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BASIC DESIGN CONSIDERATIONS FOR A SMALL SCIENTIFIC SATELLITE

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ABSTRACT

Small scientific satellites serve as platforms for sensors and instrumentation which will measure and observe natural or man made phenomena of earth, its satellite and their environment. The engineer and designer of the spacecraft must propose and evaluate many interrelated ideas about the structure, the experiments, and associated equipment. Overlooking a basic consideration or requirement for the spacecraft could result in schedule delays or possibly a mission failure.

This report is a codification of the basic considerations for the mechanical design of scientific spacecraft.

Author

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BASIC DESIGN CONSIDERATIONS FOR A SMALL SCIENTIFIC SATELLITE

INTRODUCTION

The intent of this report is to serve as a guide or reference for the mechanical systems engineer during the feasibility and design phases of small scientific satellites. These design considerations are based on experience and knowledge gained in the engineering and design of spacecraft for the Explorer series of satellites by members of Goddard Space Flight Center's Mechanical Systems Branch. In addition to the design of spacecraft structure, this group is responsible for the design of spacecraft handling equipment, transportation of the spacecraft, and the spacecraft areas of the vehicle/spacecraft interface. This report will include all four areas because problems and requirements in each area will contribute to the final design of the satellite.

The reader and/or user of this document should not presume that these design considerations are all inclusive for all spacecraft. Each spacecraft will have specific or unique requirements which will dictate new or unusual design considerations.

The design considerations are presented in outline form and are divided into three major categories:

A. The Spacecraft

B. The Spacecraft/Vehicle Interface

C. Handling Equipment and Transportation

Each major category is subdivided, as required, with questions pertaining to that particular subdivision, which the design engineer should answer or have answered.

For detailed information about the design of small satellites the reader is invited to review Reference A.

A. The Spacecraft

1. Design Safety Factor
   a. Is there a required or recommended design safety factor of the cognizant spacecraft organization?
   b. Have Q levels in the spacecraft structure been assumed, evaluated and established for design calculations?

c. What are the test levels to which a prototype spacecraft will be exposed?
d. What are the test levels to which a flight spacecraft will be exposed?

2. Spacecraft Weight
   a. Is the spacecraft weight within the orbiting capabilities of the vehicle?
   b. Has a reasonable "cushion" been included in the predicted component weights to prevent an overage?
   c. Is an up-to-date weight schedule being maintained?
   d. Is any launch vehicle hardware, such as attach fittings, accountable to the payload weight?

3. Shape or Configuration
   a. Are there any mission or scientific requirements to dictate a particular spacecraft shape or configuration?

4. Moments of Inertia
   a. What will be the spacecraft spin moment of inertia?
   b. What will be the maximum transverse moment of inertia?
   c. For spin stabilized spacecraft, is the ratio of the spin MOI to the maximum transverse MOI greater than one?

5. Balance Requirements and Weight Distribution.
   a. Static Balance—Has an optimum arrangement of spacecraft packages and components been considered? What are the launch vehicle static balance requirements?
   b. Dynamic Balance—What is the maximum coning angle acceptable by the experimenters? What are the launch vehicle dynamic balance requirements?

6. Spin Rates
   a. Orbital—What is the required spin rate? Will the spin rate vary with time?
   b. Launch—What is the spin rate required for launch vehicle stability?
   c. Is a despin system required?
   d. Is a spin up system required?

7. Structural Materials Requirements
   a. Are there requirements governing the use of magnetic or non-magnetic materials?

b. Are there requirements governing the outgassing of materials?
c. Will the contact of dissimilar materials cause harmful or excessive galvanic action?
d. Are there structural materials which are not compatible with experiments?
e. Can damping materials be used to reduce the transmissibility of the structure?

8. Experiment Look Angles
   a. Will a look angle be obstructed or infringed upon by part of the structure or an appendage?
   b. Is there a requirement for referencing one look angle to another?
   c. Is there a requirement for a look angle on the spin axis?

9. Experiment Location
   a. Will the proximity of housekeeping equipment affect the sensors?
   b. Will the proximity of other experiments affect the sensors?
   c. Has consideration been given in locating subsystems to an optimum cable design?

10. Booms, Antennas & Other Appendages
    a. What is the size and shape?
    b. What is the location on the spacecraft?
    c. Is it necessary to fold or telescope the appendage to meet the launch envelope requirements?

11. Solar Cells
    a. Will solar cells be required?
    b. What is the total area of solar cells required to power the spacecraft?
    c. Will the solar cells be located on the spacecraft surface or on paddles?
    d. If the solar cells are on the structure, can they be removed or protected during handling and transportation?
    e. What will be the orientation of the solar paddles?

