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FLEXIBLE ROLLED-UP SOLAR ARRAY

TENTH QUARTERLY REPORT

JANUARY 1971

PREPARED FOR:
Air Force Aero Propulsion Laboratory
Research and Technology Division
Wright-Patterson Air Force Base, Ohio 45433

PROJECT NO. 682J/DATA NO. HS207-205(10)/CONTRACT NO. F33615-68-C-1676

PREPARED BY:
Hughes Aircraft Company / Space Systems Division
(Under Contract F33615-68-C-1676)

AUTHORS: E. O. Felkel
G. Wolff
Et al.

Hughes Ref. No. 71(41)-10798/B3532-020

SCG 10013R

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FOREWORD

This report was prepared by Hughes Aircraft Company, Space and Communications Group, El Segundo, California, under Contract F33615-68-C-1676. The work was administered under the direction of L. D. Massie, APIP-2, Air Force Aero Propulsion Laboratory.

The period covered extends from 28 September 1970 to 27 December 1970. Contributors to this report include E. O. Felkel, G. Wolff, M. C. Olson, W. N. Turner, R. E. Daniel, G. P. Steffen, D. Plummer, R.K. Geiser, G. Lindenman, C. Duncan, and W. Ferguson, all of Hughes Aircraft Company, Space and Communications Group, El Segundo, California.

The work covered herein was accomplished under Air Force Contract F33615-68-C-1676, but this report is being published and distributed prior to Air Force review. Publication of this quarterly, therefore, does not constitute approval by the Air Force of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

ABSTRACT

The main activities on the Flexible Rolled-Up Solar Array (FRUSA) program during the tenth quarterly reporting period consisted of completion of assembly of the qualification model and start of assembly of the flight model of the orientation mechanism, solar arrays, drum mechanism, control electronics unit (CEU), solar cell electronics unit (SCEU), instrumentation conditioning unit (ICU), battery charge controller (BCC), power conditioning unit (PCU), and load bank.

The bi-stem actuator units have been refurbished and, together with the arrays, ICU, and SCEU, integrated with the drum to complete the qualification model of the solar array subsystem. The qualification model of the orientation subsystem has been completed and delivered to the system test area. All qualification model elements of the power conditioning and storage subsystem have been fabricated.

Flight model fabrication and assembly are on schedule. All flight cell groups of the arrays have been fabricated and tested. Drum mechaism and orientation mechanism detail parts are 70 percent complete. All electronic circuit boards are nearing completion, and all battery cells have been received.

Several working group meetings were held between SAMSO/Aerospace/LMSC and Hughes to resolve interface problems and to review system test procedures. The FRUSA mission sequence was modified to coincide with the integrating contractor orbital mission planning. An upgraded system test plan has been released.

CONTENTS

SECTION I

INTRODUCTION AND SUMMARY

This document reports progress in the tenth quarter (28 September to 27 December 1970) on AFAPL contract F33615-68-C-1676, Flexible Rolled-Up Solar Array, Project Number 682J.

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Several working group meetings were held between SAMSO/ Aerospace/LMSC and Hughes to resolve interface problems and to review system test procedures. The FRUSA mission sequence was modified to coincide with the integrating contractor orbital mission planning. An upgraded system test plan has been released.

The format of this quarterly report is designed to present the status of each major system element in a separate section.

SECTION II

PROGRAM STATUS

The Flexible Rolled-Up Solar Array (FRUSA) program is divided into five phases, as described in the paragraphs that follow. The current program schedule and status are shown in Figure 1.

PHASE I - PROGRAM DEFINITION

Major milestones associated with this phase and scheduled during this period have been completed. Included in this category are all program requirements, design, and test requirements.

PHASE II - DESIGN STUDY AND ANALYSIS

The study phase of the program has been completed and a firm baseline design established. Design packaging details have been completed. Additional analysis tasks defined during the interface working group meetings have been completed. These tasks include the installation of a support axis position indicator assembly/sensor element to be provided by the mission integrating contractor; a Thorad/Agena structural dynamics analysis to define ascent structural excitation levels and frequencies for the three-point attachment to the vehicle forward rack; and a shading analysis to determine power output variations occurring during eclipse season light-time transient shading of the flexible array experiment solar panels by the SESP 71-2 vehicle fixed rigid solar panels. The electromagnetic compatibility study to determine the potential interference effects to the Agena and the effect of the Agena payload and telemetry on FRUSA has been initiated and will be completed during the next reporting period.

PHASE III - FABRICATION

All engineering drawings have been released. Fabrication and assembly of the qualification model, with the exception of the power conditioning and storage subsystem, have been completed. Fabrication of the flight model has been initiated. Numerous Air Force/Aerospace/Hughes/LMSC working group meetings to resolve interface problems have been held and more are scheduled during the next reporting period.

PHASE IV - QUALIFICATION AND FLIGHT ACCEPTANCE TESTS

Qualification and flight acceptance tests will be conducted according to the test plan. Qualification tests are scheduled to be completed during the next reporting period.

PHASE V - FLIGHT TEST AND DATA ANALYSIS

The flight test and data analysis phase will include prelaunch checkout and countdown procedures as well as in-orbit operation and analysis.

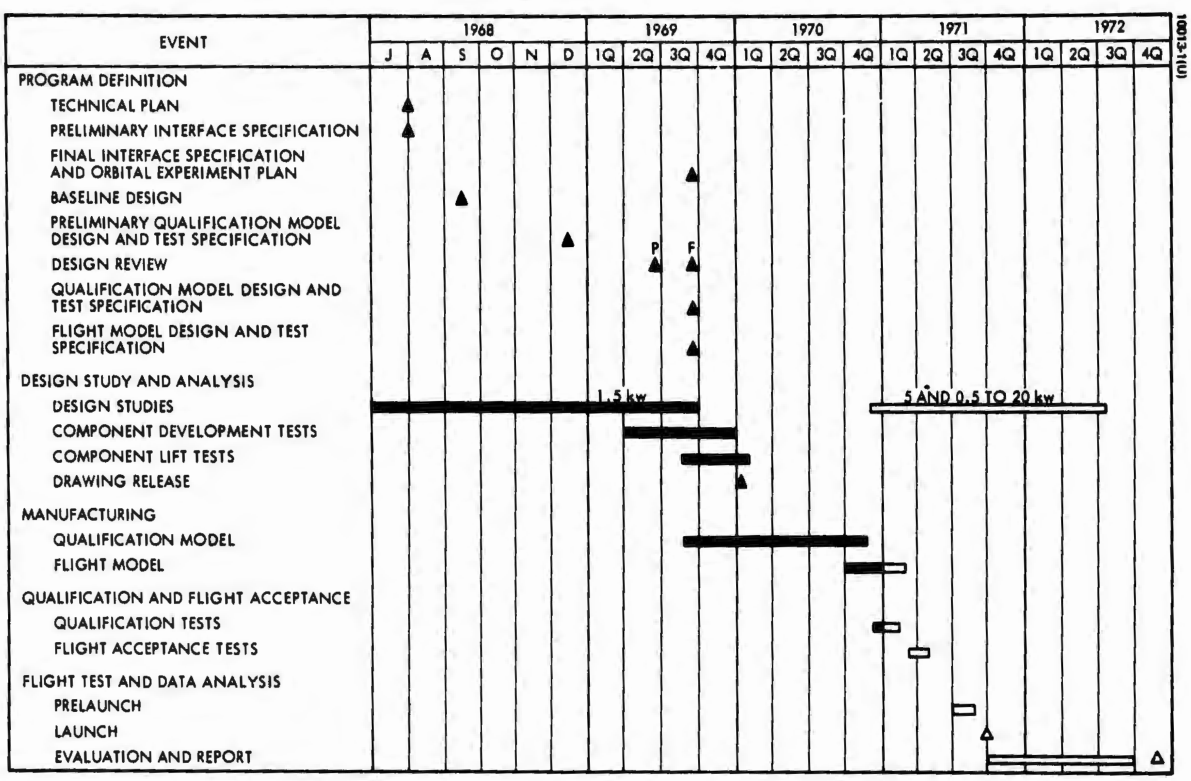

Figure 1. Program Schedule

SECTION III

SYSTEMS ENGINEERING

SUMMARY

The systems engineering activity during this period included:

- Resolving Agena/FRUSA/ONR-001 interference problems
- Modifying mission sequence in accordance with latest LMSC orbital mission planning
- Conducting meetings to resolve interface problems
- Updating weight summary

RESOLUTION OF AGENA/FRUSA/ONR-001 INTERFERENCE PROBLEMS

The two unsolved SESP 71-2 vehicle interference problems were the obscuration of the ONR-001 antennas by FRUSA and obscuration of FRUSA by the Agena fixed solar array. These problems have been analyzed and evaluated with the integrating contractor during many meetings and telephone conversations. The resolution of these problems is detailed below.

