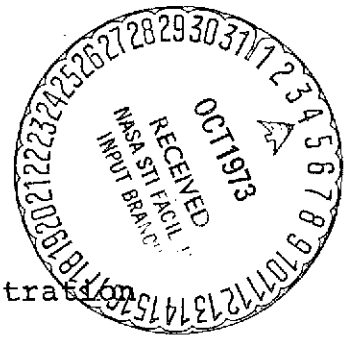
NASA CR-132800

ENGINEERING DESIGN, STRESS AND THERMAL ANALYSIS,

and

DOCUMENTATION FOR SATS PROGRAM



PREPARED FOR:

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Contract No. NAS 5-21750

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INTRODUCTION

The "Engineering Design, Stress and Thermal Analysis, and Documentation for Small Applications Technology Satellite (SATS) Program" was a 10 month study directed toward the understanding and development of the mechanical aspects of the solar array for the SATS spacecraft.

The objective of this contract* was to provide an in-depth analysis and mechanical design of the solar array stowage and deployment arrangements and their associated mechanisms. To accomplish this objective the program was divided into a series of tasks, each having a well defined output. The following paragraphs give a brief description of the tasks and identifies the nature of the work performed.

A. Concept Development Task

This task provides the basis for the work to be accomplished under the Contract. In this task the development and evaluation of alternate approaches for the major elements of work are performed. These elements include array stowage and deployment arrangements, the spacecraft and array behavior in the spacecraft despin mode, and the design of the main hinge and segment hinge assemblies. Feasibility calculations are performed and the preferred approach is identified. The output from this work is a report describing the development of the major items and the presentation of the feasibility calculations. In addition, programmatic and technical ground rules used for the analyses and design are summarized and included in the report.

B. Solar Array Deployment Analysis

Potential deployment concepts developed as part of the Concept Development task are evaluated in this task. The

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* The Contract NAS 5-21750 was performed by RCA Corporation, Astro-Electronics Division, P.O. Box 800, Princeton, New Jersey 08540

computer-aided evaluations consider the kinematic behavior of the solar array within the established sequencing constraints. The results of the analysis specify the time to complete deployment, requirements for deployment springs, and the need for dampers. Data obtained from this task in conjunction with data developed in other areas of the study are used to select the preferred deployment concept. This task provides a report describing the work performed.

C. Solar Array Design

This task consumes the major portion of time and funds allocated to this Contract. This task has a dual scope. The first is to produce manufacturing detailed drawings and specifications covering the major mechanical elements: launch support assembly, spacecraft despin system, deployment sequencing, main hinge assembly, and segment hinge assembly. Approximately 80 design drawings were developed with specifications covering their implementation. Copies of these drawings and specifications are contained in the Drawing Book.

The second part of this task is the performance of an in-depth, dynamic and stress analyses. For the dynamic analysis a structural model(s) was developed consistent with the finite element structural computer program, DYNAL. This program examined and predicted response to launch loadings imposed by the Scout booster. The loadings are defined in the ground rules portion of the Concept Development report. Additionally, a stress analysis of the mechanical parts designed under this Contract, was performed. The data developed by these activites are contained in the Dynamic and Stress Analysis Report.

D. Reports

The various reports written as part of this Contract are organized as follows:

Vol. I - Summary Report

Vol. II - a. Concept Development Report (with Appendices)
b. Solar Array Deployment Analysis

Vol. III - Dynamics and Stress Analyses

Vol. IV - Drawing Book

SUMMARY

To provide a summary of the work performed, the Monthly Status Letters written during the course of this Contract forms a part of this document. These Status Letters have been edited to remove only programmatic information where such information does not contribute to an understanding of the conduct of the program or the development of the technical work.

Eight Status Letters are contained herein; the last being issued February 10, 1973. The program was concluded, however, the first week of April 1973.

COMPILATION
of
MONTHLY STATUS LETTERS
(SUMMARY ONLY)

Monthly STATUS LETTER No. 1 Issued: July 10, 1972

Summary of Work Performed During Reporting Period

This reporting period was devoted primarily to establishing program plans and some of the principal ground rules to be adopted for the study. Additionally, an understanding of current program requirements and their influence on design philosophy and technical matters was developed at a planning meeting held at GSFC on June 23, 1972.

Monthly STATUS LETTER No. 2 Issued: August 10, 1972

SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

During this reporting period a study was made of some methods used for solar panel deployment. Seven satellite systems were examined including the method depicted on GSFC's SATS Drawings.

Some effort was directed to initiate RCA computer analysis for solar array deployment.

A Design Coordination Meeting was held with GSFC personnel (agenda attached) to discuss basic design concepts and to investigate requirements for using the GSFC's N-BOOM computer program.

Monthly STATUS LETTER No. 3 Issued: September 10, 1972

SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

This report covers the month of August and that period in September which includes the SATS Program Review meeting. This meeting is considered extremely important because of its influence on the design work.
During this reporting period, three different solar array deployment concepts, eighteen different segment hinge designs (variations of three basic types), and six different panel catch designs were investigated.

Several runs were made using a previously developed RCA computer program to investigate the dynamics of the deployment schemes. A computation was made to determine the maximum allowable opening velocities of the panels, based upon the allowable stresses in the panel substrates. Panel velocities were determined for a number of cases and were compared to the maximum allowable velocities to determine damping requirements and maximum allowable spring torques.