12. Batteries
    a. What type of batteries are required?
    b. What quantity of batteries are required?
    c. What is the size and shape of the cells?
    d. Is there a power requirement which governs the arrangement or distribution of the cells?
    e. Will batteries be encapsulated or sealed?

13. Thermal Requirements
    a. Will the spacecraft have an active thermal control system?
    b. Will the spacecraft have a passive thermal control system?
    c. Will the thermal paints and finishes be compatible with the experiments?
    d. Are heat sinks required for any components or experiments?

14. Electronic Support
    a. Will the turn on plug or card be accessible through the fairing?
    b. How many umbilical connectors are required and are they accessible through the fairing?
    c. Is there a requirement for a separation switch?
    d. Is there a requirement for turning off and locking out an experiment during launch?
    e. Have provisions been made for R.F. shielding around all openings?

15. Safety Considerations
    a. Will spacecraft explosive devices meet the launch site safety requirements?
    b. Do the explosive devices have electrical shorting and safing features?
    c. Do the explosive devices have mechanical safing features?
    d. Are safing and shorting devices colored or flagged for visual observation?
    e. Will spacecraft pressure vessels meet launch site safety requirements?

16. Seals
    a. If pressure or vacuum seals are required should they be organic or inorganic?
    b. Will backup or secondary seals be required?

17. Documentation
    a. Has a mechanical interface documentation for the structure/subsystems interface been prepared and distributed?
    b. Has an assembly procedure and field check off document?

B. Spacecraft/Vehicle Interface

1. The Vehicle
    a. What vehicle will be used to launch the spacecraft?
    b. Is there more than one vehicle configuration?

2. The Attach Fitting
   a. Which attach fitting or separation system will be used?
   b. Does the attach fitting (or separation system) have provisions for an electrical interface connector?
   c. Does the attach fitting have mechanical provisions for a separation switch?

3. The Fairing (Heat Shield)
   a. Which fairing or heat shield will be used?
   b. Is the payload accessible through the fairing? Where?
   c. What are the provisions in the fairing for umbilical connectors?

4. Payload Envelope
   a. Has a compatibility drawing been prepared?
   b. What provision can be made for tieing down or supporting spacecraft appendages?

5. Launch Thermal Problems
   a. Is special insulation required under the fairing to protect the spacecraft?
   b. Is insulation required around the last stage to protect the spacecraft?

6. Despin and Separation Sequence
   a. Has a sequence been planned for the erection of appendages and separation of the spacecraft?

7. Gantry Operations
   a. What are the electrical power requirements for ground support equipment on the gantry?
   b. What are the restrictions and limitations on the installation of explosives on the gantry?
   c. What are the restrictions and limitations on the use of radioactive materials on the gantry?
   d. What are the restrictions and limitations on the use of other materials on the gantry?

C. Handling Equipment and Transportation

1. Dolly
   a. Is a satellite dolly required for transportation and assembly of the payload?
   b. What are the shock and vibration requirements for a dolly?
   c. What are the requirements for rotating the spacecraft on the dolly?

2. Shipping Container
   a. Is a satellite shipping container required for transportation to the launch site?
   b. What means of transportation, air or truck, will be used?
   c. What are the shock and vibration requirements for the shipping container?
   d. What limitations should be placed on the size, shape and weight of the container?
   e. Does the spacecraft have requirements for a controlled atmosphere while in the container?

3. Handling Equipment and Special Tools
   a. Is there a need for lifting slings or lifting rigs?
   b. Is there a need of special tools to assemble the spacecraft?
   c. Should the handling equipment or special tools be nonconductive, nonsparking, or nonmagnetic?

4. Special Considerations
   a. Is there a requirement for safety shoes, hard hats or flameproof clothing?
   b. Is there a requirement for a spacecraft protective cover?
   c. Is there a requirement for protective covers on the sensors?

CONCLUSIONS

In the preliminary design phase of a spacecraft numerous special considerations are set forth. These special considerations are required to meet mission and scientific objectives and they will be weighed, discussed and evaluated many times. The constant emphasis of special considerations may lead the design engineer to overlook or ignore one or more of his basic considerations. This report is only to serve as a reminder of these basic considerations.

Revisions and redefinements of the mission and scientific objectives will dictate reexamination and reevaluation of the basic design considerations. This type of constant surveillance will reduce or eliminate delays in project schedules caused by failures and the need to redesign.

Reference A. Structures for Small Scientific Satellites
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