A second ERIS antenna is being added to minimize the interference area with the ONR-001 experiment. However, this still leaves significant interference sectors that must be avoided. This will be accomplished by feathering the FRUSA at preselected times in positions of minimum interference during ONR-001 read-in periods.

Stored program commands and timer signals from the Agena will provide control signals to the orientation mechanism torquers and power conditioning unit (PCU) to restrict the FRUSA position and minimize the resulting power loss.

It is planned to use three operating modes during the mission.

Mode I will be used primarily to prevent FRUSA sun acquisition slewing during eclipse when the ONR-001 experiment is in a read-in mode. A stored program command (preset at a tracking station to execute at the desired time) will turn off power to the orientation mechanism torquers and stop sun tracking. At the same time, an Agena timer (preset for 40, 50, 75, or 100 minutes and designated timer 2) will be started. When the latter times out, it will generate a command to reactivate the FRUSA torquers. After the torquers are initially inactivated, the FRUSA array will continue to provide power until the sun moves off the array normal by 15 degrees, or when an eclipse is encountered. This results in loss of the sun lock-on signal from the control electronics unit (CEU) and transfer of the FRUSA electronics to internal battery and also transfer of the SAMSO-002 load to internal battery. After the timer generates a torquer turn-on command, the FRUSA will again seek and lock onto the sun.

Mode II operation, a power saving mode that differs somewhat from Mode I, will be used when it is necessary to inactivate the orientation mechanism torquers a long time before the onset of an eclipse. Once again, a stored program command will inactivate the torquers and start the timer that will reactivate them after it has timed out. In addition, a Sun Lock-on Override, Enable command will be sent to the PCU to prevent switchout of the FRUSA array after the sun lock-on signal goes low. The array will continue to support the FRUSA electronics and the SAMSO-002 load to the best of its ability. As the sun angle continues to move off the normal, the FRUSA bus voltage will drop and the SAMSO-002 battery will transfer from a charge mode to a discharge mode. The SAMSO-002 and FRUSA electronic load will be shared by these two power sources . After the FRUSA array power capability is reduced below approximately 150 watts due to a low sun angle (approximately 82 degrees off the normal) or eclipse entry, the FRUSA electronic load will transfer to the SAMSO-002 battery, if no steps are taken to prevent it. This occurs because the override command prevents transfer of FRUSA electronic loads to the internal FRUSA batteries. To preclude this, another timer (designated timer 1) has been added by LMSC. This timer is also activated by the stored program command. When it times out (it is preset to 25 or 35 minutes), it will generate a Sun Lock-on Override, Disable command to the PCU. This will remove the FRUSA array from the power bus and also disconnect the SAMSO-002 batteries from the FRUSA power bus. FRUSA loads will now transfer to internal battery.

The Sun Lock-on Override, Disable command must be sent for another reason also. The orientation mechanism torquers must be connected to internal batteries to reacquire the sun after the torquer enable command is received from timer 2. If the PCU remained in the override mode, it would not be possible to reacquire the sun if the array would be pointing away from the sun and the SAMSO-002 batteries were disconnected from the bus.

Finally, Mode III will be used during special operations when it is necessary to deactivate the FRUSA torquers for a period of time longer than one complete orbital revolution (100 minutes). Once again, a stored program command will deactivate the torquers. However, both timers and the sun lock-on override signals will be disabled. FRUSA and SAMSO-002 will operate on internal batteries when the sun moves off the FRUSA arrays by more than 15 degrees. A ground command will be required to reactivate the torquers.

The operational modes described above will result in satisfactory FRUSA operation if the automatic commands are executed properly. For safety reasons, tracking stations will be required to verify that these commands functioned properly. If the torquers were inadvertently left off, internal FRUSA batteries would eventually discharge completely and the FRUSA experiment would go dead. The maximum time the torquers can be disabled in Mode III is 8 hours. If this period is exceeded, the batteries would be discharged to an unsafe level.

Partial shading of the FRUSA arrays by the Agena fixed solar arrays will cause overheating at one of the FRUSA array tips when the shadow-line moves slowly. This will occur near the beginning of the mission for a 15 day period when β is between 60 and 75 degrees. Rolling up the FRUSA arrays by approximately 4 feet, or 25 percent, will eliminate this problem. This will lower the power available to SAMSO-002 during this time period. However, since the eclipse season does not start until a β of 63 is reached, this probably will not cause a power problem for SAMSO-002.

MODIFIED MISSION SEQUENCE

The FRUSA mission sequence included in Revision A of the Space Experiment Plan was modified to coincide with orbital mission planning being conducted by LMSC for SESP 71-2. Major changes include:

1) Addition of a telemetry assessment early in the mission and prior to drum mechanism deployment

2) Power turn-on of FRUSA 1/2 or 1 revolution prior to drum mechanism deployment

3) Drum mechanism deployment by the Agena auxiliary sequence timer in lieu of real-time ground command on the 13th revolution

4) A 3 revolution standby period was included to allow data readout from SAMSO-002 prior to array extension at the beginning of the 16th revolution

In addition to the above orbital changes, it was necessary to make a minor modification to the prelaunch commanding sequence. A change was recently incorporated into the PCU solar array motor drive circuitry to preclude the boom cycling problem that occurred during the developmental model testing of the solar array subsystem. In the launch configuration, the solar array motor power turnoff circuit actuates a winding of a latching relay continuously if the retract logic override is placed in the disabled mode. Therefore, it is necessary to send the command Retract Logic Override Enable prior to launch and before the array is to be retracted from its extended position during that portion of the mission when the array is retracted and extended 10 times.

FRUSA WEIGHT SUMMARY

Current system weights by individual units are listed in Table 1. Of the total anticipated system weight, approximately 95 percent is "actual" weight.

The 1 pound adapter plate for relocating the CEU on the orientating mechanism housing to eliminate the antenna interference problem is included in the 58 pounds allocated for the orientation mechanism. The 7.5 pounds representing weight for the reference cell/module electronics has been included in the 14.1 pounds allocated for instrumentation.

WORK TO BE PERFORMED DURING NEXT QUARTER

- Continue to work interface problems with LMSC/SAMSO/Aerospace
- Update Space Experiment Plan to include current mission planning and revised telemetry calibration data

TABLE 1. FRUSA FLIGHT WEIGHT SUMMARY

Subsystem	Weight, pounds
Orientation	
Orientation mechanism* (includes (CEU adapter plate)	58.0
Control electronics*	12.3
Solar sensor group	1.0
Subsystem total	71.3
Solar array	
Solar array panel*	34.0
Storage drum mechanisms*	35.8
Subsystem total	69.8
Power conditioning and storage	
Battery/charge controllers**	42.8
Power conditioning unit**	19.6
Subsystem total	62.4
Instrumentation* (includes reference cell/module)	14.1
FRUSA system total	217.6
Load bank for I-V tests**	28.4
Contingency	4.0
Total experiment weight	250.0

*Actual weight

**Approximately 90 percent actual weight; 10 percent estimated weight

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SECTION IV

SOLAR ARRAY SUBSYSTEM

SUMMARY

The solar array subsystem consists of two flexible solar cell arrays that are stored, deployed, and retracted by the drum mechanism. During the tenth quarter of the program, the following major tasks were accomplished.

- Completion of solar array shading analysis
- Completion of "hot spot" analysis due to shading by the fixed Agena panel
- Preparation of test summary for reference cell/modules
- Successful completion of 2000 thermal cycles on representative sector of solar array
- Finalization of acceptance test plan for solar array subsystem

DESIGN AND ANALYSIS TASK

Power Reduction Due to Solar Array Shading

The analysis to determine the effect of shading by the fixed Agena panel on the output characteristics of the FRUSA solar arrays has been completed. With the aid of approximately 86 photographs (see Figure 2), the percent of power available under shadow conditions was calculated and plotted as a function of orbit angle (theta). The actual conditions evaluated are shown in Figures 3 and 4 by symbols for orbit inclination angles (beta) from 0 to 70 degrees. The points have been connected by straight lines for legibility.

"Hot Spot" Failure Analysis

The most critical hot spot condition will occur when two cells (out of three parallel cells) are shadowed, while the remaining cell is illuminated. This condition can exist on the FRUSA solar arrays when the shadow tip of the LMSC solar panel crosses into a 3 x 81 cell group. The hot spot problem is the most serious for large inclination angles (beta) where the rate of movement of the shadow becomes very low. Under conditions of low shadow rates, the cell may heat up sufficiently to melt solder at the cell interconnect.

