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ASD TECHNICAL NOTE 61-141
PART I
TECHNICAL MEMORANDUM ASNDS-61-4

Detail Requirements and Status Air Force Structural Integrity Program

Part I Background and Requirements

COMPILED BY

R. W. BACHMAN

AND

H. M. WELLS, JR.

STRUCTURES AND AIR ENVIRONMENT DIVISION

SEPTEMBER 1961

AERONAUTICAL SYSTEMS DIVISION

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September 1961

Aeronautical Systems Division
Air Force Systems Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

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FOREWORD

Technical Memorandum ASNDS 61-4 was prepared in order to update WCLS Technical Memorandum 58-4 and to review the status of the Aircraft Structural Integrity Program. The Technical Memorandum is published as ASD Technical Note 61-141 to permit distribution by ASTIA in accordance with ARDC Regulation No. 80-5. This technical note will be revised periodically to show changes in progress and any changes in requirements which occur.

The authors wish to thank all of the personnel of the Aeronautical Systems Division who contributed to the compilation and organization of this report. Appreciation is also extended to the secretarial staff in ASNDS for its work in typing and reproducing this document. Extracts have been used from so many internal and published reports that it is impossible to include a complete list of these documents.

ASD-TN-61-141 is published as three separate physical documents: Part I, UNCLASSIFIED; Part II, UNCLASSIFIED; and Part II, Supplement I, CONFIDENTIAL. Part II, Supplement I entitled "Appendix B, Correspondence on ASIP," is classified CONFIDENTIAL because it includes Hq. USAF message AFCV C27229-M, dated 19 November 1958, and Hq. USAF letter, AFODC, dated 5 October 1959, both of which are classified CONFIDENTIAL. All other portions of Part II, Supplement I are UNCLASSIFIED.

Part I and Part II are available from ASTIA; Part II, Supplement I will be available only on a need-to-know basis from Aeronautical Systems Division.

ABSTRACT

This report:

1. Outlines the principal documentation which evolved during the period when the Air Force initiated and re-oriented the necessary research and development and service engineering required to evaluate the structural capability and life expectancy of USAF aircraft.

2. Documents the requirements for insuring Structural Integrity as outlined at the instigation of the ASIP.

3. Establishes the updated requirements for the ASIP to give the program the benefit of experience and events, and

4. Shows the status of the ASIP phases and the status of the application of these phases to each weapon system now in use by the Air Force.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

W. A. DAVIS
Major General, USAF
Commander
Aeronautical Systems Division
Air Force Systems Command

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Aeronautical Systems Division
Air Force Systems Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

Technical Memorandum ASNDS 61-4 Aeronautical Systems Division
26 September 1961

I. INTRODUCTION

I.1 PURPOSE

The purpose of this report is to:

a. In Section I.3, outline the principal documentation which evolved during the period when the Air Force initiated and re-oriented the necessary research and development, and service engineering required to evaluate the structural capability and life expectancy of USAF aircraft.

b. In Section I.4, document the requirements for insuring Structural Integrity as outlined at the instigation of the ASIP.

c. In Section II, establish the updated requirements for the ASIP to give the program the benefit of experience and events.

d. In Section III, show the status of the ASIP phases and the status of the application of these phases to each weapon system.

I.2 OBJECTIVES

The objectives of the Aircraft Structural Integrity Program are:

a. Establish, evaluate, and substantiate structural integrity (static strength and service life) of the system.

b. Continual re-evaluation of the initial structural integrity program utilizing the inputs from operational usage.

c. Develop statistical techniques for evaluation of operational usage and for logistic support (maintenance, inspection, supplies, etc.)

d. Develop structural criteria and methods for design, evaluation and substantiation of future systems.

I.3 BACKGROUND

I.3.a Initial Documentation by WCLS-TM-58-4.

Following the investigation of the B-47 accidents, presentations were made by ARDC Structures personnel from WPAFB to principal Air Force staff members. These presentations precipatated the TWX's and letters of Appendix B. These TWX's directed AMC, ARDC and consequently WADD to take all necessary steps to insure adequate service life. The Aircraft Laboratory issued Technical Memorandum WCLS-TM-58-4 on 27 June 1958 to "allow immediate implementation of this newly required fatigue evaluation"*. TM-58-4 was prepared "to present, in a detailed manner as possible, the general requirements incident to this new fatigue certification program"*. Since this was the initial documentation, the requirements were "presented as a guide to establishing the required fatigue evaluation programs and are not necessarily hard and fast requirements"*. USAF did establish specific requirements for service life in terms of flight hours and number of landings.

I.3.b. Formal Documentation of Air Force Structural Integrity Program (ASIP)

This program was formally established by Hq USAF message dated 19 Nov 58 AFCV C27229-M and documented by "ARDC-AMC Program Requirements for the Structural Integrity Program for High Performance Aircraft", dated 16 February 1959, and prepared jointly by ARDC and AMC. This document divided the work of the ASIP into eleven phases. All work to date on the ASIP has been performed under these phases. A brief description of each of the eleven phases as specified in the above report is given below:**

I.3.b.1 DESIGN CRITERIA

The design criteria phase establishes (from existing technology and the operational requirements) the design conditions to which the weapon system and its components must be designed and the methods of analysis and testing required to adequately prove the weapon system strength and estimate the expected fatigue service life.

The objective of this phase is to establish the design loading conditions, life requirements, design specifications, etc., and the methods of test and analysis to be used. Information for establishing this criteria comes from numerous sources, such as: MIL Specs; R&D in technical areas such as materials, construction techniques, atmospheric environments, etc; operational use predicted by the using command, etc; previous service loads programs (including 8 channel) on similar types of aircraft; and ground handling techniques.

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* Quotes are from WCLS-TM-58-4

** It should be noted that terminology and definitions are per original documentation. New definitions are contained in Part II.

I.3.b.2 MISSION PROFILE DATA

A mission profile of an air vehicle includes the following key items of data in terms of time as it performs its prescribed operational missions; i.e., gross weight, altitude, speed, flight configuration and incidence of unusual maneuver or loading conditions.

Mission profile data, when used in conjunction with statistical information on actual flight maneuvers, turbulence and ground loading conditions encountered, provide an improved basis for development of rational structural fatigue design requirements.

I.3.b.3 STATIC TEST

A static test consists of a planned series of tests conducted in a laboratory during which the thoroughly instrumented primary structure of the air vehicle is subjected to several load increments, increased step by step to 100 percent of the ultimate load point, for all critical flight and ground handling conditions. Temperature effects will be simulated on airframes on which elevated temperature environments impose significant effects.

The objective of flight vehicle static tests are: to insure that all flight vehicles are structurally adequate for the required design loads; to determine the degree of compliance with prescribed structural design criteria; to determine degree of growth potential available in the air vehicle structure; and to alleviate and prevent, where possible, future structural maintenance difficulties.

I.3.b.4 FLIGHT LOAD SURVEY

The flight load survey program consists of flying a completely instrumented aircraft through maneuvers and at speeds which duplicate the maximum required performance of a weapon system to verify the calculated load distribution and substantiate the structural integrity of each new airplane design. The flight load maneuvers are accomplished by flying the airplane through a series of design-type maneuvers (pull-ups, push-downs, rolling pull-out and rudder kicks) to obtain the structural loads on the wing, tail, and aft fuselage by strain gage or pressure measurements. The dynamic response portion of the survey is accomplished by measuring the structural loads while flying the airplane through atmospheric turbulence and during taxi and landing conditions.

The objectives of a load survey are as follows: flight determination and the evaluation of loading conditions which produce the critical structural load and temperature distributions; Verification or refutation of the analytical structural loads and temperatures used to design the airplane structure, structural integrity flight demonstration of the airplane for the critical structural flight conditions within the design envelope; flight investigation and evaluation of the elastic response characteristics of the structure to dynamic load inputs (gusts, taxi, and landings) for use in substantiating or correcting the fatigue analysis and interpreting the service loads (VGH) data.

