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ENVIRONMENTAL TEST PROGRAM AND SYSTEM EVALUATION OF THE SYNCOM COMMUNICATION SATELLITE

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GODDARD SPACE FLIGHT CENTER
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ENVIRONMENTAL TEST PROGRAM AND SYSTEM EVALUATION OF THE SYNCOM COMMUNICATION SATELLITE

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TEST PROGRAM STATUS

This is the final report on the Syncom Environmental Test Program. Three spacecraft were orbited from Cape Kennedy, Florida: Syncom I, February 14, 1963; Syncom II, July 26, 1963; and Syncom III, August 18, 1964. The Delta vehicle successfully placed all three spacecraft into their correct parking orbits, but communication with Syncom I was lost during apogee motor burn. Syncom II and III are presently operating satisfactorily in their respective synchronous orbits. With the launching of Syncom III, the Syncom program was terminated.

AUTHORIZATION

GSFC Job Order No. C-70-01

ENVIRONMENTAL TEST PROGRAM AND SYSTEM EVALUATION OF THE SYNCOM COMMUNICATION SPACECRAFT

SUMMARY

The Environmental Test program for the Syncom spacecraft was performed by the Hughes Aircraft Company (HAC), developers and producers of the spacecraft, at their Culver City and El Sequndo, California, facilities. Special tests were performed by various sub-contractors at their respective facilities. The test program was under the surveillance of the GSFC Test and Evaluation Division representative.

This report encompasses the Qualification and Acceptance tests completed in accordance with the HAC Environmental test plans 496000-062 and 496000-063, approved and modified by NASA/GSFC.

The Syncom Environmental Test Program was accomplished in three phases. The first test phase saw the prototype and Flight Models I and II under test. This phase terminated with the orbiting of Flight Model I spacecraft.

The second test phase saw the prototype and Flight Models II and III under test. This phase terminated with the orbiting of Flight Model III spacecraft.

The third test phase saw Flight Model II spacecraft under test. This phase, as well as the Syncom program, terminated with the orbiting of Flight Model II spacecraft.

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ENVIRONMENTAL TEST PROGRAM AND SYSTEM EVALUATION OF THE SYNCOM COMMUNICATION SATELLITE

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INTRODUCTION

Syncom is an active synchronous orbit communication satellite system. Its mission is to demonstrate the feasibility of obtaining a synchronous orbit and conducting communication experiments with a synchronous orbit system. To accomplish this mission, the following primary objectives were pursued:

1. To design a lightweight fully functional spacecraft which can be placed in a synchronous orbit by an existing booster.

2. To demonstrate that the available booster systems plus an on-board apogee motor can place the spacecraft in a nearly synchronous orbit.

3. To demonstrate that simple, lightweight orbit correction system can achieve the necessary exact synchronism and orientation, and to maintain these over extended periods.

4. To demonstrate communication via a synchronous satellite and to obtain experimental information on propagation effects.

The first Prototype Qualification Test program was accomplished during the period October 3, 1962, to January 5, 1963. Flight Acceptance Testing on Flight Models I and II commenced November 11, 1962, and was completed January 17, 1963. On February 14, 1963, Flight Model I spacecraft was successfully launched from Cape Kennedy, Florida, aboard the Delta vehicle. All contact with the spacecraft was lost approximately twenty seconds after ignition of the apogee motor.

A spacecraft improvement and retest program was initiated on the remaining spacecraft, based on the knowledge obtained from the Syncom I launch. Prototype and Flight Acceptance testing was accomplished during the periods

May 27, 1963, to June 18, 1963 and June 4, 1963, to July 17, 1963, respectively. The following changes were made to the remaining Flight spacecraft (F-II, III):

1. The two telemetry transmitters will operate concurrently on two frequencies. An additional battery is provided to power one of these transmitters (and the associated encoder) directly during apogee motor firing.

2. The range filter has been removed since it is not essential to the circuitry.

3. An accelerometer and associated circuitry has been added to obtain telemetry information on acceleration, vibration, and nutation during orbit.

4. The spacecraft wiring harness has been modified to decrease the probability of failure, and to provide further assurance that failure in one portion of the harness or circuitry will not affect other portions.

5. The three year timer was deleted.

6. The JPL starfinder apogee motor replaced the Thiokol motor.

7. The ground plane finish was changed to raise the overall spacecraft temperature by 10°F.

8. Nitrogen pressure was reduced from 3670 psi to 3000 psi nominal.

On July 26, 1963, Flight Model III spacecraft was successfully launched from Cape Kennedy, Florida, aboard the Delta vehicle. The spacecraft was adjusted to a true synchronous orbit with the orbit node at 55° W longitude. All systems and functions of the satellite were proven with only minor exceptions.

The third remaining spacecraft, Flight Model II, was acceptance tested from March 17, 1964, to April 17, 1964. The following modifications were made from the Syncom II configuration:

1. The nitrogen control unit was replaced with a hydrogen peroxide control unit. The spacecraft now has two redundant hydrogen peroxide units.

2. The apogee motor timer was removed. The motor is now fired by command.

3. Four temperature sensors replaced the previous two sensors.

4. The standby battery was eliminated.

5. The type P-N solar cells were replaced with the type N-P cell.

6. A bandwidth of 10 mc with a capacity of changing to a 50 kc bandwidth on command was incorporated in the narrowband transponder which previously had a 500 kc bandwidth.

On August 18, 1964, Flight Model III spacecraft was successfully launched from Cape Kennedy, Florida, aboard the Thrust Augumentated Delta (TAD). The spacecraft was adjusted to a true synchronous equatorial orbit above the International Date Line. At the time of this report, all systems were functioning satisfactorily.

TEST OBJECTIVES

The primary objectives of the Syncom Design Qualification and Flight Acceptance Environmental Test Program were:

1. To insure adequacy of design by exposing the prototype model to qualification test levels more severe than would be expected from ground handling, launch, and orbital operation.

2. To expose defects of workmanship and material in flight hardware by subjecting flight units to predicted environmental levels, thereby assuring that none of the essential design characteristics of the spacecraft had been degraded during manufacture.

3. To gather data and knowledge for assuring the reliability of the spacecraft system by the evaluation of test procedures, tests, and test results.

TEST PLAN

Background

The test plan submitted is to define test requirements, methods, and general procedures to be followed in testing the prototype and flight models of the Syncom spacecraft as governed by the Delta launch vehicle specification.

In conjunction with the environmental testing, a detailed System Performance Test is included to assist in evaluating the spacecraft design and operation.

Prior to conducting environmental testing, the spacecraft was subjected to the System Performance Test under ambient conditions and all necessary data was recorded to determine performance of the spacecraft within specifications. The spacecraft is again subjected to the system performance test before and after each environmental exposure.