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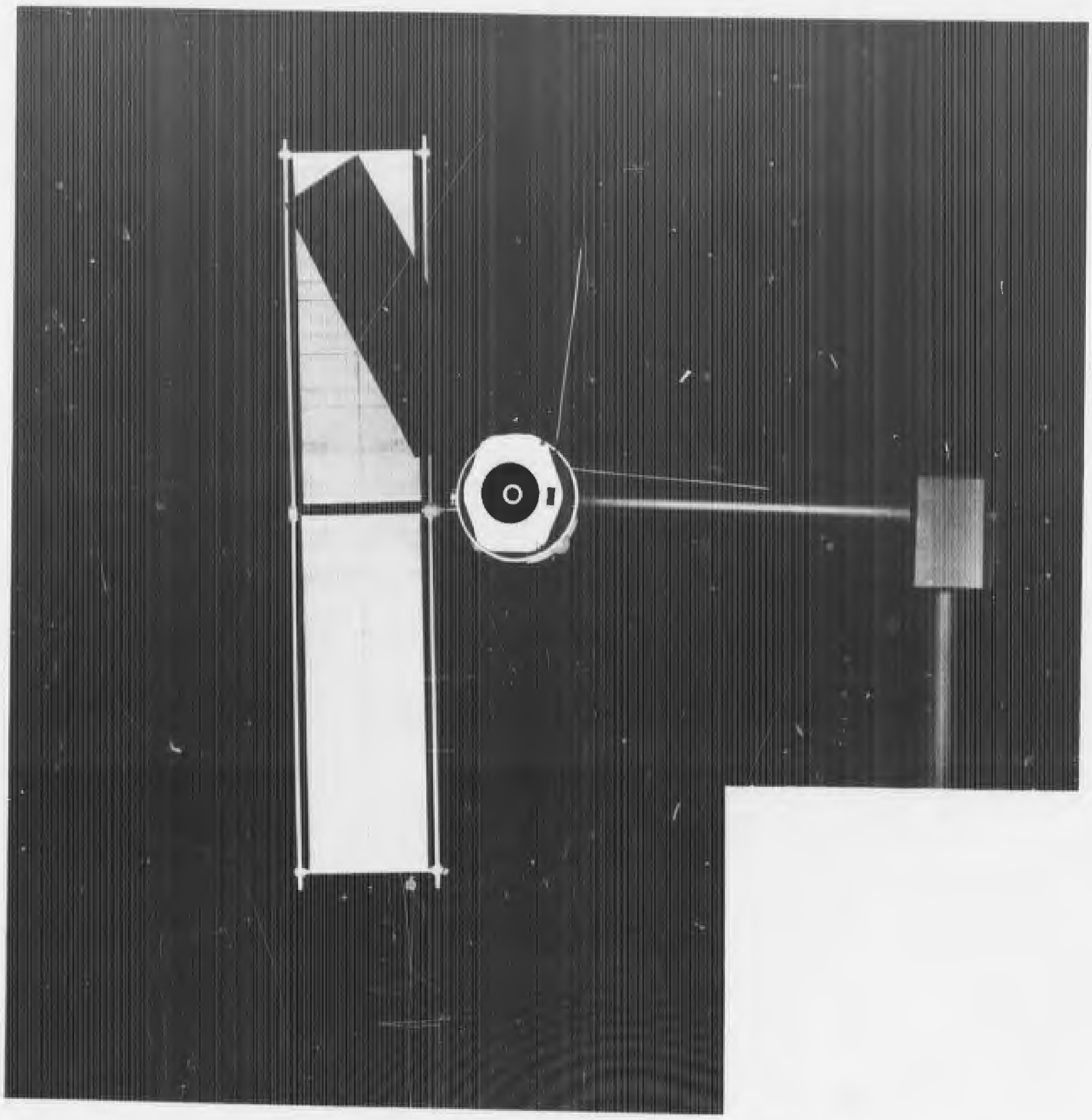

Figure 2. Typical Shading Photograph
(Photo 10013-2)

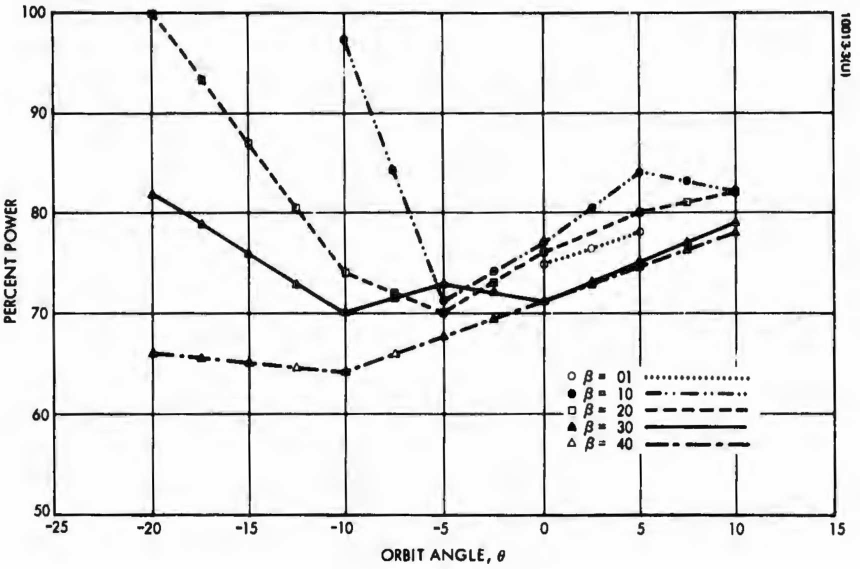

Figure 3. Percentage of Total Power Versus Orbit Angle $\beta = 1$ to 40 Degrees

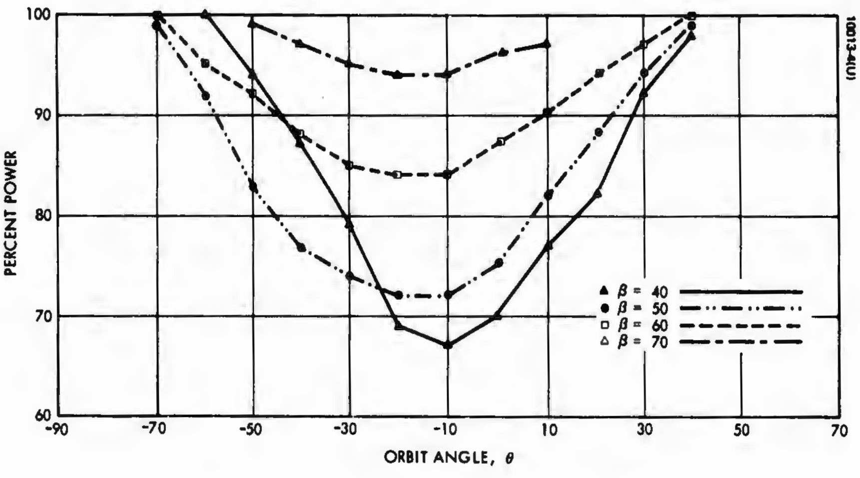

Figure 4. Percentage of Total Power Versus Orbit Angle $\beta = 40$ to 70 Degrees

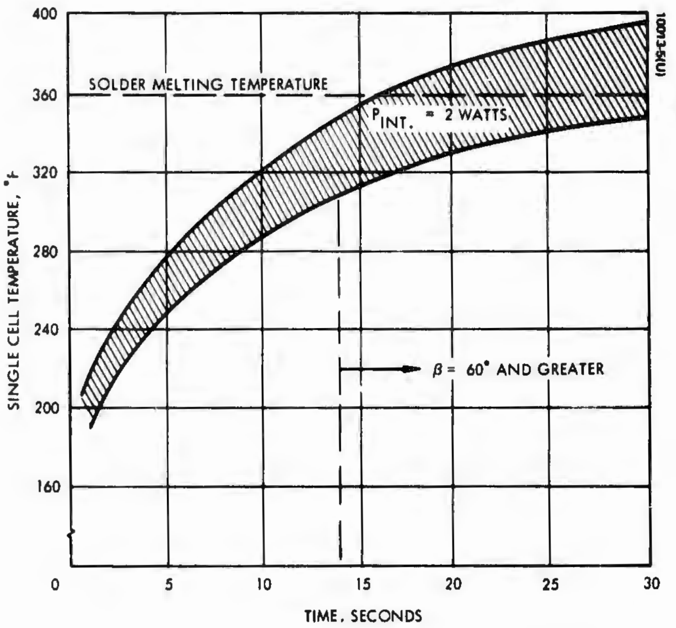

Figure 5. FRUSA Cell Temperature History After Step Input of Internal Power-Panel at Subsolar Point

In addition to the shadow movement rate, other factors influencing the severity of the hot spot problem include:

1) Minimum operating voltage of the solar array bus

2) Maximum voltage the nonshaded cells in a partially shaded 3 x 81 group can develop

3) Amount of current that a reverse biased cell can pass

For the FRUSA arrays, the minimum voltage of the solar array bus at the panel is about 25 volts. Since the cell temperature during the shading period is at least 150°F, the maximum voltage that the illuminated cells in series with the shaded cell(s) can produce is approximately 35 volts. The hot spot cell, therefore, will be reverse-biased no more than 10 volts. Tests on FRUSA 8 mil cells indicate that the cells will pass less than 180 ma at (-) 10 volts. This results in a power dissipation of under 1.8 watts.

