NASA SPACE VEHICLE DESIGN CRITERIA

NASA SP-8002

FLIGHT-LOADS MEASUREMENTS DURING LAUNCH AND EXIT

VOLUME III: STRUCTURES
PART D: TESTING
CHAPTER 3: STRUCTURAL TESTS (FLIGHT)
SECTION 1: FLIGHT-LOADS MEASUREMENTS DURING LAUNCH AND EXIT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

NASA experience has indicated a need for uniform design criteria for space vehicles. Accordingly, criteria are being developed in five areas of technology, outlined as follows:

- Volume I - Environment
- Volume II - Material Properties and Processes
- Volume III - Structures
- Volume IV - Stability, Guidance, and Control
- Volume V - Chemical Propulsion

The individual components of this work are regarded as being sufficiently useful to justify publication separately in the form of monographs as completed. This document, Section 1 of Volume III, Part D, Chapter 3, is one such monograph. The planned general outline of Volume III is set forth on page ii.

These monographs are to be regarded as guides to design and not as design requirements, except as may be specified by NASA project managers or engineers in formal project specifications. It is expected, however, that these documents, revised as experience may indicate to be desirable, will eventually become uniform design requirements for NASA space vehicles.

Comments from addressees concerning the technical content of the monographs are solicited. Please address such comments to the National Aeronautics and Space Administration, Office of Advanced Research and Technology (Code RVA), Washington, D. C. 20546.

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PLANNED OUTLINE OF VOLUME III: STRUCTURES

Volume III: Structures
Part D: Testing
Chapter 3: Structural Tests (Flight)

SECTION 1: FLIGHT-LOADS MEASUREMENTS DURING LAUNCH AND EXIT

1.1 INTRODUCTION

Inadequate knowledge of the structural environment and responses of space vehicles during launch and exit has established a need for flight-loads measurements. Such measurements are needed to:

a. Assess the adequacy of the design of space vehicles by determining simultaneously the environments and resulting structural responses, loads, and stresses

b. Provide information to validate or improve general methods and procedures used in design

c. Provide a basis for refinements in design leading to weight saving and improved performance of future models of the system under test

d. Assist in failure analysis

It is therefore desirable that measurements of the environment and of the reactions and responses of space vehicles to the environment be obtained from a well-planned and well-conducted flight-loads measurement program.

During the latter phases of space-vehicle development, it is difficult to introduce flight-test instrumentation into the system because of space and weight limitations or schedule considerations. The flight-loads instrumentation system should therefore be specified at the inception of the project and the specification should include the delineation of instrumentation types, weights, and locations, and the number and types of telemetry channels that will be required.

1.2 STATE OF THE ART

The current state of the art of flight instrumentation, data acquisition, and data reduction on the whole permits the collection of flight-loads data. Transducers such as accelerometers, pressure cells, and strain gages are available, and miniature flight telemeter and ground-receiving equipment located at the major ranges are generally adequate. The application of such instruments to the measurement of flight loads and related quantities is, however, not always performed in an acceptable manner. The successful acquisition of flight-loads data requires attention to details and to reliability and quality control in the design, installation, calibration, and operation of the instrumentation system. For example, an accelerometer mounted on a flexible bracket may measure only the vibrations of the accelerometer-bracket system.

Notwithstanding the general paucity of flight-loads information, data of the desired type have been obtained on some vehicles. For example, references 1 and 2 contain some data from Saturn flights and reference 3 has data from a Ranger flight. Reference 4 describes the flight-loads instrumentation for an Orbiting Astronomical Observatory (OAO) in combination with an Atlas-Agena launch-vehicle system.