TEST DESCRIPTION

Balance

The spacecraft is dynamically balanced about its spin axis to assure stability of the spacecraft spin axis in space.

Weight, Center of Gravity, and Moment of Inertia

These parameters were measured for use in predicting launch vehicle performance and spacecraft orbit injection and final orbit stability and performance.

Spin

To stimulate the rotation of the spacecraft which is necessary for stabilization, the spacecraft was mounted on a spin machine and rotated at the prescribed level.

Spin Acceleration

To simulate the spin-up of the Delta third stage, the spacecraft was mounted on a spin acceleration machine and accelerated to the expected spin speed.

Acceleration

To simulate the loading of the Delta launch vehicle, the spacecraft was mounted on centrifuge and accelerated along each of three coordinate axes. The applied force is measured at the spacecraft center of gravity.

Control System Alignment

In order to assure that the spin rate of the spacecraft will not change during control jet operation, the thrust vectors of each lateral jet must pass through the spacecraft center of gravity. The axial jets must be aligned with the spacecraft spin axis.

Vibration

Requirements of the spacecraft vibration test are based on excitations generated by rocket motor operation, as well as aerodynamic and acoustic sources. Exposure of the prototype and flight spacecraft to the vibration test series was in three orthogonal directions. These are the thrust axis and the two lateral axes defined by two orthogonal lines passing through the control system fuel tanks. The spacecraft is vibrated at two interfaces, one being the Delta launch vehicle connection flange and the other, the apogee motor interface.

Shock

To simulate booster and apogee motor shock, the spacecraft was mounted on the shock machine with the thrust axis of the spacecraft aligned with the applied shock.

Thermal Vacuum

This test was used to subject the spacecraft to the temperature extremes over its designed operating range in a vacuum chamber. The test duration was five days: three days at the highest expected operating temperature, and two days at the lowest expected operating temperature. The chamber vacuum was 1×10^{-5} torr or greater during the test.

Apogee Motor Heating

To simulate the heat generated by the burning of the apogee motor, a dummy apogee motor was installed aboard the spacecraft. The test was conducted in a vacuum, using a heating element to raise the temperature of the motor case to the expected value.

Humidity

To insure that the spacecraft will survive the atmosphere conditions that exist at AMR, the prototype spacecraft was placed in a controlled humidity chamber. The spacecraft was wrapped in its plastic shipping container.

Radio Frequency Interference

This test measures the spacecraft radiation over the frequency range of 1kc to 1gs. The corrected radiation interference levels measured over this frequency range, which exceed the limits specified in Figures 6 and 8 of MIL-I-26600, will be plotted to form part of a spectrum signature of the Syncom spacecraft.

Radiation Susceptibility

The susceptibility of the spacecraft to a radio frequency field over the frequency range of 10 mc to 10 kmc is measured during this test. No malfunction or degradation of the spacecraft is allowable during this test.

Combined Acceleration-Vibration

To simulate the combined environments of vibration and acceleration that occur during boost and apogee motor operation, the spacecraft was attached to a vibration exciter mounted on a centrifuge. The spacecraft was tested at both the X-248 and apogee motor interfaces.

TEST SEQUENCE

The following is the actual test sequence that was employed during environmental testing:

Phase One

Prototype—

1. Optical alignment of N_2 and H_2O_2 jets
2. Dynamic alignment of N_2 and H_2O_2 jets
3. Balance and mass properties
4. Thermal vacuum
5. Balance and mass properties
6. Optical alignment of N_2 and H_2O_2 jets
7. Dynamic alignment of N_2 and H_2O_2 jets
8. Vibration
9. Solar vacuum
10. Thermal vacuum - hot only
11. Acceleration
12. Thiokol apogee motor vibration
13. Humidity
14. Apogee motor heating
15. JPL apogee motor vibration
16. Apogee motor heating

Flight Model I—

1. Balance and mass properties
2. Optical alignment of N_2 and H_2O_2 jets
3. Dynamic alignment of N_2 and H_2O_2 jets
4. Spin
5. Vibration
6. RFI
7. Thermal vacuum
8. Optical alignment of N_2 and H_2O_2 jets
9. Dynamic alignment of N_2 and H_2O_2 jets
10. Optical alignment of H_2O_2 jets
11. Balance and mass properties
12. Thrust axis random vibration

Flight Model II—

1. Balance and mass properties
2. Optical alignment of N_2 and H_2O_2 jets
3. Dynamic alignment of N_2 jets
4. Spin
5. Vibration
6. Thermal vacuum
7. Optical alignment of N_2 and H_2O_2 jets
8. Dynamic alignment of N_2 and H_2O_2 jets
9. Optical alignment of H_2O_2 jets
10. Balance and mass properties
11. Thrust axis random vibration

Phase Two

Prototype—

1. Balance and mass properties
2. Shock
3. Lateral vibration
4. Centrifuge vibration (apogee interface)
5. Spin acceleration
6. Apogee motor heating
7. Centrifuge vibration (X-248 interface)

Flight Model II—

1. Balance and mass properties
2. Acceleration (apogee and X-248 interface)
3. Shock
4. Vibration
5. Spin acceleration
6. Optical alignment of N_2 and H_2O_2 jets
7. Dynamic alignment of N_2 jets
8. Thermal vacuum
9. Apogee motor heating
10. Balance and mass properties

Flight Model III—

1. Balance and mass properties
2. Optical alignment of N_2 and H_2O_2 jets
3. Vibration
4. Shock
5. Spin acceleration
6. Acceleration (X-248 and apogee interface)
7. Dynamic alignment of N_2 jets
8. Thermal vacuum
9. Apogee motor heating
10. Balance and mass properties

Phase Three

Flight Model II—

1. Preliminary thermal vacuum
2. Balance and mass properties
3. Shock
4. Vibration
5. Thermal vacuum
6. Optical alignment of N_2 and H_2O_2 jets
7. Balance and mass properties

TEST RESULTS

A complete review of Syncom environmental test history is presented in Appendix A. The following is a general summary of the outstanding problems.

Communication

During prototype testing, failures of the TWT's occurred during thermal vacuum and vibration. The defective tubes were replaced with spares, and the Watkin-Johnson TWT's were eventually eliminated. The flight spacecraft flew with HAC TWT's. The only TWT problem that occurred during acceptance testing was in cold thermal vacuum. The TWT would not turn on, so it and the convertor was replaced with flight spares.

Command

A transistor failure was noted in the prototype spacecraft decoder. The transistor was replaced and no further problems were encountered throughout the entire environmental test program.