I.3.b.5 LOW ALTITUDE GUST ENVIRONMENT

Gust intensity is a function of air density, terrain discontinuity and local meterological conditions in terms of time. It is essential that extensive fully instrumented data on gusts be accumulated between 0-1000 feet above the terrain since modern high performance aircraft are often forced by operational necessity to operate at low altitude where gust loads are most severe. To accomplish this goal a flight program has been established using an instrumented B-66. This aircraft incorporates a ten foot long instrumented boom extending forward from the aircraft's nose. This boom is used to measure the gust velocities, both horizontal and vertical, which exist at absolute altitudes of less than a thousand feet.

The objective of this program is to define the power spectral density (or gust intensity vs frequency) with regard to altitude, terrain, climate, and weather. It will also provide a verification or correction of existing theoretical methods of computing the transfer functions relating atmospheric turbulence to the response of known structural configurations. As a dividend, some of the aeromedical aspects of pilot response to low altitude turbulent flying will be determined The results of this program will be used to provide accurate and realistic inputs to the knowledge of fatigue of USAF aircraft on low altitude missions. The results will also contribute significantly to the service life determination program and to the formulation of more realistic design criteria for future flight vehicles. Photographic coverage of flight tracks should lead to improved methods of estimating gust loads and intensities over similar types of terrain regardless of location. The results of this program will be made available to the aeronautical industry.

I.3.b.6 FATIGUE TEST

The fatigue test of an air vehicle is a test program performed in the laboratory in which a spectrum of cyclic loads simulating anticipated or actual flight vehicle usage, or both, is applied repeatedly to the total aircraft structure and to selected (and separate) critical structural components. These tests are to determine probable sources of fatigue damage and to establish those structural fixes required to give the aircraft structure a satisfactory operational service life. Temperature will be simulated during the fatigue tests on aircraft for which elevated temperature environments impose significant effects.

The objective of this program is to determine, by test, the actual fatigue life of the flight vehicle. The fatigue tests are to provide: a ready reference gage of possible damage by comparison of tests results with service usage; for possible redesign early enough in the history of the weapon system to insure significant improvement in the life of the aircraft at relatively little increase in cost; for reduction or elimination (depending upon the timeliness of the test program) of maintenance problems which are incurred by structural fatigue; and a check of theoretically derived fatigue life.

I.3.b.7 SONIC FATIGUE PROGRAM

This program covers the investigation and developmental work resulting from fatigue failure of flight vehicle structures as caused by the magnification of stresses produced by alternating forces having frequencies near structural resonances. Such forces include powerplant noise, pseudo-noise in turbulent and separated air flow, and localized vibratory forces. Sonic fatigue failures can constitute a major maintenance burden and may affect safety of flight.

The objective of this program is to obtain for present and future flight vehicles an airframe subsystem embodying fail-safe design: which will preclude catastrophic failure due to sonic fatigue cracks; which can be readily inspected and repaired before failures occur affecting the safety and reliability of flight; and which exhibits low incidence of sonic damage consistent with a reasonable maintenance burden. A further objective is to recommend actions which will prevent adverse effects of sonic fatigue on flight vehicles.

I.3.b.8 HIGH TEMPERATURE

This phase covers the investigation of operational environmental conditions that may cause changes in stress distribution and/or the physical properties of airframe structural materials. This condition may cause or accelerate a fatigue type failure of structures subjected to repeated heating cycles.

The objectives of the high temperature structures phase are to determine: the operational environment of time-temperature-load; the effects of this environment on the structure of air vehicles; and the construction necessary to operate within this environment. The effects of time-temperature-load include changes in the loading and stress distributions, changes in the strength, life and fatigue characteristics, and existence of new modes of failure resulting from creep.

I.3.b.9 INTERIM SERVICE LOAD

The interim service load recording phase is a special, short-term effort to gather structural load information on current operational aircraft in order to provide the basis for establishing or re-evaluating the loading spectrum for full-scale fatigue cyclic tests.

The objective of this phase is to expedite the collection of service loads data on service aircraft pending delivery of a VGH life history recorder. The data from these programs will be processed and analyzed to provide the basis for establishing or re-evaluating the loading spectrum for full scale fatigue cyclic tests.

I.3.b.10 VGH LIFE HISTORY RECORDING

The VGH life history recording phase is to determine the structural loads encountered by operational type aircraft in order to provide a realistic basis for the establishment or re-evaluation of fatigue spectra, service life expectancy, inspection schedules and techniques, IRAN schedules, new mission techniques and operational limitations. This program involves all types of first line aircraft of the USAF fleet. The combined efforts of AMC, ASD and the using Operational Commands are necessary.

The objective of this phase is to instrument approximately 20% of selected operational aircraft with life history recorders measuring Velocity (V), Normal Acceleration (G), and Altitude (H). Certain aircraft of high performance and/or limited quantity will be instrumented to larger percentages.

I.3.b.11 8-CHANNEL SERVICE LOAD RECORDING PROGRAM

The 8-channel service load recording program is a program to determine structural loads imposed on operational aircraft relative to six (6) degrees of freedom in order to provide a realistic basis for the refinement of the VGH life history program as well as refinement of criteria for structural design of future weapon systems.

This program is to instrument approximately three hundred (300) first line aircraft with the 8-channel recording systems. Angular rate sensing devices (pitch, roll and yaw) and three (3) component linear accelerometers will be procured and utilized with the Signal Data Recorder (A/A24U-3) systems to provide the 8-channel capability. This requires no modification of the basic VGH recording systems. The data from this program will be processed, evaluated, analyzed and presented in a form suitable for use in the refinement of the VGH life history data and criteria for structural design of future weapon systems. These data will also be correlated with that obtained from the static and cyclic tests, flight load surveys and the flight dynamic analysis tests.

I.4 UPDATING THE ASIP

The above phases which have been used to subdivide the Structural Integrity efforts to date were not and are not sufficiently definitive to adequately organize and document the efforts on the ASIP. As a result, some important aspects of the work have been forced into a status of a sub-phase of the closest associated phase. As a consequence, this report has re-oriented and/or retitled some of the original eleven phases of the ASIP as outlined in Figure 1. Discussions of the program in the remainder of this report will be written in terms of the new phasing as shown in Figure 1 and 2 and defined under the appropriate paragraphs.

A list of reports prepared by ASD is included (Appendix A) for the purpose of updating at least some of the research and development effort performed since the start of the ASIP. They are intended to be of use to personnel working in the areas of the ASIP and related projects.