With nominal parameters, a thermal analysis indicates that a cell dissipating 2 watts will approach the solder melting temperature (see Figure 5). Although the curve shows that more than 40 seconds are required to reach this temperature, there are sufficient tolerances on the parameters used to cause a 25° to 50°F variation on the temperature at any particular time. The analysis, therefore, shows that a problem due to the hot spot condition could develop on the FRUSA panels. This is especially true for beta angles of roughly 60 to 70 degrees and greater.

To fully evaluate the extent of the hot spot problem, a rather sophisticated thermal-vacuum test must be conducted on a representative sample of the array. The results of this test would reduce the 25° to 50°F uncertainty on the calculated temperatures. Since this in effect would only allow a more accurate prediction of the critical beta angles, the test is not recommended. The preferred solution is to eliminate shading of the panels at the higher beta angles. Some of the possible approaches that prevent the shadowing conditions leading to the hot spot problem include:

- Rotate arrays about support axis to other side of vehicle for beta angles of 60 degrees and larger

- Retract arrays the amount necessary to eliminate shadows for beta angles of 60 to 75 degrees

- Turn off system for beta angles of roughly 60 to 75 degrees

- Modify location, size, and/or geometry of LMSC panels

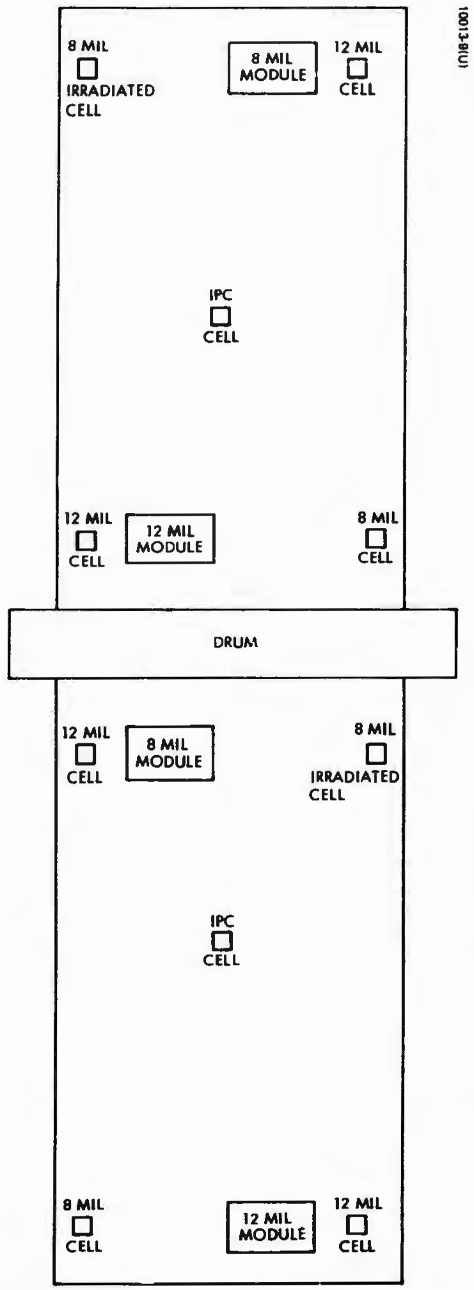

Figure 6. Location of Reference Cells and Modules on Flight Solar Arrays

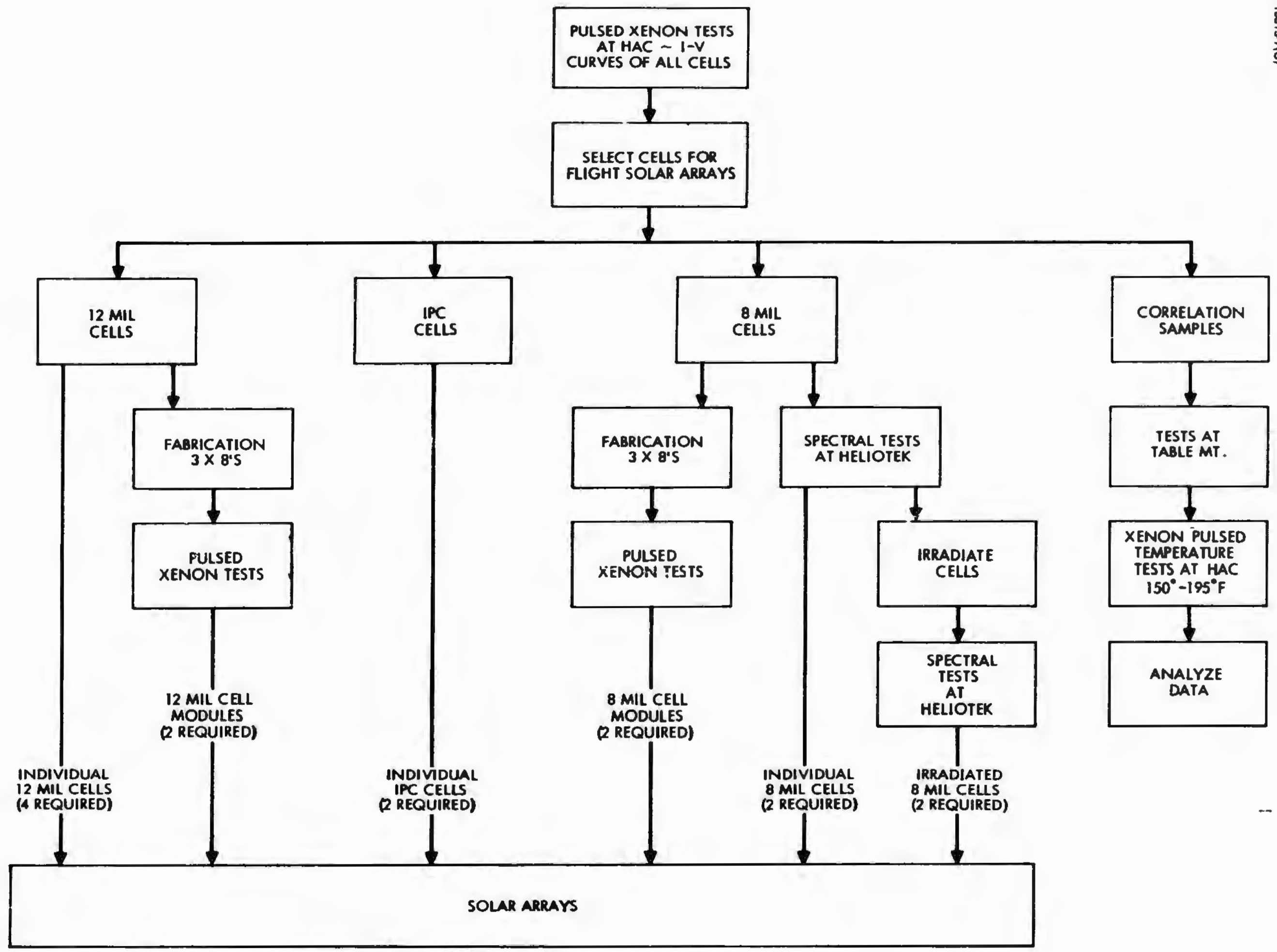

Figure 7. Reference Cells/Modules Flow Diagram

TEST ACTIVITIES

Reference Cells/Modules Program

The test and calibration plans have been established for the reference cells/modules on the flight solar arrays. In addition, some changes have been made in the types of reference cells being employed. The revised arrangement of cells/modules to be flown are as follows:

Type of Cell	No. of Cells/Panel	Total No. Being Flown
IPC 10 ohm-cm N/P	1 single cell	2
Heliotek 10 ohm-cm N/P 12 mil cell/2 mil integral cover	1 module and 2 single cells	2 modules and 4 single cells
Heliotek 2 ohm-cm N/P 8 mil cell/6 mil cover	1 module and 1 single cell	2 modules and 2 single cells
Irradiated Heliotek 2 ohm-cm N/P 8 mil cell/6 mil cover	1 single cell	2 single cells

The location of these items on the flight solar arrays is shown in Figure 6. Test and assembly plans for the individual cells and modules are presented in Figure 7. In general, all tests on the cells to be flown will be done with the Hughes pulsed xenon simulator. Test data correlation will be obtained by evaluating samples of each cell type in natural sunlight at Table Mountain and under the pulsed xenon illuminator.