Control System

Leaking valves were a problem throughout the entire environmental test program. Corrosion of the H_2O_2 valve seats was caused by the reaction of the H_2O_2 and air. Scored seats and foreign particles also contributed to leaks in the H_2O_2 valves. These valves were all disassembled, inspected, and replaced when necessary. During the test programs for Syncom II and III, H_2O_2 was not on board the spacecraft which eliminated the corrosion problem. However, leaks still appeared at random intervals, either directly out of the jet or from the soldered joints. Leaks directly from the jets were generally corrected by (a) the H_2O_2 jets were heat seated, and (b) the N_2 jets were pulsed. Heat seating consisted of holding the valve open, thereby raising the temperature of the seat, then pulsing the jet. Leaks from the soldered joints were corrected by reheating the solder.

Power

Battery packs were replaced in the prototype spacecraft due to electrolyte leaking. The caps were sealed with epoxy to minimize the leakage.

A diode that protects the batteries from shorting during umbilical removal was missing from Flight Models I and II spacecraft. These were apparently missed during assembly.

A tantalum capacitor failure in the dc convertor was discovered in the F-2 spacecraft along with a transistor failure in the same unit aboard the prototype spacecraft.

Propulsion

The Government-furnished apogee motor timer failed during cold thermal vacuum. The timer was disqualified from Syncom and replaced with a HAC timer.

During a system performance check on the prototype spacecraft, a diode in the apogee motor timer was found to be shorted to ground. Investigation revealed that the insulating washer was missing. This condition also existed on the flight spacecraft. All timers were reworked to install the missing washers.

A transient appeared on F-2 spacecraft common battery bus when the control jets were operated. This transient could fire the apogee motor SCR. Capacitors were added to correct the problem. However, nothing was done to F-3 spacecraft, which was designated for flight. Further investigation on the prototype at AMR revealed the same condition. It, therefore, became necessary to install the capacitors in F-3, which was already mounted on the launch vehicle.

SPACECRAFT PERFORMANCE IN ORBIT

With the orbiting of Syncom II, the objectives of the Syncom program were met: the feasibility of a spin stabilized synchronous orbit, active communication satellite was demonstrated. Orbital control was achieved without difficulty. Launch by the Delta and apogee motor boost resulted in the expected near-synchronous orbit. Velocity corrections and spacecraft orientation were made in the predicted manner, and the spacecraft was adjusted to a true synchronous orbit with the orbital node at 55° West longitude. The results of the communication experiments were excellent with high quality voice signals being transmitted with signal-to-noise ratios up to 40 db. Facsimile photographs were transmitted with a resolution better than standard television. By mid-August, 1963, Syncom II had acquired the following records:

1. The first satellite available for continuous communication.

2. The first satellite to provide coverage of a sporting event and a conversation between heads of state.

3. Over 280 hours of communication experiments. This time exceeds the combined communication times of both Telstar and Relay satellites.

Syncom III was placed in a true equatorial orbit over the International Date Line. This spacecraft was utilized to broadcast live the opening ceremonies of the 1964 Olympic Games.

At the time of this report, both Syncom II and III are operating satisfactorily. These launchings further established man's dominion over the limitless sphere of space and marked the first step in joining all the nations of the world into one giant communication network. Success in this venture demonstrated a significant application of this nation's scientific space program to the service of all mankind.

APPENDIX A

BACKGROUND INFORMATION

APPENDIX A

BACKGROUND INFORMATION

BACKGROUND AND HISTORY

Planned and managed by NASA-GSFC, Syncom was developed and constructed by the Hughes Aircraft Company for NASA.

Project Syncom is another step toward an operational world-wide communication system using microwave radio. Microwave frequencies are capable of carrying great quantities of communication, but can only travel in straight lines. Hence, their useful range is limited without the aid of a satellite for the re-transmission of the signals to other parts of the world. Many people feel that the synchronous orbit communication satellite is the ultimate satellite communications system because of its fixed location with respect to the earth. Because of this, it is capable of continuous use 24 hours a day.

DESCRIPTION OF SYNCOM I

The Syncom spacecraft is cylindrical in shape (28-inch diameter) with the outer surface of the cylinder (15 inches high) covered with solar cells. A thermal radiation barrier and ground plane covers the aft (apogee motor end) and forward (antenna end) extremities of the spacecraft. Seven (7) solar sensors are mounted on the outer circumference of the aft end. Provisions are available for mounting the Delta third stage to one end and the apogee motor to the other end. A rod shaped communications antenna extends from the center forward end and is aligned with the spin axis. Four whip-type Telemetry and Command antennas, located 90° apart, are mounted on the outer circumference, aft end of the spacecraft.

The electronic components are equally distributed and mounted on the outer periphery except for the antenna electronics, which is located on the spin axis forward of the apogee motor. Four spherical storage tanks, two for H_2O_2 and two for N_2, are spaced at 90° intervals around the apogee motor. The H_2O_2 and N_2 axial jets are located on the outer periphery parallel to the spin axis with the H_2O_2 and N_2 lateral jet normal to the spin axis. Syncom III had the N_2 system replaced with a H_2O_2 system.