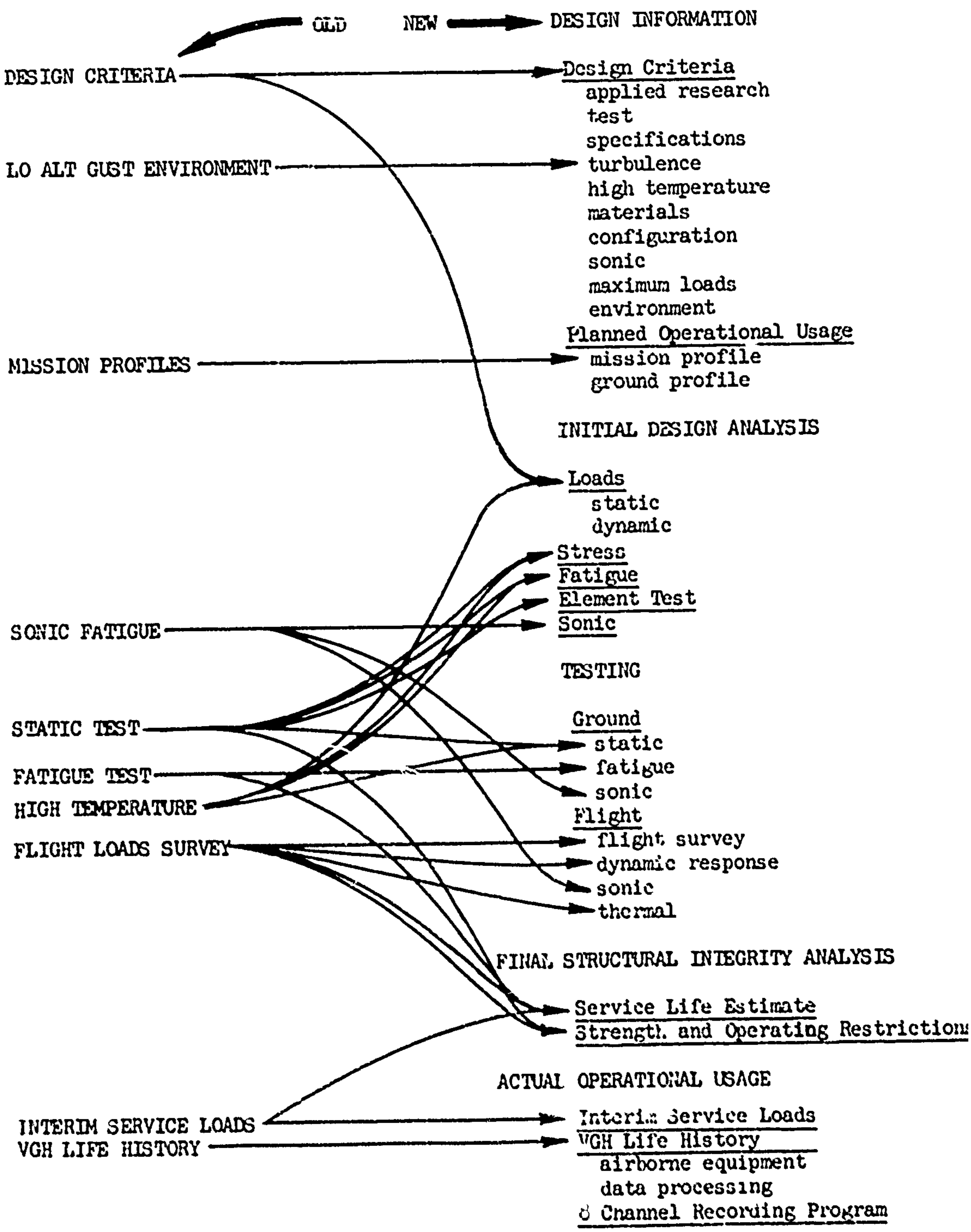

FIG. 1 Elements of the AIR FORCE STRUCTURAL INTEGRITY PROGRAM

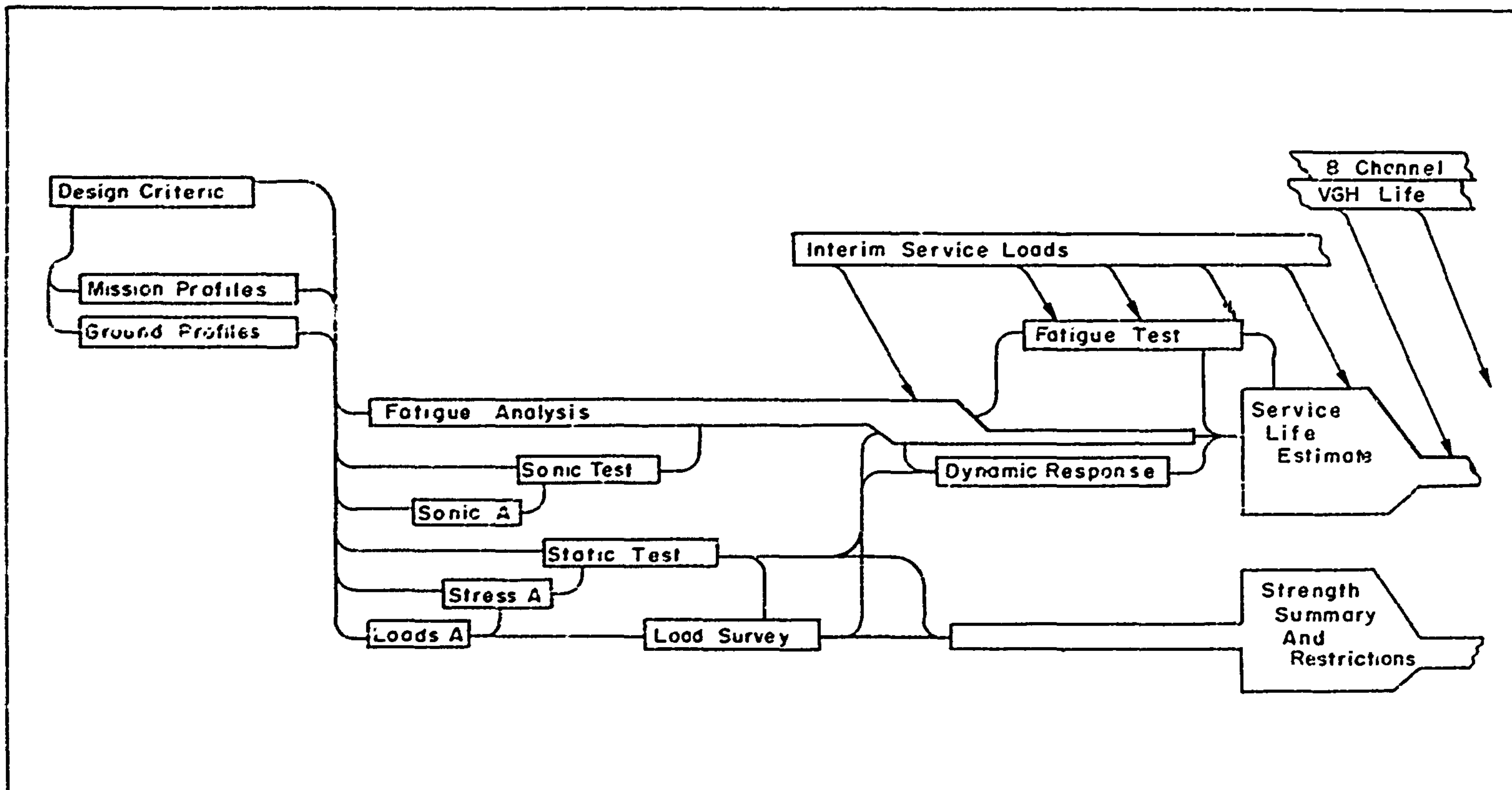

FIGURE 2 A S I P FLOW DIAGRAM

II. DISCUSSION OF ASIP REQUIREMENTS BY PHASES

II.1 RESEARCH AND DEVELOPMENT ORIENTED PHASES

II.1.a. Design Information

Design information encompases all research efforts required to provide the theoretical and practical applied research necessary to maintain structural design criteria for all present and future flight vehicles and to establish structural limitations. The goal is to insure the structural integrity of the vehicles and their components during operational use and throughout the required service life. To insure adequate design information, research programs, demand a continual re-examination to provide concepts, and techniques for their application, which will have universal validity. The efforts in this research area are not directed to any one weapon system but are critical items in advancing state-of-the-art of structural design criteria. Areas of concern include, but are not limited to, materials research, sonic fatigue, configurations, manufacturing and construction processes, hot and cold stress analysis techniques, atmospheric environments, etc.