Of the hinge designs considered a preferred configuration was identified. This preference is based upon design simplicity in performing its intended function. Knowing the maximum and minimum allowable spring torques a tentative spring design was generated.

A preferred catch design has been identified but identification of a preferred deployment scheme requires further study.

A review meeting was held at RCA on September 8, with GSFC personnel to summarize progress to date and to bring to light any questionable areas. Vu Graphs and drawings were used; copies of the Vu-Graphs are attached and drawings were distributed to the attendees.

The results of the meeting are as follows:

1. A potential shroud and/or experiment module interference problem may be significantly reduced or eliminated if GSFC and McDonnell Douglas Corp. determine that the Delta adapter is (or can be) 2 to 3 inches shorter than shown GE 1081013. In the event the approach is not feasible several other options are available and were discussed.

2. A discussion of the different deployment schemes brought out the fact that the scheme-rotation of the paddle assembly first-was not desirable as it would probably cause interference with spacecraft antennas.

3. The GSFC N-BOOM program will be helpful in choosing which of the remaining candidate deployment schemes---"Positive Sequencing or "Delayed Release, Pitch Last"--would be preferable. At the present time the N-BOOM program is being debugged.

Monthly STATUS LETTER No. 4 Issued: October 10, 1972

SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

During this reporting period, basic design concepts were selected and decisions made influencing the technical progress of the work remaining. These decisions were developed at the fourth program review meeting (Agenda attached) and are identified as follows:

- Arrangement of solar array in launch position selected.
- Adoption of the Yo-Yo assembly concept.
- Selection of solar array "pitch" angle range from 0^{o} to 180^{o}.
- Investigation of an alternate approach for initiating array "pitch" rotation.
- Selection of Positive Sequence deployment method.
- Selection of segment hinge design.
- Adoption of an alternate approach for developing data needed for the N-Boom Analysis task.

Technical effort proceeded in all tasks allowing completion of the Ground Rules Development and the N-Boom Analysis tasks. It is expected that the Concept Development task will be completed during the early portion of the next reporting period.

Monthly STATUS LETTER No. 5 Issued: November 10, 1972

SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

At the conclusion of this reporting period the remaining technical work to be completed is involved with the Solar Array Detail Design task. However, it is expected that a limited amount of iteration of completed work will be undertaken as the program progresses. Reports for the completed tasks are being written.

Early in the reporting period pyrotechnical initiation of solar array rotation was selected in preference to mechanical initiation. This selection allowed the Concept Development task to be completed.

Program progress was discussed at the 6th SATS Program Review meeting. Copies of Vu-graphs are attached. Concept design calculation notes were distributed at this meeting.

Stress analysis, dynamic analysis, and the detail mechanical design of the solar array is in process.

Program costs and schedule are in accordance with the program plan - attached.

Monthly STATUS LETTER No. 6 Issued: December 10, 1972

SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

The major portion of the dynamic analysis of the solar array in the stowed position has been completed. Results of the analysis show that if the spacecraft's natural frequency coincides with the solar array's natural frequency a significant overstress and high tip deflection condition would result. Data obtained from spacecraft designed and built by RCA suggests that this is a most unlikely situation. However, if the frequency separation is not within proper range then an unfavorable stress and tip deflection condition could still result. Several approaches to eliminating this potential condition have been suggested. To aid in the evaluation of these approaches parametric analyses, limited in scope, are being considered.

The detail mechanical design of the solar array is proceeding according to plans. Where it appears that options in the details are avaliable they are highlighted and discussed at program review meetings. The 7th SATS Program Review meeting was held at GSFC wherein such matters were discussed. The agenda for this meeting is attached.

Monthly STATUS LETTER No. 7 Issued: January 10, 1973

SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

The dynamic analysis of the solar array subjected to qualification test conditions has been completed. Data are provided using two different models of the array including the behavior (assumed) of the spacecraft.

Stress analysis is completed also. The results of this analysis showed that only a small number of changes in structural detail are required.

The detailed concepts of the Main Hinge Assembly and the Despin Assembly (Segment Hinge Assembly was completed previously) were completed and the detail drawings of the Main Hinge Assembly have begun.

The Dynamic and Stress Analyses report and the Solar Array Deployment Analysis report have been submitted. The organization of these and the remaining reports were agreed upon at the 8th SATS program review meeting. In-depth technical discussions, the principal purpose of the review meeting, were held also.

Monthly STATUS LETTER No. 8 Issued: February 10, 1973

SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

The principal design activity during this reporting period consisted of refining the Main Hinge Assembly and the Segment Hinge Assembly, including the Sequencer, in preparation for producing fabrication drawing. At the conclusion of the reporting period close to 90 percent of the fabrication drawings describing these assemblies were delivered for discussion at the SATS review meeting.

The major analysis activity concerned the performance of the spacecraft and the solar array during the spacecraft's despin mode. The analysis covered the determination of angular acceleration, angular velocity, and angular displacement of the spacecraft and the resulting loads on the solar array. Similarly, the angular acceleration, angular velocity, and angular displacement of the solar array was developed. Additionally, tension in the despin cables was determined. The results of the analyses suggest certain modifications be included in the arrangement for deploying the solar array.

A re-evaluation of the despin weight assembly was made and certain changes are suggested here too.

The items noted above were discussed in a great deal of detail at the 9th SATS program review meeting held at GSFC (agenda attached).