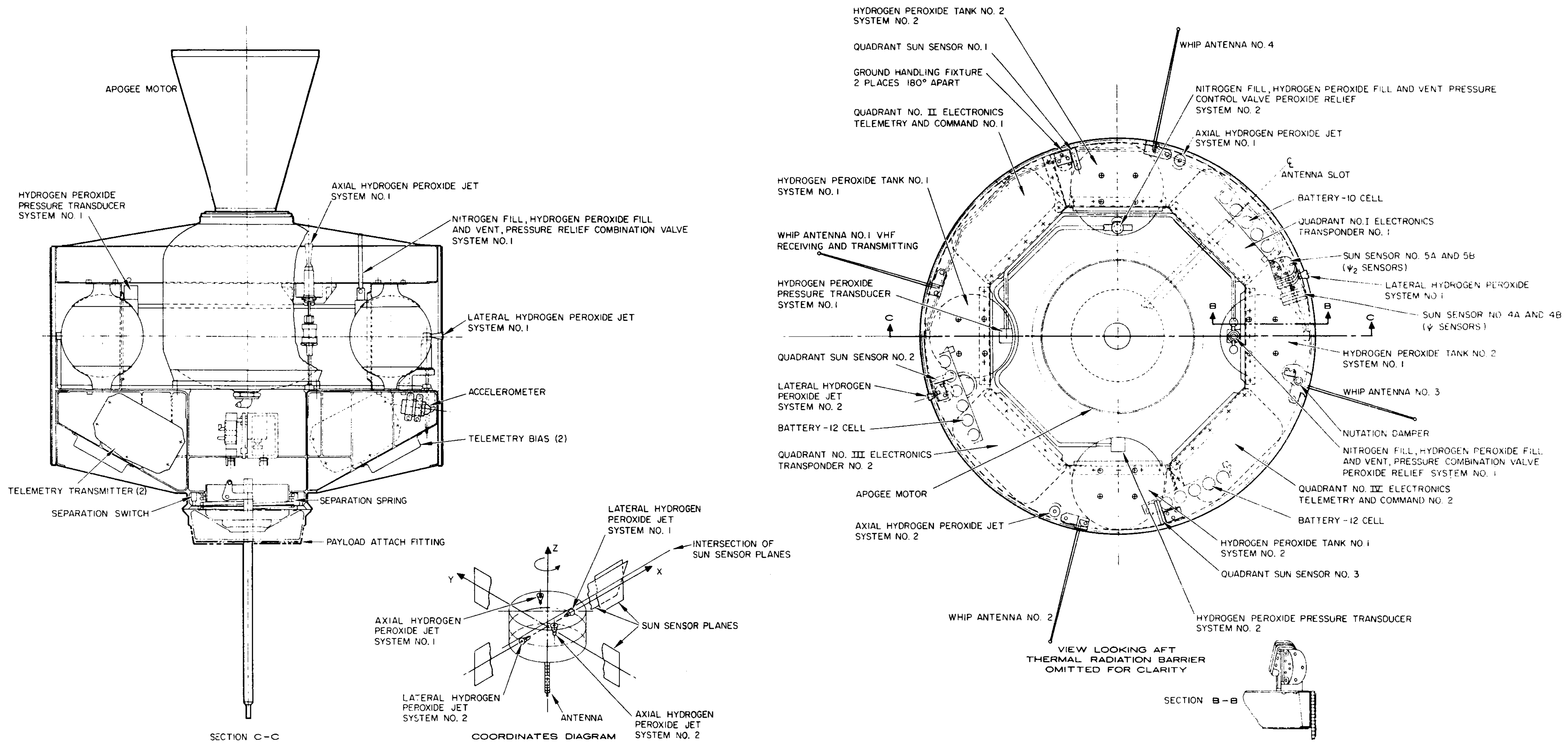

Figure 1. General Arrangement Syncom F2

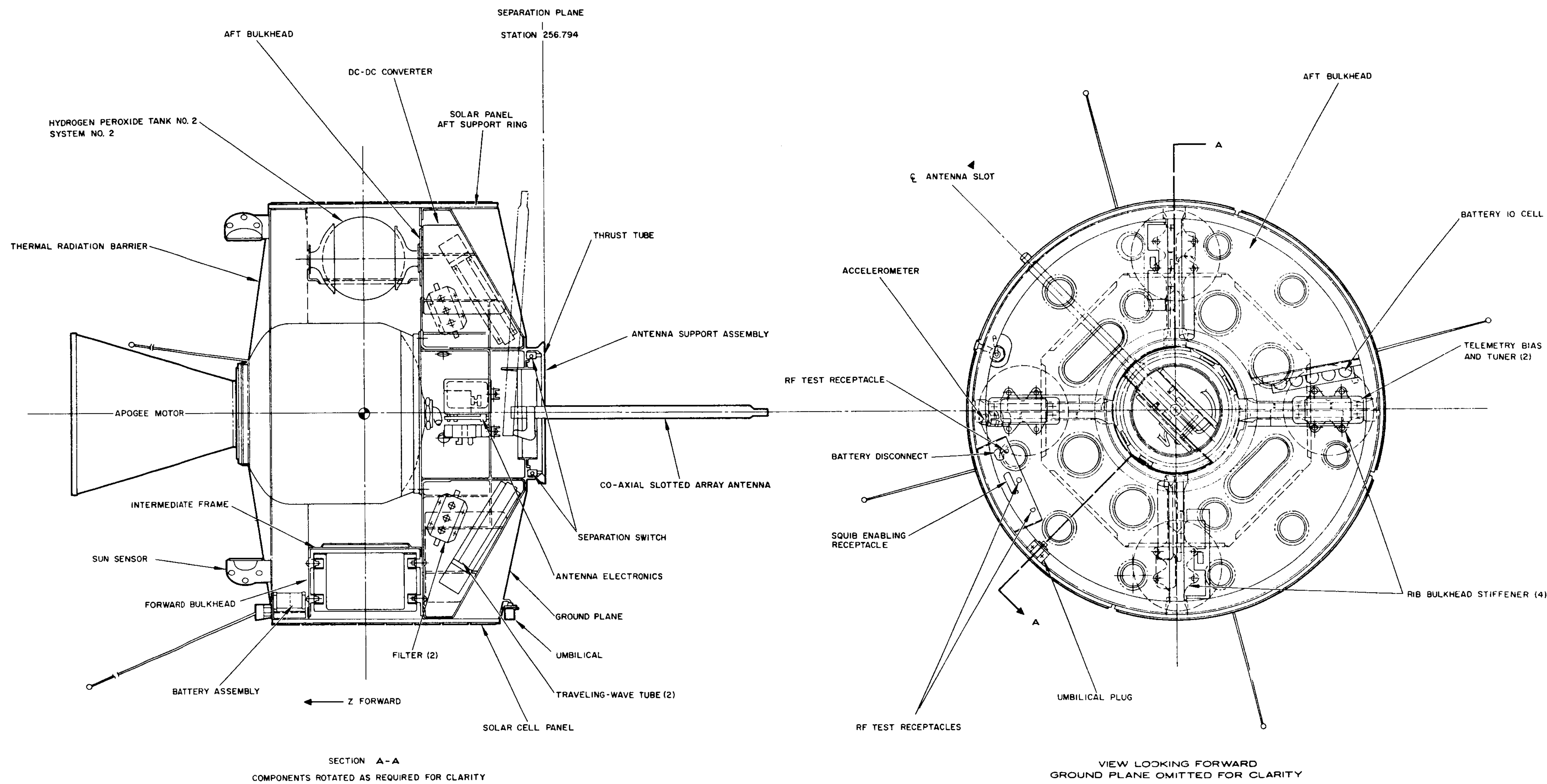

Figure 2. General Arrangement Syncom F2

APPENDIX B

SPECIAL TESTS

APPENDIX B

APOGEE MOTOR FIRING TEST
AT ARNOLD ENGINEERING DEVELOPMENT CENTER (AEDC)
TULLAHOMA, TENNESSEE

Apogee motor firing tests were conducted at Arnold Engineering Development Center, utilizing the T-4 spacecraft. The configuration of this spacecraft was the same as Syncom I, launched February 14, 1963. The purpose of this test was to collect vibration and thermal data by firing the Thiokol and JPL motors aboard an operating spacecraft in a simulated environment. The first firing was conducted on June 10, 1963, with a Thiokol motor. The chamber was evacuated to 125,000 feet and the motor was fired. Due to an error in the length-to-diameter ratio of the diffuser duct, the spacecraft was exposed to a "blowback" of hot exhaust gases. The spacecraft was consequently exposed to temperatures in excess of those experienced during normal burn. The spacecraft was removed from the chamber and a performance check revealed the following difficulties: One sun sensor failed to operate, and the transponder output was degraded due to a defective cable. Both of these problems were attributed to the high heat level caused by "blowback".