II.1.b Test Research

Continuous effort is required to develop the technique of laboratory simulation and associated test criteria to have an acceptable state-of-the-art ready for the weapon system when its development cycle reaches the test stage. It is worthy to note that the advanced test techniques for future vehicles require lead time in development commensurate with, and sometimes greater than, that required for the vehicle itself.

Included in the test research effort associated with the ASIP effort are the techniques and methods of ultimate load structural test with thermal environment simulated, fatigue test of composite structures, and laboratory tests of composite structures in a sonic environment.

II.1.c Actual Operational Usage

To satisfy the objectives for the VGH Life History Program and 8-Channel Recording Program as outlined in Paragraph I.3.b.10 and I.3.b.11, research and development of data acquisition techniques are required to provide instrumentation that will accurately record data for long periods of time with minimum attention by line personnel and lend itself to automatic data processing. Installation requirements dictating limited size, weight and power provisions further support the need for research and development.

To minimize the time interval from collection to application of the vast amount of data obtained from these programs, it is necessary to continue the development of automatic data processing facilities.

II.2 SYSTEMS ORIENTED PHASES

II.2.a Design Information

Design Information encompasses all efforts required to apply the existing theoretical and applied research results to a specific structural design criteria for all present and future flight vehicles. The objective is to insure the structural integrity of each weapon system during design and throughout its required service life. These efforts therefore require re-examination throughout the service life of the weapon system.

II.2.a.1 Design Criteria

The Design Criteria efforts are directed toward specifying the detailed requirements for design of the structure of a weapon system with respect to such things as materials, construction techniques, environment, etc.

The Aeronautical Systems Division will use data from all phases of ASIP to generate revisions or additions to the MIL-Spec series as necessary. The specific design criteria will be given to the contractor as existing MIL-Specs or equivalent existing government aircraft design publications, as altered and revised by Model specifications and contractual agreements.

Once the design criteria are established and the vehicle becomes a physical entity, certain steps are required to assure the Air Force that it is receiving a vehicle which meets the design criteria. These steps are covered in the other phases of the ASIP which are described in subsequent sections.

II.2.a.2 Planned Operational Usage

The Planned Operational Usage efforts are directed toward predicting, either in the design stage or during service life, the specific utilization of the weapon system of the using commands. Consideration must be given to the loads and conditions of use resulting from flight during various missions, as well as those resulting from ground operations such as taxi, towing and engine run-ups.

The information obtained, when used in conjunction with statistical data on actual flight maneuvers, turbulence and ground loading conditions encountered, provide an improved basis for development of rational structural fatigue spectra and design or retrofit requirements. The data required from each of these phases are discussed in the following paragraphs.

II.2.a.2.a Mission Profiles

The Mission Profile of a weapon system includes the following key items of data in terms of time as it performs each prescribed mission from take-off to touchdown: gross weight; altitude; speed; flight configuration; mission phases; landings; stores released; and any other unusual characteristics of the flight. Using commands will be continuously consulted to determine data on planned and existing flight mission profiles. Where possible VGH Life History data and interim service loads data will verify or revise the using commands estimate of mission profiles, and the amount of flight time spent in each type of mission. Contractors performing a fatigue analysis will be provided the various mission and usage information for their aircraft.

II.2.a.2.b Ground Profiles

A Ground Profile of a weapon system includes the following key items of data in terms of time and rates of occurrances; taxi speeds and durations, braking and turns, engine runs, towing, runway roughness characteristics and mission aborts.

Steps must be taken to determine the loads encountered during these ground handling operations. The data will normally be estimated during the design phase using knowledge acquired from observation of previous aircraft having similar operational usage. Following delivery of the weapon system to the using command a survey of the utilization of the aircraft while on the ground must be made an input to the fatigue analysis. This should include statistics on accumulated engine time on the ground under various engine operating conditions for confirming or modifying estimates made in sonic fatigue analyses and tests.

II.2.b Initial Design Analysis

The initial design analysis consists of determining: the loads environment; the stresses resulting from these loads; the life estimate based upon the loads, stresses, and element tests; and the sonic environment.

The objective is to establish, analytically, the structural integrity and estimated service life of the aircraft.

II.2.b.1 Loads Analysis

The loads analysis consists of establishing the magnitude and distributions of all applied external loads such as aerodynamic loads, ground reactions, inertia loads and fatigue load spectrums. The analysis will include the effects of temperature and aeroelasticity.

The objective is to establish the loading conditions which the structure must withstand in the performance of its missions.

A loads analysis shall be performed for the analytical determination of the critical loads used in the structural design of the air vehicle. The detail requirements are contained in Spec MIL-S-8868 (ASG).

II.2.b.2 Stress Analysis

The stress analysis consists of the analytical determination of the stresses resulting from the loads and temperatures imposed on the airframe.

The objective is to establish the ability of the airframe to sustain the critical loading conditions within the specified strength requirements.

A stress analysis shall be performed for the analytical determination of the ability of the aircraft structure to support the critical loads and to meet the specified strength requirements. Detailed description of the extent of the analysis and subsequent stress analysis report is contained in Spec MIL-A-8868 (ASG)

II.2.b.3 Fatigue Analysis

The fatigue analysis consists of the analytical determination of the service life of the airframe resulting from the application of repeated loads and thermal conditions.

The objective is to establish the ability of the airframe to sustain repeated loading conditions for the required life.

For each aircraft series and for any model of the series where there is a significant change in the structural configuration or loads, the contractor shall perform a fatigue analysis. For those weapon systems in the process of design, the analysis will indicate those structural changes necessary to provide the safe life as outlined in Table 1 and as stipulated in paragraph II.2.c.2. The analysis will indicate the life inherent in the structure and any structural changes required to provide the desired life for those weapon systems that are in service. The detail requirements are contained in Spec MIL-S-8868 (ASG).

The analysis shall be approved by ASD prior to the start of static test for those aircraft which are in the design stage. This is to assure that any structural modifications indicated by the analysis are incorporated into the static test article. The analysis should be approved by ASD prior to the start of the cyclic test for those aircraft that have completed the static test phase.

The load spectrum used shall be based on the planned combat and training operational usage, and the number and type of missions to be flown on a yearly basis as determined by the using Command and ASD. The mission profile data shall be supplemented by actual operational profiles as determined by VGH Life History programs on the subject weapon system or on similar aircraft. The loading spectrum shall also include appropriate and pertinent statistical loads data collected on gust, maneuver, landing and taxi loads by the various government agencies. Consideration shall be given to the effect of the dynamic (rigid and elastic) response of the aircraft on the amplitude and frequency of load. Aircraft in design stage shall use the spectra specified in Spec MIL-A-8866 (ASG).

II.2.b.4 Sonic Loads

Sonic loads are expressed in terms of an external noise level which impinges on the vehicle structure. By considering the pressure loads and exposure times from all noise sources at each vehicle operational condition during anticipated missions, the sonic fatigue design loads can be established within reasonable limits for all areas of the vehicle structure.

The application of the estimated sonic loadings to a structural design primarily involves due cognizance of fatigue design principles including application of fail-safe construction. Where noise levels on the external surface of the structure exceed 145 db, experience has indicated that sonic fatigue is likely to occur in light secondary components. Therefore, when the noise levels increase, so must the design fatigue resistance be increased. The structural designer must consider materials, dimensions, spacings, stress risers, stiffness and construction details which affect the fatigue life as well as incorporation of fail-safe design where required. Honeycomb sandwich and bonded constructions are especially useful for aircraft where noise levels are relatively high.

Lack of precision and deficiencies in methods of accomplishing reliable sonic fatigue analyses necessitates a considerable amount of component or element testing to establish fatigue characteristics with regard to sonic loads. Component testing should be accomplished as early as possible in conjunction with the design fatigue analysis. Two types of component testing are generally accomplished as follows: (1) Evaluation of fatigue life of components is accomplished by properly orienting the structure in an actual or properly simulated noise field. (2) Evaluation of relative improvements in fatigue life is accomplished in a horn or siren test facility.