Qualification Model Tests

The qualification model solar arrays have been tested with the pulsed xenon simulator. The output of the live 3 x 81 cell groups was found to be essentially the same as before bonding to the panels. This is significant since, in addition to the bonding and handling operations, the panel was furled/unfurled on the water table approximately 20 times. Evaluation of the reference cells/modules with the simulator uncovered some incorrect wiring, which has been reworked.

In-process tests have been conducted on various components of the drum mechanism during the refurbishment operations. These have included;

- Drum bearing torque
- Drum bearing plus flexible cable torque

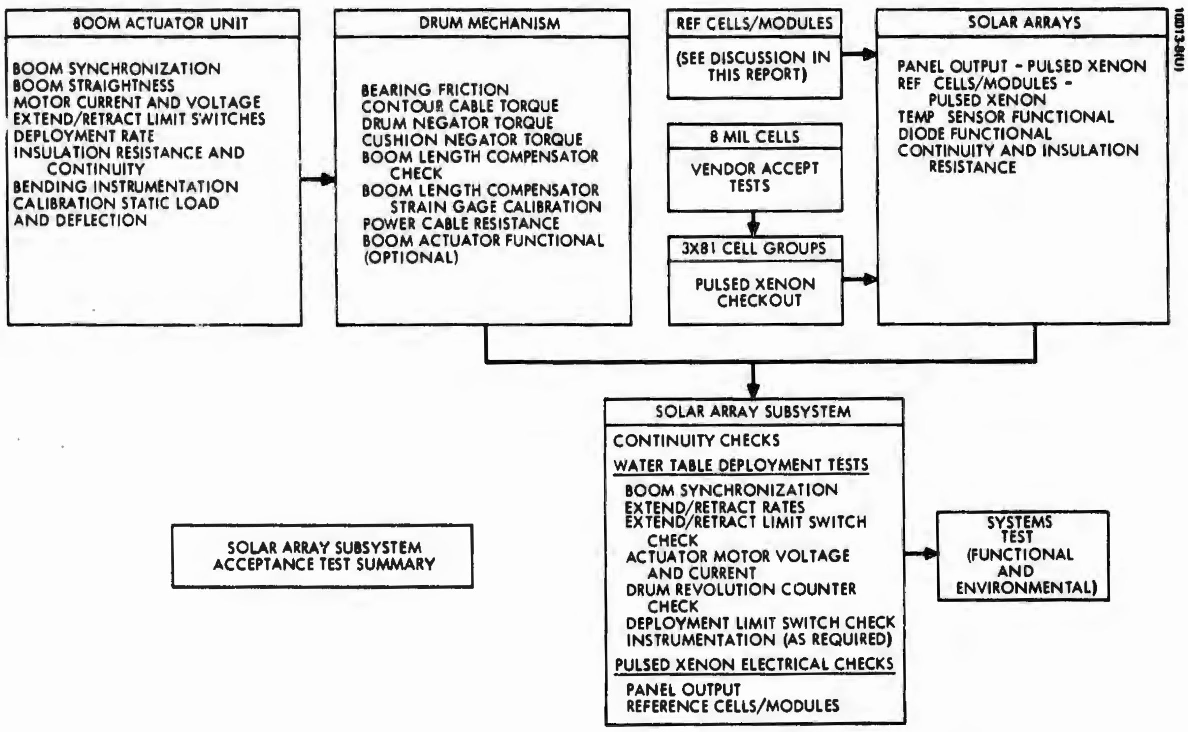

Figure 8. Solar Array Subsystem Acceptance Test Summary

- Drum bearings, flexible cable, and negator torque characteristics

- Boom length compensator check including strain gauge calibration

- Cushion reel negator torque

All data appear to be normal and within the specification limits. The panel tension resulting from the negator, bearing, and cable characteristics is near the high limit of the current specification.

A summary of the solar array subsystem test program is shown in Figure 8.

Thermal Shock and Cycling Tests

The thermal shock and cycling tests on a panel segment at NASA Lewis have been completed. A total of 2000 cycles were performed with no mechanical or electrical degradation noted in the test sample. A typical cycle for these tests was 55 minutes at +189°F, followed by cooling to -163°F in 30 minutes.

Fabrication Status

The qualification model solar array subsystem will be ready for systems qualification tests about the first week in January. The solar arrays for this subsystem are complete and tested. Among the tasks remaining or in progress at this time are the following:

- Installation and wiring of the boom actuator unit

- Final wiring of some instrumentation units

- Deployment acceptance tests on the water table

The following items have been accomplished on the flight model of the solar array subsystem:

- All flight cell groups have been fabricated and tested.

- Bus and substrate fabrication has been completed with bonding under way.

- Fabrication of drum mechanism detail parts is about 70 percent complete.

WORK TO BE PERFORMED DURING NEXT QUARTER

- Qualification tests on solar array subsystem

- Continuation of fabrication and assembly of flight model

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SECTION V

ORIENTATION SUBSYSTEM

SUMMARY

The orientation subsystem automatically maintains the solar panel normal to the sunline. It also provides signal and power transfer from the solar panel to the spacecraft and a deployment mechanism that deploys the stowed array to its normal operating configuration. The subsystem consists of essentially three subassemblies: sensor group, control electronics unit, and orientation mechanism.

Activity during this period centered on completion of assembly and acceptance testing of the mechanism and electronics unit. These units were delivered to system test on 23 December.

BRUSH MODIFICATION

During unit assembly, it was found that the seating of the power brushes was very sensitive to dimensional tolerances. This was not sufficiently appreciated at the time of the original design when the inner surface of the brush slot was utilized as the basic brush-positioning surface. As a consequence of this problem, the design was altered to utilize the ring surface as the basic reference, with slight angular freedom of the brush attitude providing an inherent capability to adapt to relative component movements and initial dimensional variations due to tolerance buildups. Testing indicates that the modification performs as intended, with the brush seating well on the ring for either direction of rotation.

ACCEPTANCE TESTS

Figure 9 is a photo of the assembled mechanism (less control electronics unit). For convenience of testing, the two axes of the mechanism were separated, each being capable of independent operation. A separate mechanism test breadboard was built up and integrated into the test panel. This breadboard provides the capability of driving the unit at selectable rates from zero up to 60 rpm, thus facilitating accelerated run-in, as well as tests at the design maximum of 1/2 deg/sec. Rate control is implemented through a loop containing the unit's own rate sensor. Because dry-lubricated brush friction is substantially lower in a vacuum or a dry inert-gas atmosphere than in normal air, most of the testing was conducted in a chamber continuously purged with dry nitrogen. Due to delayed delivery of the 1500 watt sliprings, the 700 watt electrical and thermal configuration was tested. Qualification of the high powered version will then be based on, 1) the 700 watt test data, 2) analytic extrapolation to the 1500 watt case, and 3) verification of the extrapolation during later

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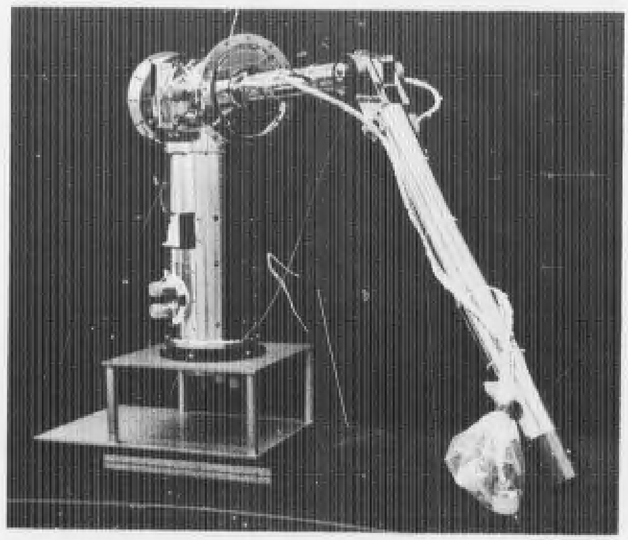

Figure 9. Orientation Mechanism
(Less Control Electronic Unit)
(Photo A28781)

acceptance tests of the 60 ampere flight unit. Typical friction and ring noise results are illustrated in Figure 10.