The second firing was conducted on June 13, 1963, with a JPL motor. The spacecraft was repaired and functioned normally before and during firing. A post test system performance test revealed no discrepancies within the spacecraft.

SIMULATED SPACECRAFT
DESTRUCTION TEST

A test was conducted on May 2, 1963, at Lockheed California Company, Sargas, California, to simulate the possible explosion of a N_2 tank on board Syncom I spacecraft. The T-1 spacecraft was built to simulate the weight of Syncom I, and one of the N_2 tanks was punctured while the spacecraft was suspended by a flexible cord in an altitude chamber, simulating 150,000 feet. Approximately ten pounds of weight was lost at the time of explosion and definitely indicated an explosion of this nature would silence the spacecraft. The spacecraft experienced a lateral velocity of 12 FPS, a pitch angular velocity of 5 rad/sec. and almost no roll velocity. However, these data did not reproduce the apparent velocity pertubation of the Syncom I spacecraft.

NITROGEN TANK PRESSURE/VIBRATION TEST

On July 11, 1963, a pressure/vibration test was performed at Wylie Laboratories, El Sequndo, California, on a Syncom nitrogen system. The purpose of the test was to gain assurance that the nitrogen system can withstand the vibration environment of launch and apogee boost. The nitrogen system was installed aboard the T-4 spacecraft and was exposed to extended random vibration while pressurized at 3000 to 5000 psig. No damage or failure to the nitrogen system was evident.

APPENDIX C

TEST LOG AND PERFORMANCE REVIEW

Chart 1

SYNCOM

PROTOTYPE SPACECRAFT PERFORMANCE REVIEW

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	TEST CONDITION		Integration	Control System Alignment	Balance and Mass Properties	Pre T-V System Performance	T-V	Post T-V System Performance	Rebuild	Balance and Mass Properties	Control System Alignment	Pre-Vibration System Performance	Vibration	Post-Vib. System Performance	Pre Solar Vac System Performance	Solar Vacuum	Post Solar Vac System Performance	T-V (Hot)	Post T-V System Performance	Acceleration	Post Accel. System Performance	Thiokol Apogee Motor Vibration	Post Vib. System Performance	Humidity	Post Humidity System Performance	Apogee Motor Heating	Post Apogee Heating System Performance	JPL Apogee Motor Vibration	Post Vib. System Performance	Apogee Motor Heating	Final Checks and Inspection
	OPERATING MODE		Test	H_2O_2 and N_2 Jets Operated	Non-Operative	Test	Orbital	Test	Non-Operative	Non-Operative	H_2O_2 and N_2 Jets Operated	Test	Launch	Test	Test	Orbital	Test	Orbital	Test	Launch	Test	Launch	Test	Non-Operative	Test	Launch	Test	Launch	Launch	Launch	Test
	DATE		Aug. Sep. 1962	10/4/62 thru 10/8/62	10/9/62 thru 10/11/62	10/12/62 thru 10/16/62	10/16/62 thru 10/22/62	10/24/62	10/25/62	10/26/62	10/27/62 thru 10/29/62	10/30/62	10/30/62 thru 11/2/62	11/3/62	11/5/62 thru 11/10/62	11/11/62 thru 12/5/62	12/6/62	12/7/62 thru 12/12/62	12/13/62	12/14/62	12/15/62	12/15/62	12/16/62	12/17/62	12/18/62	12/19/62 thru 1/2/63	1/2/63	1/3/63	1/4/63	1/5/63	1/5/63 thru 1/9/63
COMMUNI-CATION	Transponder	A				■ R	⊟ ■ C		⊟				■ C					◪													
	Antenna	B			■ R																										
TELEMETRY	Transmitter	C	⊠ R																												
	T&C Antennas	D																													
	T&C Balun & Hybrid	E																													
	T&C Diplexer	F																													
	Encoders	G											■ R																		
COMMAND	Receiver	H			⊟																										
	Decoder	I													■ R																
CONTROL	Tanks	J		◪			◪																								
	Plumbing	K														■ R															
	Control Jets	L	■ C			■ C																									
POWER	Solar Array	M												■ R																	
	Batteries	N				■ C			⊟																						
	Regulators	O																													
	DC-to-DC Converters	P													■ R																
STRUCTURE	Basic Frame	Q														E															
	End Planes	R														⊟ M												⊞			
PROPULSION	Apogee Motor	S																													
	Firing Circuitry	T				⊞ R	■ C	■ M																							

CODE

E - Facility Induced Problem
■ - Failure
◪ - Questionable Operation
⊟ - Adjustments Required
⊠ - Procedural Failure
⊞ - Special Problem
R - Subsystem Repaired
C - Subsystem Changed
M - Subsystem Modified

323-67-5/64

SYNCOM PROTOTYPE SPACECRAFT
PERFORMANCE REVIEW

COMMUNICATION

Line Item	Comments
A-4	Narrow-band transponder oscillated. Trouble traced to defective GRFF cable. Cable replaced.
A-5	A tuning cavity drifted due to the dielectric changes between air and vacuum. Cavity was returned.
A-5	Output of TWT dropped between 2 and 3 db during cold soak. Tube was returned to Vendor for checkout.
A-7	Master oscillator frequency was readjusted.
A-11	The Watkins-Johnson and HAC TWT's failed. The tubes were replaced.
A-16	TWT failed to operate in vacuum. Returned to ambient and TWT operated normally. Evacuated chamber and TWT continued to operate normally
B-3	A cable connection in the antenna electronics broke. The cable was replaced.

TELEMETRY

Line Item	
C-1	Connector damaged when mated.

Line Item	Comments
G-11	Encoder gave no telemetered temperature data. Resistor lead broke. Resistor was replaced.

COMMAND

Line Item	
H-3	Command receive would not operate. The unit was retuned.
I-13	Transistor failure. The transistor was replaced.

CONTROL

Line Item	
J-2	N_2 pressure transducer was sticking. Operation of the jets corrected the trouble.
J-5	Pressure drop indicated by telemetry pressure system. Continuous monitoring during thermal vacuum did not indicate recurrence.
K-14	A leak was found at N_2 orientation jet solder joint. The joint was resoldered.
L-1	Corrosion of H_2O_2 valve seat. Unit returned to vendor for rework.
L-4	H_2O_2 axial jet failed to hold pressure due to excessive clearance between poppet and guide bore. Poppet was replaced with one dimensionally correct.