II.2.c Testing

II.2.c.1 Static Tests

The static tests difinition and objective are contained in paragraph I.3.b.3.

All aircraft will be static tested in accordance with MIL-A-8867 (ASG) to ultimate loads in the critical conditions. These tests and the combined flight load survey and structural integrity flight demonstration will be used to verify the structural integrity of the aircraft for critical load conditions. The static test constitutes the initial test in the total test program.

II.2.c.2 Fatigue Tests

The fatigue test definition and objective are contained in paragraph I.3.b.6.

The verification of the fatigue life predicted by the fatigue analysis will require a full-scale cyclic test of the complete airframe. This test program shall be scheduled after the completion of the major portion of the static test program in order that a completely representative airframe, incorporating any required structural changes, will be employed. The test article shall be a complete basic airframe with no previous flight or test history. This includes all necessary alighting gear for independent test of these components.

The fatigue life requirements (Table I) in terms of safe life service hours and number of landings are presented for use in the fatigue evaluation. These hours do not include any statistical factors to allow for scatter in fatigue results or for predicting fleet safe life from a limited number of test articles. Consideration will be made in the design stage to successfully demonstrate adequate fatigue life during cyclic test, as outlined below.

Continual review of the results associated with aircraft undergoing fatigue testing and their service experiences, and the statistical nature of fatigue has resulted in the application of test factors. These test factors are applied to the results of the full scale test program and are used for the establishment of inspection periods, retrofit periods and safe life for service aircraft. The full scale fatigue test program shall demonstrate a duration of 4 times the safe life requirements of Table 1 or as directed by ASD. Two full scale aircraft will be considered for fatigue test. The second aircraft will be used to establish the integrity and life of fixes established as a result of premature failures of the first aircraft. Both aircraft are to preceed the flight hours of the fleet with the first aircraft preceeding the fleet by at least a factor of 4. The establishment of time periods for fleet inspection and retrofit procedures shall be based upon a reduction factor of 4 from the time failure occurred in the fatigue test article.

The test spectrum shall be derived from the load spectrum and shall consist of a minimum of five load levels. Application of the test spectrum in block form should not exceed a total of approximately fifty hours of equivalent flight hours per block. The test load simulation shall be able to reasonably duplicate the intended shear, moment, and torsion throughout the test component involved.

Adequate instrumentation and inspection shall be maintained to insure, within practical limits, that when and if fatigue cracks occur they may be detected as near their inception as possible. Crack detection and stress instrumentation shall be subject to approval by ASD. Special attention shall be paid to those areas shown critical by fatigue analysis and areas that do not lend themselves to accurate stress analysis or ease of inspection.

The extent of element and component fatigue tests in addition to the full scale tests will be dependent upon the indications of the fatigue analysis and the full scale test results.

II.2.c.3 Sonic Tests

Sonic loads should be determined by actual measurement of the external noise levels which impinge on the structure and associated vibratory responses and stresses during service type missions, including ground operation of power plants. The test is necessary to confirm or reveal deficiencies in load estimates which have formed the basis for design. This testing is normally accomplished in several phases starting with measurements in test cells for development engines and concluding with final tests on the actual full scale flight vehicle.

A proof demonstration test is the final step in the development cycle. It is normally a test of a full scale airplane. However, use of major portions of the airplane in ground test stands is sometimes acceptable. The requirement for this test phase results from deficiencies in the methods of fatigue analysis which are essentially state-of-the-art deficiencies, and also from compromise in number and inadequate simulation of component testing forced by production schedules. The proof demonstration for sonic fatigue reveals the design details and areas of the structure which have inadequate service life in the final vehicle. It also serves as a basis for estimating the repair maintenance burden for developing inspection and repair techniques for the using services. The proof demonstration has been accomplished in the past by operating the power plants on the ground under the most severe condition of noise impingement on the structure for a sufficient time to indicate reasonable structural service life. In certain aircraft, special problems will arise requiring specialized approaches.

II.2.c.4 Flight Load Survey

The definition and objective of the flight load survey are contained in paragraph I.3.b.4 except for references to the dynamic response tests.

All aircraft will perform a combined flight load survey and structural integrity flight demonstration in accordance with Spec MIL-S-5711.

II.2.c.5 Dynamic Response Tests

The dynamic response tests are defined and the objective stated in paragraph I.3.b.4 except that taxi condition are broadened to include towing conditions.

These tests shall consist of performing a gust load survey, landing and taxi tests, and typical mission profiles as outlined below and of measuring the dynamic loads, gust velocities, and test condition parameters as appropriate for each type of test. Unless otherwise specified, the dynamic response tests shall be performed on the flight loads aircraft at the conclusion of the flight load survey program. In the event these tests can be phased into the program without delaying the flight load survey tests, this should be accomplished subject to the approval of the Procuring Activity.

The gust load survey investigation shall consist of flights through turbulence with the aircraft loadings, configurations, and speeds that are representative of service operation. If Mach number or altitude effects are expected to be signifcant, several test ranges shall be investigated. In addition, for those airplanes capable of inflight refueling, tests shall be conducted during simulated in-flight re-fueling with the aircraft loading, configurations, altitudes, and speeds that are representative of service operation.

The dynamic landing loads tests shall consist of a sufficient number of soft, moderate, and hard landings to adequately define the landing gear loads, and transfer functions between gear loads and the wing and fuselage structure. The taxi load tests are intended to define the effects of various taxi and towing as well as runway roughness with respect to the dynamic elastic effects of the aircraft landing gear and structure at representative loadings, configurations, and speeds.

The mission profile tests are for verifying or improving the analysis and fatigue test load spectrums for incorporation into the fatigue test program to determine service life for actual operational usage.

The contractor shall confer with the Procuring Activity to establish the extent of the dynamic response tests required for his particular aircraft.

The flight loads information so gathered will be used for establishing the loads and load distributions and transfer functions in conjunction with the load factor, gross weight, airspeed and altitude occurrences determined by the VGH Life History Program (or Interim Service Loads Program).

II.2.c.6 Thermal Flight Tests

Thermal flight tests are those tests conducted as part of the flight load survey during which the aircraft encounters significant temperature conditions on the airframe. The objective is to obtain flight determination of the temperature conditions for verification or refutation of the analytical temperatures used in the design of the airframe.

Flight tests to determine the temperatures of various components of the airframe shall be conducted as a part of the Flight Load Survey (II.2.c.4).

II.2.d Final Structural Integrity Analysis

II.2.d.1 Strength Summary and Operating Restrictions Analysis.

The strength summary and operating restrictions analysis consists of summarizing the strength of the aircraft for all specified design conditions and recommendations for restrictions for operational use of the aircraft as based upon the results of ground and flight tests.

The objective is to establish the structural integrity of the aircraft for the design conditions or the necessary flight and ground restrictions required to maintain structural integrity within the boundary of the actual strength of the aircraft.

A strength summary and operating restrictions analysis is required for each aircraft as per Spec MIL-S-8868 (ASG) and described further in ASTIA Document No AD 118326 (WADC TR 57-162). This analysis (and subsequent report) is to be revised as changes are made to the aircraft structure.

II.2.d.2 Service Life Estimate Analysis

The Service life estimate analysis consists of integrating the results of the ground and flight tests, and service loads data if available, into the fatigue analysis (II.2.b.3).

The objective is to establish the estimated service life of the aircraft for its defined operational usage and to permit future revisions in the event of significant changes in the operation of the aircraft.