Seven minor discrepancies were uncovered during the tests:

1) Brush force was slightly low on six signal brushes. This is not significant, was not correlated with noise, and is correctable.

2) Friction levels in air were high. The specification was intended to apply only to vacuum conditions; the air measurement requirement will be deleted.

3) A few signal brushes showed occasional (rare) noise spikes in excess of the 5 mv specified. These measurements were made at a 5 deg/sec rate to reduce test time. It was demonstrated that the noise is in specification at rates approximating the 1/2 or 1 deg/sec maximum flight rates. The specification will be changed to call for testing at 1 deg/sec.

4) On the drum axis, stall torque measurements were corrupted by attached cables. A better test setup will be devised for the next unit.

5) Signal circuit resistance was over specification in some channels. This is believed to be partly a matter of averaging the specified allocation to each axis, and averaging the correction for test-lead resistance. Specification and technique will be refined for tests of the next unit.

6) Two temperature sensors (thermistors) were inoperative. This was subsequently traced to a wiring error, and corrected.

7) Bearing preload was 13 to 14 pounds instead of the 20 (minimum) specified. The actual preload is acceptable from a performance standpoint, and will be dispositioned "use as is" for this unit. Following system-level qualification tests, it will be decided whether to change the specification or use more care in selection of shim thickness during assembly of the flight unit.

ENGINEERING TESTS

Because of apparent clearance problems resulting from LMSC's placement of their telemetry antennas, a short series of engineering tests was conducted of deployment-arm performance, utilizing different geometrical arrangements of the cable loop at the deployment hinge. As the aim was simply to evaluate the effect of differences in cable routing, the

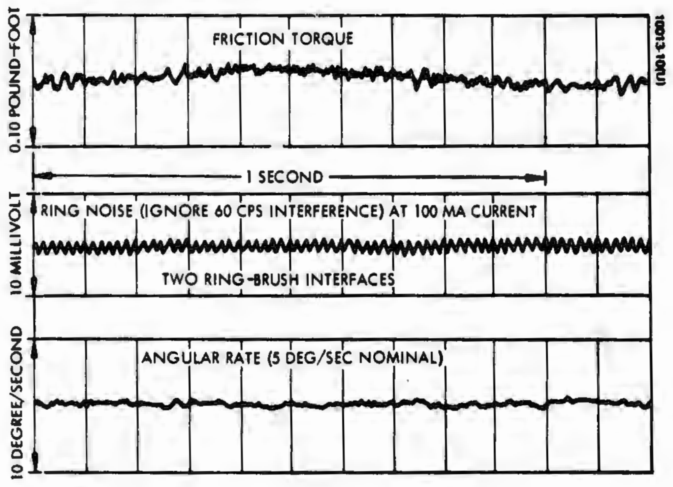

Figure 10. Typical Friction and Ring Noise Measurements Support Axis, Orientation Mechanism

latch was removed and no simulated inertia load was provided. A timer was connected to switches operated by the starting and stopping of the outer (deployed) arm. Little effect of loop size or placement was discernible at room temperature, and an arrangement ensuring clearance of the LMSC antennas was adopted. Further engineering tests of deployment and latching performance at cold and hot temperatures and with simulated array inertia remain to be conducted.

SUN SENSORS

Qualification and flight sun sensors are being assembled simultaneously. This work was delayed due to late delivery of a special optical/thermal internal paint, but this material is now in hand, and unit delivery is scheduled for early January. One sensor group will be utilized immediately for preliminary system testing, while the other is in calibration at the Hughes sun-sensor test facility at Tucson. The first unit will then undergo calibration at a later date.

FLIGHT HARDWARE

Most of the hardware for the flight mechanism has been received. Deployment bearings are the pacing item, but all hardware is expected by 21 January 1971, allowing completion of assembly in February. Assembly of the flight CEU boards has been static at 80 percent complete for some time, holding for problem parts procurement. Assembly completion is anticipated in January, however, followed by 2 weeks of testing and delivery.

LIAISON EFFORT

From time to time, LMSC, because of a potential interference of the FRUSA array with the LMSC fixed array and the ONR-001 antennas in some orbits, has inquired as to the practicality of various means of controlling or limiting the array position in a nonstandard manner. The problems have now been resolved by stored program and timer commands, eliminating the need for modifications to the array control logic.

WORK TO BE PERFORMED DURING NEXT QUARTER

Events planned for the next quarter comprise completion of qualification, assembly, and acceptance tests of the flight units.

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SECTION VI

POWER CONDITIONING AND STORAGE SUBSYSTEM

BATTERY/CHARGE CONTROLLER

The assembly of the qualification model battery/charge controller unit (BCCU) has been completed (Figure 11). Functional tests of the charge control electronics at room temperature, 35°F, and 112°F have also been completed. In general, the electronics performed well and demonstrated the following significant features of the design:

- Charge current varied less than 5 ma over the temperatures tested.
- Charge and discharge current telemetry was practically unaffected by temperature.
- Charge current-limiting was demonstrated to be within specification limits.

The two 12-cell battery packs for this unit have been assembled and successfully tested. The tests consisted of leak tests, internal short checks, and capacity measurements at 40°, 75°, and 90°F. After mounting of the packs on the chassis, the complete unit will be subjected to high and low temperature cycling tests before delivery to systems test.

The current status of the flight BCCUs is as follows:

- Battery cells have been received and are being acceptance-tested.
- Chassis have been fabricated.
- Charge controller electronics are being assembled.

The battery cells for this unit were shipped about a month late by the vendor and are now the pacing items. Delivery problems with other high reliability components have been eliminated by negotiating improved delivery dates with the vendors.

BATTERY DEVELOPMENT TEST PROGRAM

To evaluate the performance of the HS-207 battery cells under simulated orbital operating conditions, the following test parameters were employed:

Charge time	54 minutes
Discharge time	46 minutes

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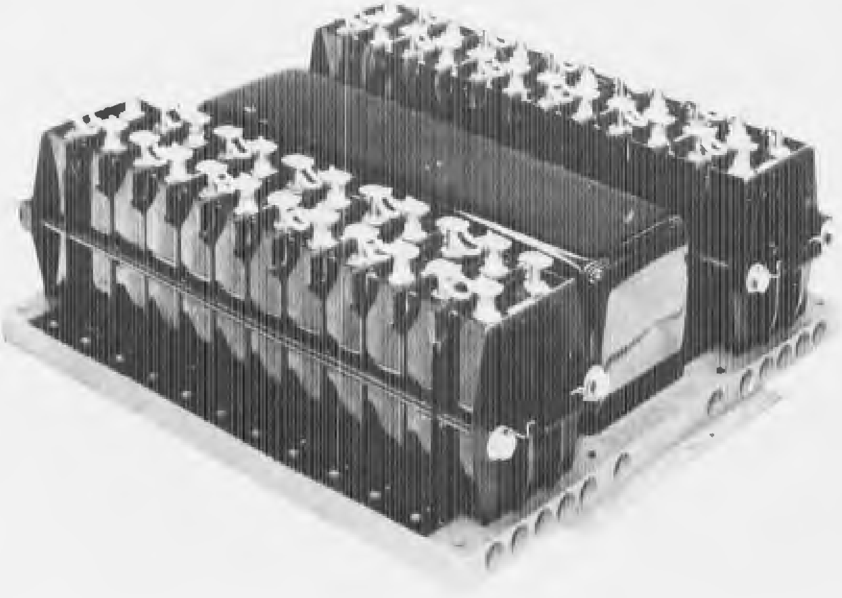
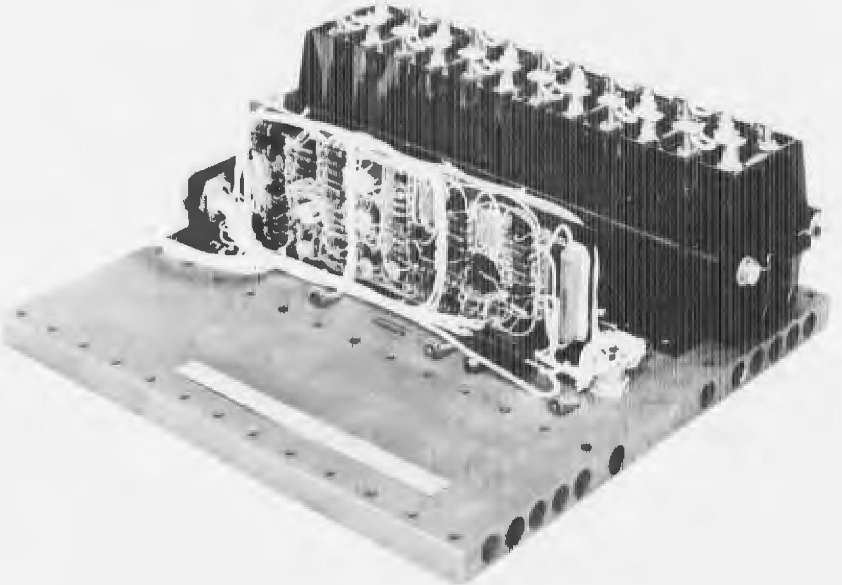


a) Photo ES1270-29815



b) Photo ES1270-29816

Figure 11. Qualification Model Battery/Charge Controller

Charge current	1.0 and 0.6 ampere*
Discharge current	0.65 ampere
Expected temperature range	40° to 80°F
Temperature range for tests	30° to 90°F

*Switched from 1.0 to 0.6 automatically when cell voltage reached 1.45 volts.