POWER

Line Item	Comments
M-12	Wire to solar sensor broke. Wire was resoldered and secured to sensor with nylon cord.
N-4	Battery pack did not pass rated discharge test. Batteries were replaced.
N-7	Battery pack relocated to minimize the balance weights required.
P-13	Transistor failure. The transistor was replaced.

STRUCTURE

Line Item	
Q-14	Spacecraft was sprayed with diffusion pump oil.
R-14	Spacecraft temperature was below predicted. The thermal coating on end planes was changed.
R-26	Paint peeled off ground plane.

PROPULSION

Line Item	
T-4	A wiring error was found in the apogee motor firing circuit. The circuit was rewired.
T-5	The apogee motor timer failed to operate at low temperature. It was replaced with a more reliable timer.

Line Item	Comments
T-6	Apogee motor squib fired when enable command was sent. A capacitor was added in the decoder.

Chart 2

SYNCOM

PROTOTYPE SPACECRAFT PERFORMANCE REVIEW

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		TEST CONDITION	Initial Electrical Shakedown	Balance and Mass Properties	Shock	Post Shock Functional Check	Lateral Vibration	Post Vib. System Performance	Comb. Acc-Vib (Apogee Interface)	Post Accel-Vib. System Performance	Spin Acceleration	Post Spin-Accel. System Performance	Apogee Motor Heating	Post Apogee Heating System Perf.	Comb. Acc-Vib (X-248 Interface)	Post Accel-Vib. System Performance	Final Checks & Inspection	AMR Operations									
		OPERATING MODE	Test	Non-Operative	Launch	Test	Launch	Test	Launch	Test	Launch	Test	Launch	Test	Launch	Test	Test	Test									
		DATE	5/63	5/27/63	5/29/63	5/20/63	5/30/63	5/31/63	6/6/63	6/9/63	6/12/63	6/13/63	6/18/63	6/19/63	6/20/63	6/21/63	7/2/63	7/4/63 thru 7/26/63									
COMMUNI-CATION	Transponder	A	⊠				■ R	■ R																			
	Antenna	B																									
TELEMETRY	Transmitter	C																									
	T&C Antennas	D																									
	T&C Balun & Hybrid	E																									
	T&C Diplexer	F																									
	Encoders	G	■ R																								
COMMAND	Receiver	H	■																								
	Decoder	I																									
CONTROL	Tanks	J																									
	Plumbing	K																									
	Control Jets	L																									
POWER	Solar Array	M																									
	Batteries	N	■ C					■ C																			
	Regulators	O																									
	DC-to-DC Converters	P																									
STRUCTURE	Basic Frame	Q																									
	End Planes	R																									
PROPULSION	Apogee Motor	S							E																		
	Firing Circuitry	T	■ M								◫ C	■ M						◪ M									

CODE

E - Facility Induced Problem
■ - Failure
◪ - Questionable Operation
⬓ - Adjustments Required
⊠ - Procedural Failure
◫ - Special Problem
R - Subsystem Repaired
C - Subsystem Changed
M - Subsystem Modified

320-87(9/64)

SYNCOM PROTOTYPE SPACECRAFT
PERFORMANCE REVIEW

COMMUNICATION

Line Item	Comments
A-1	Transponder limiting was low. Procedure for this test was changed to improve repeatability.
A-5	Two RF connections came loose. These were replaced and secured with epmid.
A-6	Filament of W-J TWT would not turn on. Intermittent open circuit in quadrant plug.

TELEMETRY

Line Item	
G-1	Telemetry readout for telemetry transmitter power reads zero. Suspect a malfunction in the encoder.

COMMAND

Line Item	
H-1	Command receiver sensitivity out of spec. Waiver requested.

POWER

Line Item	
N-1	Batteries shorted, electrolyte leaked. Sealed caps with epoxy.

Line Item	Comments
N-6	The standby batteries were dead. Replaced.

PROPULSION

Line Item	
S-7	The protective shield broke and damaged the motor nozzle.
T-1	Output SCR shorted by safety plug when timer fired. Safety plug was redesigned to isolate the SCR output from ground.
T-9	Separation switch damaged while mounting on spin machine.
T-10	Diode in apogee motor timer was shorted to ground. Insulating washer was missing. Repaired correctly.
T-16	Transients appeared on the common battery buss when control jets were operated. These were sufficient to fire the SCR. Capacitors added in series to ground.

Chart 3

SYNCOM

FLIGHT I SPACECRAFT PERFORMANCE REVIEW

		TEST CONDITION	Initial Electrical Shakedown	Balance and Mass Properties	Control System Alignment	Spin	Post Spin System Performance	Vibration	Post Vib. System Performance	RFI	Pre T-V System Performance	T-V	Post T-V System Performance	Control System Alignment	Spacecraft Inspection	Control System Alignment	Final Bal. and Mass Properties	Thrust Axis Vibration	Post Vib. System Performance	Ship to AMR	AMR Operations	Launch					
		OPERATING MODE	Test	Non-Operative	N_2 and H_2O_2 Jets Operated	Test	Test	Launch	Test	Test	Test	Orbital	Test	N_2 and H_2O_2 Jets Operated	Non-Operative	Non-Operative	Non-Operative	Launch	Test	Non-Operative	Test	Launch					
		DATE	10/62	11/18/62	11/20/62	11/21/62	11/22/62	11/28/62 thru 12/2/62	12/4/62	12/5/62 thru 12/7/62	12/26/62	12/27/62 thru 1/1/63	1/1/63	1/2/63 thru 1/4/63	1/5/63 thru 1/14/63	1/5/63 thru 1/7/63	1/15/63	1/17/63	1/17/63	1/18/63	1/19/63 thru 2/14/63	2/14/63					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
COMMUNICATION	Transponder	A						◫ R		■ C																	
	Antenna	B																									
TELEMETRY	Transmitter	C																									
	T&C Antennas	D													C												
	T&C Balun & Hybrid	E																									
	T&C Diplexer	F																									
	Encoders	G	■ C																								
COMMAND	Receiver	H																									
	Decoder	I																									
CONTROL	Tanks	J							■ R																		
	Plumbing	K																									
	Control Jets	L									■ C				◫												
POWER	Solar Array	M							◫ C	■ R																	
	Batteries	N									■ C				◫		C										
	Regulators	O																									
	DC-to-DC Converters	P																									
STRUCTURE	Basic Frame	Q																									
	End Planes	R																									
PROPULSION	Apogee Motor	S																									
	Firing Circuitry	T	◫ C					◫ C																			

CODE

- E - Facility Induced Problem
- ■ - Failure
- ◩ - Questionable Operation
- ⊟ - Adjustments Required
- ⊠ - Procedural Failure
- ◫ - Special Problem
- R - Subsystem Repaired
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- M - Subsystem Modified

323-87(9/64)

SYNCOM FLIGHT I SPACECRAFT
PERFORMANCE REVIEW

COMMUNICATION

Line Item	Comments
A-6	TWT mounting screws came loose. Loc-tite specified.
A-8	35 mc channel in IF filter limiter indicated a low output. A defective connection to a tuning capacitor was found. Quadrant was replaced.