A service life estimate analysis should be maintained and revised on a continuing basis. All significant information from interim service loads recording programs, VGH Life History recording programs, structural integrity flight load surveys, flight dynamic response tests, static tests, full-scale cyclic tests, element fatigue tests and component cyclic tests shall be incorporated.

Since the fatigue analysis is dependent to a great extent on the operational usage, there is no "complete" final analysis as inputs from the VGH Life History programs may require a revised analysis. Proposed mission changes shall require a fatigue analysis in order to predict the impact on the life of the weapon system. Therefore, the fatigue analysis should be conducted and reported in a manner as to enable such revisions to be made with only minor effort.

II.2.e Actual Operational Usage

The establishment of service life expectancy is dependent to a large extent on the accuracy of the loads spectrum used in the fatigue tests and in the analyses. In order to establish or refine the loads spectrum of each of the aircraft in the ASIP program, it is required that the actual loads encountered by these aircraft be measured. These measurements will be made by the installation of VGH recorder systems as specified by ASD.

II.2.e.1 Interim Service Loads Program

The definition and objective of the interim service loads program are stated in paragraph I.3.b.9.

The lack of a suitable VGH recorder system for use in the VGH Life History program has imposed the requirement for conducting interim service load recording programs beyond the scope of the original program which included only SAC aircraft. This is due to the need for load spectrum information for use in fatigue tests and analyses on aircraft presently undergoing such tests and analyses. These data were to have been available from the VGH Life History Program. The particular aircraft, number of recorders, period of recording and data processing are presented in Figure 3.

II.2.e.2 VGH Life History Program

The VGH Life History Program is defined and objectives stated in paragraph I.3.b.10.

The detail requirements for each of the aircraft, are presented in Table 2. The recorder requirements are listed under two dates. This was done to indicate that if recorders were not available for January 1962 installation, certain adjustments in quantity would be necessary due to attrition of aircraft and introduction of new aircraft systems.

Table 1 Service Life Requirements*

Aircraft Type - Operation	Flight Hours	No of Landings
Bomber, Ground Alert	10,000	5,000
Air Alert	40,000	6,000
Air/Ground Alert	10,000	4,000
Tactical	5,000	2,500
Cargo, Assault	10,000	5,000
Medium	30,000	12,000
Heavy	30,000	12,000
Utility	15,000	15,000
AEW & C	50,000	10,000
Tanker	10,000	7,500
Fighter, Interceptor	4,000	4,000
Tactical	4,000	4,000
Trainer, Subsonic	15,000	37,500
Supersonic	15,000	37,500

* This information was extracted from Hq USAF (AFODC) Ltr "Aircraft Service Requirements", 5 Oct 5[illegible] copy of which is contained in Appendix I.

Table 2 VGH Life History Recorder Distribution Requirements

Aircraft	Original	Recorder Requirements	
		On Jan 62	On Jul 63
B-47E	370	184	174
B-52 A-F	92	98	96
B-52 G	193	168	167
B-52 H	(1)	102	102
B-58 A	154	105	104
B-70	62	0	(3)
F-100C	375	25	24
F-100D	375	84	82
F-100F	375	25	24
F-101 A/C	20	17	14
F-101B	100	90	87
RF-101 A/C	40	32	30
F-102A	166	65	60
TF-102A	(1)	18	17
F-104 C	60	25	24
F-105 B/D	65	40	39
F-106 A	100	51	51
F-106 B	100	12	12
TFX	(1) (3)	0	(3)
C-130A	70	35	35
C-130B	70	25	25
C-130E	70	0	30
C-130 BL, GC	70	10	10
C-133 A/B	38	15	15
KC-135A	112	110	109
C-135 A	(1)	30	30
VC-137	(1)	3	3
C-140	(1)	5	5
C-141	(1) (3)	0	(3)
T-37 A/B	152	60	60
T-38	184	50	50
T-39	(1)	40	40
(2)	155		
Total	2508	1532	1527

(1) Not in Original Program (2) C-124, F-108 and B-66 (3) Planned

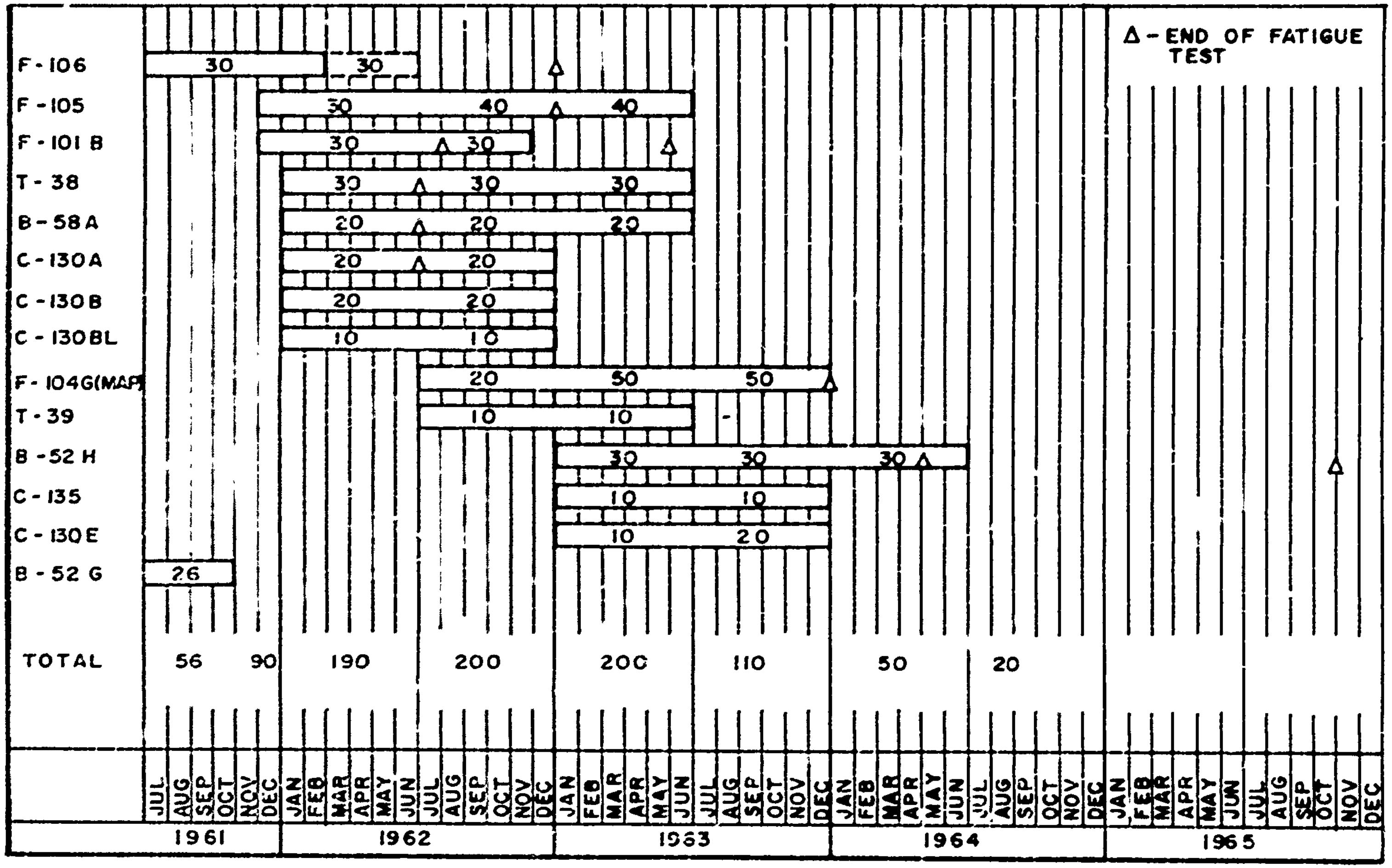

FIGURE 3. INTERIM SERVICE LOADS PROGRAM

APPENDIX A

APPENDIX A

This Appendix contains a partial list of ASD reports deemed appropriate to the overall SIP Program.