The breadboard charge controller with two cells from the qualification model lot were used for the tests.

A total of 174 simulated orbits were run during the program. The performance of the subsystem was normal at all test temperatures.

POWER CONDITIONING UNIT

The qualification model power conditioning unit (PCU) has been completed (Figure 12) and is ready for preliminary functional tests. These tests are intended to verify proper operation at the expected temperature extremes. Each submodule for this assembly has been checked out at ambient temperature prior to installation on the chassis. Although some of the select-in-test components have been installed, most will be installed during the functional thermal tests.

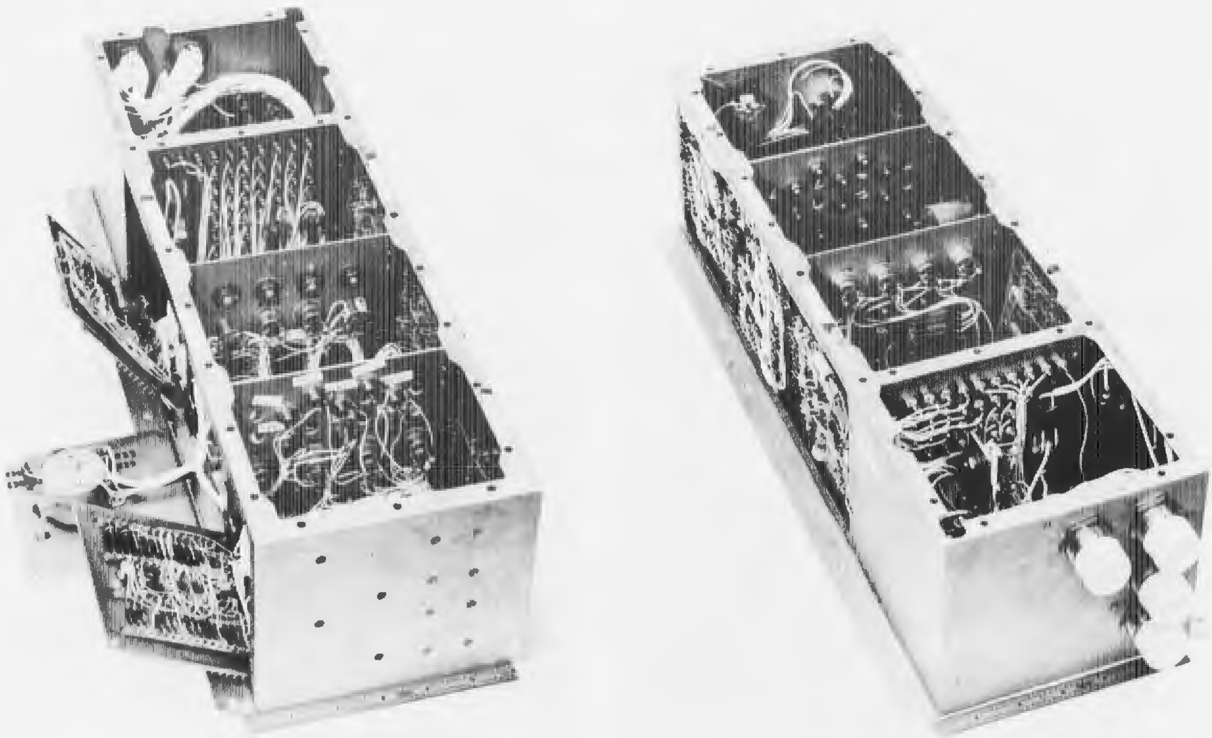
Flight unit assembly on the PCU submodules is in progress, and the main chassis has been completed. In order to minimize problems during unit checkout, each submodule will be checked out before installation.

LOAD BANK

The load bank assembly (see Figure 13) for the qualification test program has been completed and functionally tested. Following conformal coating, painting, and a final test, this unit will be delivered to the systems area for test.

WORK TO BE PERFORMED DURING NEXT QUARTER

- Completion of fabrication and test on units for qualification model
- Continuation of assembly on flight units



a) Photo ES1270-29813 b) Photo ES1270-29814

Figure 12. Qualification Model Conditioning Unit With Covers Removed

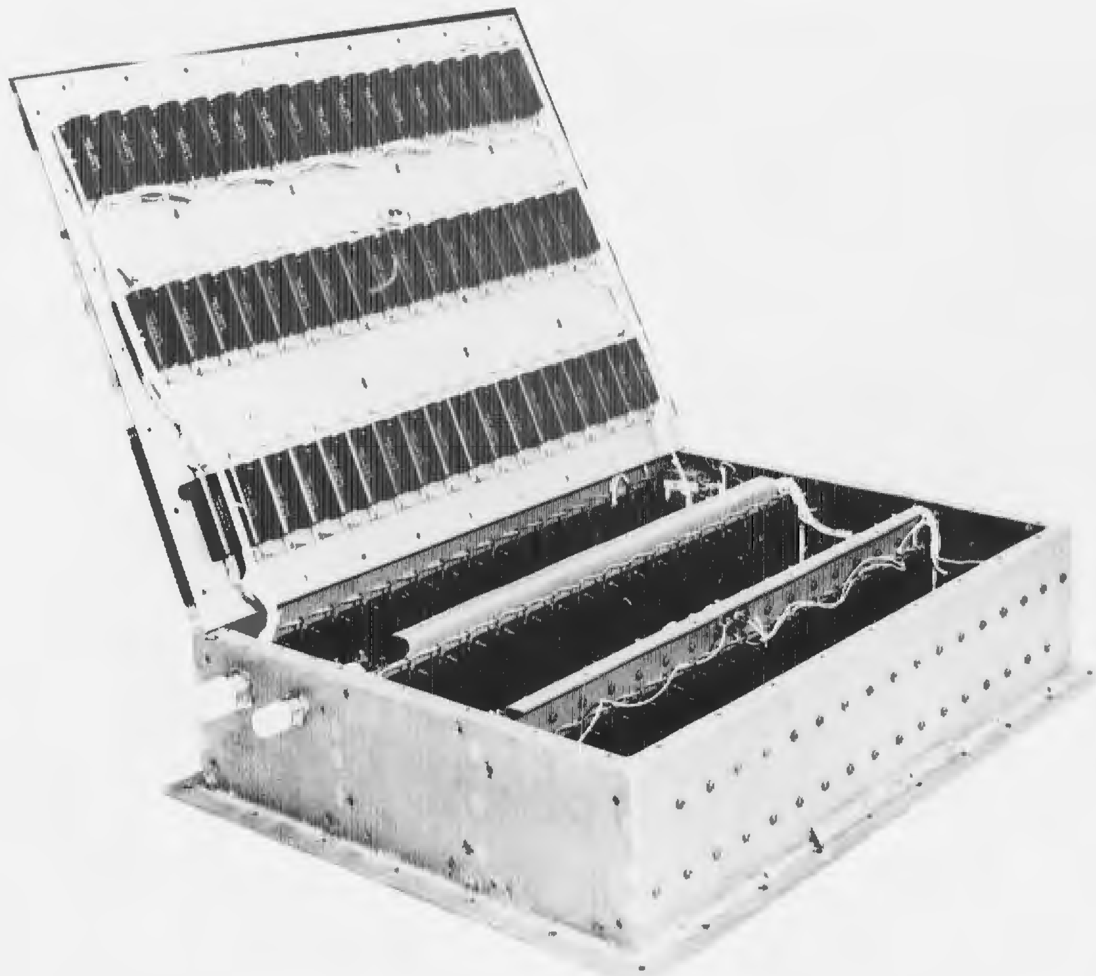


Figure 13. Qualification Model Load Bank Assembly
(Photo ES1270-29818)