TELEMETRY

Line Item	
D-13	T&C antennas were changed.
G-1	VCO in encoder No. 1 out of spec. VCO replaced.

CONTROL

Line Item	
J-7	Filler valve leaked. A new nut was installed.
L-9	Axial H_2O_2 jet would not operate. Corrosion was present in valve. Valve was replaced.
L-13	H_2O_2 valves disassembled and inspected for corrosion of valve seat.

POWER

Line Item	Comments
M-7	Solar panel reveals apparent crack on three adjacent cells. Suspect handling. Replaced module.
M-8	Wire broken at termination point on sun sensor. Wire reconnected.
N-9	Electrolyte leaking. Replaced defective batteries.
N-13	A shorting protection diode was missing from spacecraft. Diode installed.
N-15	Batteries were changed.

PROPULSION

Line Item	
T-1	Timer pin connections incompatible with wire harness. Harness was changed.
T-6	Leaf spring on separation switch was broken while placing spacecraft on vibration fixture. Replaced springs.

Chart 4

SYNCOM

FLIGHT II SPACECRAFT PERFORMANCE REVIEW

	TEST CONDITION	OPERATING MODE	DATE	COMMUNI-CATION: A Transponder	COMMUNI-CATION: B Antenna	TELEMETRY: C Transmitter	TELEMETRY: D T&C Antennas	TELEMETRY: E T&C Balun & Hybrid	TELEMETRY: F T&C Diplexer	TELEMETRY: G Encoders	COMMAND: H Receiver	COMMAND: I Decoder	CONTROL: J Tanks	CONTROL: K Plumbing	CONTROL: L Control Jets	POWER: M Solar Array	POWER: N Batteries	POWER: O Regulators	POWER: P DC-to-DC Converters	STRUCTURE: Q Basic Frame	STRUCTURE: R End Planes	PROPULSION: S Apogee Motor	PROPULSION: T Firing Circuitry
1	Initial Electrical Shakedown	Test	11/62	⬒						■									■ R				■ M
2	Control System Alignment	N_2 Jets Operated	12/4/62																				
3	Balance and Mass Properties	Non-Operative	12/5/62																				
4	Pre-Spin System Performance	Test	12/6/62		■ M																		
5	Spin	Orbital	12/6/62																				
6	Post Spin System Performance	Test	12/6/62																				
7	Vibration	Launch	12/7/62 thru 12/8/62	◫																			
8	Post Vib. System Performance	Test	12/9/62																				◫
9	T-V	Orbital	12/13/62 thru 12/19/62	◫																			
10	Post T-V System Performance	Test	12/19/62												■ C								
11	Control System Alignment	N_2 and H_2O_2 Jets Operated	12/19/62 thru 1/3/63																				
12	Spacecraft Inspection	Non-Operative	1/2/63				C								◫								
13	Control System Alignment	Non-Operative	1/5/63																				
14	Balance and Mass Properties	Non-Operative	1/10/63																				
15	Pre-Vib. System Performance	Test	1/14/63												■ R		◫						
16	Thrust-Axis Vibration	Launch	1/14/63																				
17	Post Vib. System Performance	Test	1/14/63																				
18	Ship to AMR	Non-Operative	1/20/63																				
19	AMR Operations	Test	1/21/63 thru 2/14/63												■								
20	Initial Elec. Shakedown & Inspection	Test	5/63 thru 6/14/63	■ R	■ R																		
21	Balance and Mass Properties	Non-Operative	6/16/63 thru 6/19/63																				
22	Acceleration	Launch	7/2/63																				
23	Post Accel. System Performance	Test	7/2/63																				
24	Shock	Launch	7/3/63																				
25	Post Shock Functional Check	Test	7/3/63																				
26	Vibration	Launch	7/3/63																				
27	Post Vib. System Performance	Test	7/3/63																				
28	Spin and Acceleration	Launch	7/4/63																				
29	Post Test System Performance	Test	7/4/63												■ R								
30	Control System Alignment	N_2 Jets Operated	7/5/63																				
31	Pre T-V System Performance	Test	7/5/63																				
32	T-V	Orbital	7/6/63	⬒						⬒													⬒ R
33	Apogee Motor Heating	Orbital	7/10/63																				
34	Post T-V System Performance	Test	7/11/63																				
35	Final Bal. and Mass Properties	Non-Operative	7/11/63																				

CODE

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⬒ - Adjustments Required

⊠ - Procedural Failure
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M - Subsystem Modified

320-81(9/64)

SYNCOM FLIGHT II SPACECRAFT PERFORMANCE REVIEW

COMMUNICATION

Line Item	Comments
A-1	Communications receiver broke into oscillations. Length of excute pulse changed (ground equipment).
A-7	Screws on TWT came loose. Loc-tite specified.
A-9	Narrow band receiver indicated excessive noise. Spacecraft was subjected to lower than design temperature.
A-20	Defective varactor in x-4 multiplier. Replaced.
A-32	Master oscillator required adjustment.
B-4	Antennas would not erect to a full locked upright position. Different washers were installed.
B-20	Gear in antenna erection mechanism worn. Replaced.

TELEMETRY

Line Item	
D-12	New T&C antennas were installed.
G-1	VCO is out of spec. No drift apparent. Waiver granted.

Line Item	Comments
G-32	Data switching too slow. Attributed to improper setting of quadrant connector.

CONTROL

Line Item	Comments
L-10	A scored H_2O_2 valve seat was discovered. Valve was replaced.
L-12	H_2O_2 valves disassembled and inspected for corrosion of valve seats.
L-15	Leaks found in N_2 orientation and H_2O_2 axial jets. N_2 leak was stopped by pulsing the jet. The H_2O_2 valve was heat sealed.
L-19	N_2 orientation jet resumed leaking. Spacecraft was returned to HAC.
L-19	Faulty N_2 valves delayed testing of spacecraft.
L-29	Leak in both H_2O_2 jets. Jets were disassembled and inspected. No evidence of foreign material. Leak was corrected by heat sealing.