REPORT NO.	TITLE
WADD TR 60-410 Parts I & II	Investigation of Thermal Effects on Structural Fatigue
WADD TR 60-411 Parts I & II	Prediction of Creep Effects in Aircraft Structures
WADD TR 60-517	Thermo-Structural Analysis Manual
WADD TR 60-541 Parts I & II	Time-Dependent, Elasto-Plastic Bending Analysis for Structures Under Arbitrary Load-Temperature Environments
WADD TR 61-151	Thermo-Mechanical Analysis of Structural Joint Study
WADD TR 61-152	An Evaluation of the State-of-the-Art of Thermo-Mechanical Analysis of Structures
WADD TR 61-153	Fatigue Prediction Study
ASD TR 61-123	The Application of Statistics to the Flight Vehicle Vibration Problem
WADD TR 61-62	Structural Vibrations in Space Vehicles
WADD TR 60-220	A Study of the Characteristics of Modern Engine Noise and the Response Characteristics of Structures
WADD TR 61-75	A Theoretical and Experimental Investigation of the Acoustic Response Characteristics of Cavities in an Aerodynamic Flow
WADD TR 61-178	The Use of Acoustic Scale Models for Investigating Near Field Noise of Jet and Rocket Engines
WADD TR 60-445	Response of Plates to Moving Shocks

WADD TR 58-343 Vol. II	Methods of Space Vehicle Noise Prediction
WADD TR 61-187	Aspects of the Response of Structures Subject to Sonic Fatigue
WADD TR 61-185	Survey of Evaluation of Sonic Fatigue Testing Facilities
WADD TR 58-547	Damping Energy Dissipated By Interfaces in Beam and Plate Supports and in Sandwich Cores
ASD TR 61-262	Sonic Fatigue Resistance of Structural Design
WADC TR 58-569	Response of Bars (With Internal and Boundary Damping) to Transient and Random Excitation
WADC TR 59-96	Damping Energy Dissipation at Support Interfaces of Square Plates
WADC TR 59-509	Damping of Flexural Vibrations by Alternate Visco-Elastic and Elastic Layers
WADC TR 59-545	Damping of Rectangular Plate Vibrations
WADC TR 60-60	Steady State Response of Beams with Translational and Rotational Damping Motions at the Supports
WADC TR 56-551	Experimental Investigation to Correlate the Recurrence of Fatigue Failure in a Typical Aircraft Structure with Vibratory Amplitude
WADC TR 58-343	Methods of Flight Vehicle Noise Prediction
WADC TN 58-189	Acoustic Design of Flight Vehicle Structures Facility
WADC TR 59-12	Performance of Intense Acoustic Facility for Flight Vehicle and Electronic Research

WADD TR 60-470	Automatic Runway Profile Measuring Instrumentation and Runway Profiles, Part I, Equipment dated February 1961
WADD TR 60-518	The Dynamic Response of Advanced Vehicles, dated September 1960
WADD TR 59-676	WADC-University of Minnesota Conference on Acoustical Fatigue
WADD TR 60-275	Hydrogen Embrittlement of Titanium Alloys
WADD TR 60-419	Effective Stress Concentration Factors for Flight Vehicle Materials under Various Conditions during Fatigue Testing
WADD TR 61-44	The Effects of Strain Rate and Hydrogen Content on the Low Temperature Deformation Behavior of Columbium
WADD TR 60-258	A Study of the Titanium-Liquid Oxygen Pyrophoric Reaction
WADD TR 61-132	Investigation of Fatigue Behavior of Certain Alloys in the Temperature Range Room Temperature to -423° F
WADD TR 61-138	The Effect of Concurrent Straining and a 1% Magnesium Addition on the Recovery Behavior of Aluminum
ASD TR 61-203	The Mechanical Properties of Tantalum with Special Reference to the Ductile-Brittle Transition
ASD TR 61-253	Elevated Temperature Strain Gage
WADD TR 60-161 Part I & II	Experiments on Slip Damping at Rounded Contacts
WADD TR 60-307	Forced Vibrations of Sandwich Panels
WADD TR 60-427	Investigation of the Fatigue Properties of Molybdenum under Various Conditions of Temperature Coatings and Stress Concentration
WADD TR 60-437	Effect of Stress Nonlinearity on External Statistics and Fatigue Life of a Simply Supported Bar

WADD TR 60-587	An Investigation of Longitudinal Shear Distribution and Damping in a Viscoelastic Adhesive Lap Joint
WADD TR 60-752	Reduction of the Endurance Limit as a Result of Stress Interaction in Fatigue
WADD TR 60-854	Fatigue Properties of Magnesium Alloy Forgings
WADD TR 61-25	Criteria for Comparing the Effectiveness of Damping Treatments
WADD TR 61-70	Experimental Study of the Random Vibrations of an Aircraft Structure Excited by Jet Noise
WADD TR 61-97	An Influence Functions in the Theory of Forced Vibrations of Membranes
WADD TR 60-157	Ultrasonics and Ceramic Coatings
WADD TR 60-393	Evaluation of Brazed Honeycomb Structures
WADD TR 60-450	Correlation of Tensile Properties of Steel Castings and Material Imperfections as Determined by Radiography
WADD TR 60-553	Application of Ultrasonics to Solid Rocket Systems
WADD TR 60-520	Research to Develop Methods for Measuring the Properties of Penetrant Flaw Inspection Materials
WADD TR 60-278	Notch Sensitivity of Refractory Metals
WADD TR 60-191	The Determination of the Effects of Elevated Temperatures on the Stress Corrosion Behavior of Structural Materials
WADD TR 60-254	The Evaluation of the Effects of Very Low Temperatures on the Properties of Aircraft and Missile Metals

WADD TR 60-310	The Effect of Several Geometrical Variables on the Notch Tensile Strength of 4340 Steel Sheet Heat Treated to Three Strength Levels
WADD TR 60-822	Investigation of the Behavior of Refractory Materials under the Influence of Thermal Stresses
WADD TR 60-777	Experimentation, Analysis and Prediction for Environmental Creep
WADD TR 60-580	Inelastic Design of Load Carrying Members
	Part I - Theoretical and Experimental Analysis of Circular Cross-Section Torsion-Tension Members Made of Materials That Creep
	Part II - The Effect of End Conditions on the Collapse Load of Columns
	Part III - The Significance of an Inelastic Analysis of Eccentrically-Loading Members
WADD TR 60-363	Investigation Into More Complete Use of Structural Materials Through a Study of the Stress-Temperature-Time Conditions of a Re-Entry Vehicle
WADD TN 60-95	Stress Corrosion of Notched and Unnotched AM-350 Alloy
WADD TR 60-245	Elevated Temperature Dynamic Moduli of Vanadium Titanium and V-Ti Alloys
WADD TR 60-839	The Effect of Concurrent Stressing on the Air Oxidation of Tantalum
WADC TR 59-466	Research and Development Leading to the Establishment of Ultrasonic Test Standards for Aircraft Materials
WADC TR 59-702 Part I & II	Mechanical Properties of Selected Alloys at Elevated Temperatures
	Part II - Design Criteria of Silicon Carbide