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SECTION VII

INSTRUMENTATION SUBSYSTEM

SUMMARY

The instrumentation activity during this period included:

- Adoption of modified 64-word FRUSA commutator format
- Addition of one new telemetry channel
- Completion of instrumentation thermal analysis
- Completion of fabrication and test of qualification unit SCEU and ICU
- Installation of all instrumentation units on FRUSA qualification model

ADOPTION OF MODIFIED 64-WORD FRUSA COMMUTATOR FORMAT

The present SCF computer software is not able to process the FRUSA 45-word commutator telemetry signals in real time during the mission. The SCF software is configured to function with commutator sizes based on a binary progression (16, 32, 64, etc.). LMSC is modifying the Carrier 1 orbit PCM type 6 unit to add 19 idling periods to the FRUSA commutator to convert it to a 64-word format. Idling periods of 6, 6, and 7 words are being added after the 15th, 30th, and 45th FRUSA commutator words. Also, the sampling rate on the main frame is being doubled by providing three additional main frame telemetry words. The FRUSA commutators will be sampled twice per Agena main frame, which means that 32 Agena main frames are required to read out the new 64-word format. Since the Agena main frame time is 8 ms, each FRUSA commutator signal will be sampled every 8 x 32 = 256 ms. The supercommutated accelerometer and strain gauge signals will be sampled every 85-1/3 ms.

The FRUSA commutators (purchased from Teledyne) were checked out with the FRUSA AGE tester. The latter provided simulated Agena frame and word synchronized pulses to the commutator. The data pulses, pedestals, and synchronization pulses in the serial data stream are all in their proper timing relationship.

To ensure compatibility between the FRUSA commutators and the Agena PCM Telemeter 6, an integration test will be conducted at Motorola, the LMSC vendor. This test is presently scheduled for January.

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NEW TELEMETRY SIGNAL

All FRUSA telemetry signals are measured with respect to the Agena telemetry return which is near the vehicle structure ground level. FRUSA unregulated power returns are connected to the structure ground through the Agena power subsystem. The voltage drop on these lines introduces a telemetry measurement error into a number of FRUSA power telemetry signals. This error can be subsequently calibrated out by measuring the voltage drop from the solar array return to the structure ground. This will be accomplished by connecting a wire from the current shunt of solar panel 1 to a spare channel on solar array commutator 1. The new telemetry signal is designated solar array return voltage drop.

INSTRUMENTATION THERMAL ANALYSIS

A thermal analysis of the instrumentation subsystem has indicated that the boom length compensator strain gauge amplifiers and several of the accelerometers could reach a temperature of 180°F. To preclude operating these units at their thermal design limits for an extended period of time, it was decided to apply a black thermal paint to all of the accelerometers and to coat two radiating surfaces of the strain gauge amplifier with a white thermal paint. This will maintain the maximum temperature of these units below 150°F, which greatly enhances their reliability.

INSTRUMENTATION HARDWARE STATUS

All instrumentation units for the FRUSA qualification model have been installed.

Fabrication of the flight ICU and SCEU is approximately 75 percent complete.

Commutators, strain gauge amplifiers, and accelerometers for the flight model are on order and will be received during the next quarter.

WORK TO BE PERFORMED DURING NEXT QUARTER

- Verify proper operation of instrumentation subsystem in qualification model system test
- Complete fabrication and test of flight ICU and SCEU
- Perform checkout and installation of flight accelerometers, strain gauge amplifiers, and commutators
- Perform integration check of FRUSA commutator and Agena PCM telemeter 6

SECTION VIII

SYSTEMS TEST

SUMMARY

System test activity during this report period includes:

- Receipt of FRUSA vibration fixtures
- Fit and shake tests of the vibration fixtures
- Completion of the STV fixture design
- Completion of the systems test electrical harness
- Continued EMC analysis and test planning
- Publication of upgraded systems test plan
- Completion of the systems test procedures
- Initiation of FRUSA systems test

The FRUSA vibration test fixtures were received from the subcontractor. There are four fixtures involved in the FRUSA vibration program. Two fixtures are required for the solar array subsystem, one for the orientation mechanism and one for the power conditioning and storage subsystem. A fit check of the fixtures to the shakerhead was conducted, and, because of the complexity of the solar array fixtures, a functional vibration of the fixtures was conducted. Results of the test indicated the fixtures were within the design ranges and that notches were experienced in the areas expected. The attach points of the solar array longitudinal and lateral fixtures required some minor machining before a fit to the shakerhead could be accomplished.

The design of the solar thermal-vacuum fixtures was completed, and the fixtures are in fabrication. Receipt of these fixtures is now expected on 15 January 1971, well ahead of the period of expected usage.

The systems test electrical harness has been completed, and delivery was made to system test. Some additional cables required for STV only are still in fabrication with delivery expected on 15 January 1971.

An upgraded version of the FRUSA systems test plan has been published and distributed. Future changes will be handled as page corrections rather than a complete revision.

The EMC test planning and analysis work were initiated. The initial analysis task to define the size, shape, and complexity of the panel mockup has been completed. The test plan in rough form is being coordinated among the appropriate subsystem and system areas.

The qualification model of the orientation subsystem was received by systems test on 23 December. Slight modifications to the wooden test fixture were required. The subsystem has been installed in the test fixture and is undergoing initial system checkout.

The vibration test plan for the FRUSA is being expanded to include the LMSC interface brackets with the solar array. In conjunction with these expanded tests, multiple pyrotechnic separation tests are being planned. Of particular interest is a separation test after vibration of the brackets and solar panel has been accomplished. In order to prevent differential movement between the support brackets as they are removed from the vibration fixtures, a support plate is being designed and fabricated. This plate will attach between the brackets and the fixture. This allows removal of the brackets, plate, and solar array to the deployment area without differential movement between brackets. The additional pyrotechnic separations planned include one during functional testing, one after vibration tests, and four under various bracket misalignments.

WORK TO BE PERFORMED DURING NEXT QUARTER

- Complete qualification tests
- Complete planning for flight acceptance test
- Coordinate with LMSC concerning the integrated systems test
- Complete a fit check at LMSC with qualified hardware

SECTION IX

RELIABILITY

The Approved Parts List continues to be revised from time to time when additional parts need to be added. The additional parts result from engineering tests on the hardware but as the design is complete, it is unlikely that there will be any more parts added.

Various subassemblies of electronic hardware have been and will be tested and witnessed throughout the entire test by Quality Control personnel.

Inspection procedures have been reviewed and revised to more stringent requirements.

RELIABILITY ESTIMATE

A new estimate of the FRUSA reliability has been completed based on the newest parts list and mission time of 1/2 and 1 year. It was assumed, during a 6 month mission, the solar array would be extended once; whereas, in the 1 year mission, it was assumed that the solar array would be extended and retracted 10 times. It was found that the reliability for 1 year was 0.695, and 0.856 for 1/2 year. The reliability goal established early in the program of 0.65 for 1 year is therefore being met.

WORK TO BE PERFORMED DURING NEXT QUARTER

- Source surveillance for high reliability parts
- Incoming inspection and test of parts
- Inspection of the qualification model components
- In-process inspection
- Processing TFRs
- Test witnessing

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13. ABSTRACT

The main activities on the Flexible Rolled-Up Solar Array (FRUSA) program during the tenth quarterly reporting period consisted of completion of assembly of the qualification model and start of assembly of the flight model of the orientation mechanism, solar arrays, drum mechanism, control electronics unit (CEU), solar cell electronics unit (SCEU), instrumentation conditioning unit (ICU), battery charge controller (BCC), power conditioning unit (PCU), and load bank.

The bi-stem actuator units have been refurbished and, together with the arrays, ICU, and SCEU, integrated with the drum to complete the qualification model of the solar array subsystem. The qualification model of the orientation subsystem has been completed and delivered to the system test area. All qualification model elements of the power conditioning and storage subsystem have been fabricated.

Flight model fabrication and assembly are on schedule. All flight cell groups of the arrays have been fabricated and tested. Drum mechanism and orientation mechanism detail parts are 70 percent complete. All electronic circuit boards are nearing completion, and all battery cells have been received.

Several working group meetings were held between SAMSO/Aerospace LMSC and Hughes to resolve interface problems and to review system test procedures. The FRUSA mission sequence was modified to coincide with the integrating contractor orbital mission planning. An upgraded system test plan has been released.

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