POWER

Line Item	Comments
N-15	A shorting protection diode was missing from spacecraft. Diode installed.
P-1	TWT filament current failed to come on. Tantalum capacitor failed. Replaced.

PROPULSION

Line Item	Comments
T-1	Capacitor in apogee timer shorted. Replaced with another higher rated capacitor.
T-8	Separation switch would not activate because of potting material on switch. Switch was cleaned.
T-32	A 5 to 6 volt transient occasionally appeared on common battery buss when jets were operated. Transient could fire the apogee motor drive SCR. Three capacitors in series to ground were added.
T-32	Apogee motor timer did not deliver fire signal. Repaired.

Chart 5

SYNCOM

FLIGHT III SPACECRAFT PERFORMANCE REVIEW

		TEST CONDITION	Initial Electrical Shakedown	Balance and Mass Properties	Control System Alignment	Pre Vib. System Performance	Vibration	Shock	Post Vib. System Performance	Spin Acceleration	Post Spin Accel. System Performance	Acceleration	Post Accel. System Performance	Control System Alignment	T-V	Apogee Motor Heating	Post T-V System Performance	Final Balance and Mass Properties	AMR Operations	Launch							
		OPERATING MODE	Test	Non-Operative	Non-Operative	Test	Launch	Launch	Test	Launch	Test	Launch	Test	CN2 Jets Operated	Orbital	Orbital	Test	Non-Operative	Test	Launch							
		DATE	5/63	6/4/63	6/10/63	6/11/63	6/12/63	6/12/63	6/13/63	6/15/63	6/15/63	6/17/63	6/17/63	6/18/63	6/20/63 thru 6/26/63	6/26/63	6/27/63	6/28/63	7/9/63 thru 7/26/63	7/26/64							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
COMMUNICATION	Transponder	A													■ C												
	Antenna	B																									
TELEMETRY	Transmitter	C																									
	T&C Antennas	D																									
	T&C Balun & Hybrid	E																									
	T&C Diplexer	F																									
	Encoders	G					■ R																				
COMMAND	Receiver	H																									
	Decoder	I																									
CONTROL	Tanks	J																									
	Plumbing	K																									
	Control Jets	L													■ R												
POWER	Solar Array	M								■ R																	
	Batteries	N																									
	Regulators	O																									
	DC-to-DC Converters	P																									
STRUCTURE	Basic Frame	Q																									
	End Planes	R																									
PROPULSION	Apogee Motor	S																									
	Firing Circuitry	T				■ M													M								

CODE

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■ - Failure
◪ - Questionable Operation
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R - Subsystem Repaired
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320-87(9/64)

SYNCOM FLIGHT III SPACECRAFT PERFORMANCE REVIEW

COMMUNICATION

Line Item	Comments
A-13	Transponder receiver oscillated. Retuned.
A-13	TWT would not turn on. TWT and convertor were replaced.

TELEMETRY

Line Item	
G-5	Two wires from VCO broke. Repaired.

CONTROL

Line Item	
L-13	Leak in N_2 velocity jet. Solder was reheated.

POWER

Line Item	
M-8	Broken wire to sun sensor. Repaired.

PROPULSION

Line Item	Comments
T-4	Diode in apogee motor timer was shorted to ground. Insulating washer was missing. Repaired correctly.
T-17	Capacitors added to the common battery buss to insure against premature firing of apogee motor.

Chart 6

SYNCOM C

FLIGHT II SPACECRAFT PERFORMANCE REVIEW

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TEST CONDITION			Initial Electrical Shakedown	Initial Thermal Vacuum	Balance and Mass Properties	Pre Vib. System Performance	Shock	Post Shock Functional Check	Vibration	Post Vib. System Performance	Thermal Vacuum	Post T-V System Performance	Control System Alignment	Final Balance and Mass Properties	Final Checks and Inspection	AMR Operations	Launch										
OPERATING MODE			Test	Test	Non-Operative	Test	Launch	Test	Launch	Test	Orbital	Test	Non-Operative	Non-Operative	Test	Test	Launch										
DATE			3/17/64	3/19/64	3/20/64 thru 3/21/64	3/26/64	3/27/64	3/27/64	3/28/64	3/28/64	3/31/64 thru 4/7/64	4/7/64	4/9/64	4/11/64 thru 4/13/64	4/14/64 thru 4/17/64	8/11/64 thru 8/19/64	8/19/64										
COMMUNICATION	Transponder	A				◫ R						■ R															
	Antenna	B													M												
TELEMETRY	Transmitter	C																									
	T&C Antennas	D																									
	T&C Balun & Hybrid	E																									
	T&C Diplexer	F																									
	Encoders	G	■								■																
COMMAND	Receiver	H																									
	Decoder	I																									
CONTROL	H_2O_2 Tanks	J									◫																
	H_2O_2 Plumbing	K								◫ R																	
	Control Jets	L										■ R															
POWER	Solar Array	M				◫ M																					
	Batteries	N																									
	Regulators	O																									
	DC-to-DC Convertors	P																									
STRUCTURE	Basic Frame	Q								◫																	
	End Planes	R																									
PROPULSION	Apogee Motor	S														M											
	Firing Circuitry	T																									

CODE

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320-87(9/64)

SYNCOM FLIGHT II SPACECRAFT PERFORMANCE REVIEW

COMMUNICATION

Line Item	Comments
A-4	Calibration of TWT power-out indicated erratic performance. GRFF connectors were not properly tightened.
A-10	Transponder No. 1 10 mc and 50 kc receiver sensitivity was low. A GRFF-RF cable was replaced after it was found to be defective.
B-13	A different spring was installed to slow the erection of the antenna.

TELEMETRY

Line Item	
G-1	Encoder No. 1, Channel No. 1 was out of specification. Waiver granted.
G-9	Encoder No. 1, Channel No. 16 was out of specification. Waiver granted.

CONTROL

Line Item	
J-9	Test equipment problem caused erroneous H_2O_2 pressure data to be recorded.

Line Item	Comments
K-8	H_2O_2 tubing rubbed against control jet mounting block. The tube was bent to clear mounting block.
L-10	Leak found in lateral Jet No. 2. Leak was corrected by heat sealing.

Note: The H_2O_2 system was charged with GN_2 in lieu of H_2O_2 for the entire environmental test program.

POWER

Line Item	
M-4	Temperature sensor on solar panel interferred with Quad-I. The sensor mounting fixture was modified.

STRUCTURE

Line Item	
Q-8	Nut, Bolt, and washer were found lying on ground plane. No missing hardware was found on the spacecraft.

PROPULSION

Line Item	
S-14	The temperature sensor on the apogee motor was deleted due to an unexpected motor change. The sensor was placed on a nearby rib.