate the aircraft for meeting the design requirements of MIL-A-8870, MIL-A-8806, and the detailed requirements outlined in CP40002-1A, CP40002-2A, and SS40001A.