WADD TR 60-155	Development of Methods and Instruments for Mechanical Evaluation of Refractory Materials at Very High Temperatures
WADC TR 57-585 Part II	Effects of Temperature-Time-Stress Histories on the Mechanical Properties of Aircraft Structural Metallic Materials
WADD TR 60-920	The Use of Ultrasonic Methods for the Examination of Fatigue Effects in Metal During the Early Stages of Stress Cycling
WADC TR 59-69 Part II	On Stress Interaction in Fatigue and a Cumulative Damage Rule
WADC TR 59-416 Part I & II	Investigation of Creep Buckling of Columns and Plates Part I - Elevated Temperature Properties of the Test Material Ti 7Al-4Mo Titanium Alloy Part II - Creep Buckling Experiments with Columns of Ti 7Al-4Mo Titanium Alloy
WADC TR 59-572	Investigation of the Compressive, Bearing and Shear Creep-Rupture Properties of Aircraft Structural Metals and Joints at Elevated Temperature
WADC TR 59-762 Part I	Ultra Short Time Creep-Rupture Equipment Manual
WADD TR 60-42	Some Quantitative Aspects of Fatigue of Materials
WADD TR 60-53	Effect of Temperature on the Creep of Polycrystalline Aluminum by the Cross-Slip Mechanism
WADD TR 60-60	Steady State Response of Beams with Translational and Rotational Damping Motions at the Supports
WADD TR 60-120	Study of Fatigue Properties of Ultra-High Strength Steel
WADD TR 60-188	Influence of Natural Frequencies and Source Correlation Fields on Random Response of Panels

WADD TR 60-240	Research on Properties of High-Strength Materials Suitable for High Temperature Applications
WADD TR 60-280	Rheological Properties of Adhesives Considered for Interface Damping
WADD TR 60-306	A System for Automatic Processing of Creep Data
WADD TR 60-308	Quasi-Orthogonal Modes of Dynamic Systems
WADD TR 60-313	Research on the Mechanisms of Fatigue
WADD TR 60-326	The Effect of Decreases in Stress on the Creep Behavior of Polycrystalline Aluminum in the Dislocation Climb Region
WADD TR 60-360	Effect of Viscoelastic Foundations on Forced Vibration Loaded Rectangular Plates
WADD TR 60-426	Fatigue and Stress-Rupture Properties of Inconel 713C, V-57C and Titanium Alloys 7Al-3Mo-Ti and MST 821 (8Al-2Cb-1Ta-Ti)
WADD TR 60-427	Investigation of the Fatigue Properties of Molybdenum under Various Conditions of Temperature, Coatings and Stress Concentration
WADD TR 60-437	Effect of Stress Nonlinearity on Extremal Statistics and Fatigue Life of a Simple Supported Bar
WADD TR 60-468	High Velocity Electric Acceleration Systems
WADD TR 60-363	More Complete Use of Structural Materials
WADD TR 60-258	A Study of the Titanium-Liquid Oxygen Pyrophoric Reaction
WADD TR 60-254	The Evaluation of the Effects of Very Low Temperatures on the Properties of Aircraft and Missile Metals
WADD TR 60-278	Notch Sensitivity of Refractory Metals

WADC TR 59-702 Part I & II	Part I - Mechanical Properties of Selected Alloys at Elevated Temperatures
	Part II - Design Criteria of Silicon Carbides
WADD TR 60-191	The Determination of the Effects of Elevated Temperatures on the Stress Corrosion Behavior of Structural Materials
WADD TR 60-310	The Effect of Several Geometrical Variables on the Notch Tensile Strength of 4340 Steel Sheet Heat-Treated to 150, 210 and 260 KSI
WADD TR 60-155	Development of Methods and Instruments for Mechanical Evaluation of Refractory Materials at Very High Temperatures
WADD TR 60-393	Nondestructive Testing of Brazed Honeycomb
WADD TR 60-157	Ultrasonics and Ceramic Coatings
WADD TR 60-450	Correlation of Tensile Properties of Steel Castings and Materials Imperfections as Determined by Radiography
WADD TN 60-197	The Present Status of Russian Metallurgy
WADD TN 60-204	Mechanical Properties of Extruded AISI 4340 Steel
WADD TR 60-275	Hydrogen Embrittlement of Titanium Alloys
WADD TR 60-419	Effective Stress Concentration Factors for Flight Vehicle Materials under Various Conditions During Testing
WADD TR 60-425	Mechanical Properties of Beryllium
WADD TR 60-523	Applicability of Present Creep Prediction Techniques for Extrapolating Very Long Time Creep Behavior
WADD TN 60-105	Strain Aging Effects in Columbium Due to Hydrogen
WADD TR 60-95	Stress Corrosion of Notched and Unnotched AM-350 Alloy

WADC TR 57-140 Parts I & II	Study of Guided Missile Structural Design Criteria
WADC TR 57-754 Parts I, II, III, IV, & V	Procedures for Including Temperature Effects in Structural Analysis of Elastic Wings Part I - An Equivalent Plate Method of Structural Analysis for Elevated Temperature Structures Part II - A Digital Computer Solution for the Equivalent Plate Methods of Thermoelastic Analysis Part III - Static Tests of Two Large Deflection Wing Models Part IV - Further Digital Computer Solutions for the Equivalent Plate Method of Thermoelastic Analysis Part V - Correlation of Analysis with Static Tests of Two Large Deflection Wing Models
WADC TR 58-196	Some Considerations of Structural Design Criteria for Guided Missiles
WADC TR 58-336	Study of Helicopter Structural Design Criteria
WADC TR 59-477	Structural Design of Guided Missiles, Suggested Criteria and Examination of Certain Problem Areas
WADC TR 59-482	Study of Design Criteria for Structures Subject to Aerodynamic Heating
WADC TR 59-627	Research Study on Ground Environment Loads Criteria for Guided Missiles
WADD TR 59-504	Development of Interium Wind, Wind Shear, and Gust Design Criteria for Vertically Rising Vehicles
WADD TR 60-305 14 Volumes 89 Parts	B-66 Low Level Gust Study Vol. I - Technical Analysis

	Vol. II - Power Spectra
	Vol. III - Auto Correlation
	Vol. IV - Cross-Correlation and Cross-Spectrum of Gust Velocities
	Vol. V - One Dimensional Frequency Distribution
	Vol VI - Two-Dimensional Frequency Distribution
	VOL. VII - Time Series
	Vol. VIII - Transfer Functions
	Vol. IX - Gust and Maneuvers
	Vol. X - Meteorology
	Vol. XI - Crew Comments
	Vol. XII - Pilot Reports
	Vol. XIII - Instrumentation
	Vol. XIV - Data Reduction and Computing
WADD TR 60-398	Optimum Fatigue Spectra
WADD TR 60-497	Development of Structural Design Criteria from Statistical Flight Data
WADD TR 60-556 Part I & II	An investigation of the Definition of Missile Structural Design Criteria Requirements on a Reliability Basis
	Part I - The Investigation of Current Data into Recommended Requirements
	Part II - The Development of a Method Framework for Determining the Quantitative Structural Design Requirements Necessary to Achieve a Given Level of Structural Reliability
WADD TR 60-691	Measurement and Analysis of Power Spectra and Cross-Power Spectra for Random Phenomena

WADD TR 60-734	Helicopter Structural Design Criteria; Analytical Solutions of Flight and Landing Maneuvers
WADD TR 61-61	Missile Structural Design Criteria for the Launch Phase of Vehicle Life
WADD TR 61-62	Missile Structural Design Criteria for the Flight Phase of Vehicle Life
WADD TR 61-99	Wind, Wind Shear and Gust Design Criteria for Vertically Rising Vehicles as Recommended on the Basis of Montgomery, Alabama, Wind Data
ASD TR 61-95	Study of Design Parameters for Structure Subject to Aerodynamic Heating
ASD TR 61-235	Optimum Fatigue Spectra
ASD TR 61-328	Uniform Heating Effects on the Response of a High Speed Vehicle to Discrete and Continuous Gusts

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2. Documents the requirements for insuring Structural Integrity as outlined at the instigation of the ASIP.

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