1.3 CRITERIA

Instrumentation shall be installed for the collection of flight-loads data on one or more flight vehicles in any space-vehicle development program. Specific measurements should include the following:

a. Horizontal wind

b. Angle of attack (in yaw and pitch planes)

c. Aerodynamic pressures

d. Structural temperatures

e. Structural vibration (accelerations)

f. Normal, lateral, and longitudinal accelerations (including orientation to measure torsion)

g. Bending moments (in yaw and pitch planes)

h. Longitudinal forces

i. Flutter response

   (1) Wing, fin, and control surface flutter
   (2) Panel flutter

j. Propellant slosh response

The following measurements, which are usually made independently of any requirement for loads data, are required as part of the loads measurements:

k. Flight path

l. Flight attitude angle

m. Rate of change of attitude angle

n. Gimbal angle (or equivalent)

o. Control commands

p. Velocity

1.4 RECOMMENDED PRACTICES

1.4.1 The flight-loads measurement program should be formulated early in a project. This program should be integrated with analysis and ground-test programs for maximum usefulness and to assist in interpretation of the flight data.

1.4.2 The horizontal wind velocities measured should be those experienced by the vehicle and, therefore, are preferably determined from on-board instrumentation. On-board measurements are necessarily based on flow-angle measuring devices, such as angle-of-attack and sideslip vanes and differential pressure gages. However, for very elastic vehicles, normal and lateral accelerometer and pitch- and yaw-rate gyro measurements near the location of the flow-direction indicator may be required in order to minimize errors in indicated flow direction due to vehicle deformation. The wind measurements from on-board instrumentation may be backed up by measurements from ground-based equipment. For example, photographs of an exhaust trail from the vehicle can be made when atmospheric conditions permit. The time resolution of all these measurements should provide a frequency content which includes at least the fundamental bending frequency of the space-vehicle system.

1.4.3 Aerodynamic pressure measurements should be made to provide a basis for determination of dynamic pressure, and also for evaluation of quasi-static aerodynamic loads and load distributions and fluctuating pressures which define the buffeting and acoustic environment. Pressure measurements should also be made as necessary to determine adequacy of venting of interior compartments. The location and frequency response of pressure cells should be guided by appropriate wind-tunnel tests, other ground tests, or analysis.

1.4.4 Structural temperature measurements serve two purposes: first, to indicate actual temperatures experienced by the structure in flight; and second, to permit accurate temperature compensation of transducers. The latter objective requires that temperature measurements be made near the location of transducers such as strain gages. The variation of temperature with time is usually slow enough to permit use of commutated data.

1.4.5 Accelerometers should be installed in such a manner that the desired data are not significantly affected by the vibration characteristics of the local structures to which they are attached. Selection of frequency-response characteristics should be guided by the results of ground tests and analysis for such problems as buffeting, acoustic vibration, and flutter.

1.4.6 Strain-gage installations for the measurement of bending moments and longitudinal and other forces in the structure should be designed to insure reasonably accurate measurements of the maximum forces expected. Usually, the desired information will require that measurements be made at locations shown by the design studies to have minimum strength margins. It is also necessary, however, for gages to be located on structure that can be accurately calibrated, such as the relatively heavy interstage structure (away from cutouts) in otherwise thin-walled vehicles. Therefore, some compromises will have to be made. If possible, all strain gages should be calibrated by the actual application of combined loads. The frequency content of these measurements should include at least the fundamental frequency of the space-vehicle system.

1.4.7 Generally, continuous flight-loads data should be obtained. The use of commutated (or interrupted) data should be minimized.

1.4.8 The flight-loads measurement program should be documented. The documentation should include descriptions of the data requirements, the instrumentation and data collecting systems, the calibration procedures, and the flight results. Photographs of all transducer installations should be provided with the flight data. The transducer type and location should be clearly illustrated in the photograph.

REFERENCES

1. Saturn SA-1 Flight Evaluation. NASA MPR-SAT-WF-61-8, Dec. 14, 1961; Suppl., Mar. 30, 1962.

2. Saturn SA-2 Flight Evaluation. NASA MPR-SAT-WF-62-5, June 5, 1962.

3. Flight Test Evaluation Report, Missile 133D. General Dynamics/Astronautics Rep. AE 62-0447, July 18, 1962.

4. Vehicle System Integration Requirements and Restraints Document for the OAO (S-18) Spacecraft. X623-62-190, NASA Goddard Space Flight Center, Rev. Dec. 20, 1962.

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