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TOPEX SATELLITE OPTION STUDY

Final Report

Submitted by

TRW Space and Technology Group
Redondo Beach, California 90278

for

Jet Propulsion Laboratory
Pasadena, California 91103
Contract No. 956199

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1. INTRODUCTION

This report documents the results of a study of TOPEX Satellite Options performed by TRW for the Jet Propulsion Laboratory (JPL), under contract No. 956199.

In accordance with the JPL study objectives, this report identifies and describes an existing TRW satellite design which forms the basis for the TOPEX mission design maximizing scientific value at least cost. The selected Fleet Satellite Communications (FLTSATCOM) spacecraft design easily accommodates any of the three TOPEX payload options with room for growth or addition of other instruments.

Spacecraft of the FLTSATCOM program operate in geosynchronous equatorial orbit, which is attained by injection onto a transfer orbit by an Atlas Centaur launch vehicle and the firing of the spacecraft's solid motor at apogee. FLTSATCOM's mission is to relay communications in the UHF and SHF bands for the Department of Defense. To do this, it maintains an earth-oriented attitude and points its payload antennas toward the nadir.

FLTSATCOM is adaptable for launch by the STS, it incorporates propulsion and guidance capability in the basic design, and with only minor modification to accommodate operation in low earth orbit rather than at synchronous altitude, the performance of the FLTSATCOM spacecraft is a close match to that sought for TOPEX. The four FLTSATCOMs presently operating on orbit have expected lifetimes that exceed TOPEX requirements, and U.S. government plans, starting with a current contract for long lead procurement, call for TRW to manufacture three additional FLTSATCOM on a schedule that corresponds closely to the projected TOPEX project start in 1984 and launch in 1987, thus making economies of multiple unit production potentially available to the TOPEX project.

The following sections present the results of the seven tasks defined by the Statement of Work in the referenced JPL contract. Section 2 summarizes our understanding of the TOPEX mission requirements. In Section 3, we identify our existing satellite design (Task 1) and propulsion subsystem approach (Task 2), including development status (Task 3) and a description of subsystem performance characteristics (Task 5). Section 4 separately addresses launch vehicle compatibility in response to Exhibit 1, Section IV, of the contract and Section 5 summarizes satellite performance capabilities with respect to the other requirements of Exhibit 1 (Task 4). The results of Task 6, including cost estimates for budgetary and planning purposes, are presented in Section 6. This report itself satisfies the documentation requirement of Task 7.

2.0 REQUIREMENTS

This study addresses the TOPEX requirements stated in Exhibit 1 of the Statement of Work of JPL Contract No. 956199. For reference, the major requirements are excerpted from Exhibit 1 and reproduced in Appendix A.

The principal purpose of the TOPEX (Ocean Dynamics Topography Experiment) is to map the level of the surface of the world's oceans. This purpose is achieved by subtracting measurements of the satellite's height above the ocean as determined by an on-board radar altimeter from the altitude of the satellite above the mean geoid surface as determined by precision tracking and orbit determination.

The requirements of the study are derived from three (optional) payloads which provide the data for these determinations, and from the requirements of the mission. Principal mission requirements include launch and ascent into a very nearly circular ($e < 0.001$) orbit, inclined 63.4 degrees to the equator, and at an altitude of 800 to 1334 km, depending on the mission option. The orbit must be established very accurately to achieve predictable ground tracks which repeat on a ten-day cycle, and it must be maintained with minimum disturbances, so that the orbit determination precision is not compromised.

Principal payload accommodations include space and field of view available for nadir-pointed antennas, capacity to carry the payload mass and supply its electrical power, pointing control, and thermal control.

In addition a communications system is necessary which can accept commands sent to the satellite and transmit data at up to ~500 kb/s. The communications links are direct to ground stations as well as via TDRSS.

Some of the quantitative requirements which can be translated into bus requirements are:

- Mission Duration: 3 years/2-year extended mission option
- TOPEX Payload Mass: 209.1 kg (worst case, Option 3)
- TOPEX Payload Power Demand: 259 W (worst case, Option 1)
- Ascent Propulsion: $\Delta V = 550$ m/s (Option 1)
- Pointing Control Accuracy: 0.15 degrees (Option 1), 0.25 degrees (Options 2 and 3)

TRW has selected the Fleet Satellite Communications (FLTSATCOM) spacecraft from its current spacecraft programs, and submits it as a candidate bus for the TOPEX mission. This spacecraft is designed for and is in use as a Department of Defense communications satellite in geosynchronous equatorial orbit. In this orbit it keeps an array of UHF, S-band, and SHF antennas directed toward the earth. For use as the TOPEX bus, this RF payload -- antennas and transponders -- will be removed, vacating a large space for instruments and their antennas to view in the nadir direction.

The FLTSATCOM bus as is can accommodate the TOPEX payload mass, satisfy the TOPEX payload power requirement, and control pointing toward earth to 0.25 degrees. With its propulsive system augmented in propellant capacity for the ascent phase, it satisfies the propulsive and attitude control requirements for ascent and in the observational orbit. FLTSATCOM is designed for and is meeting a five year lifetime in orbit.

The FLTSATCOM attitude is controlled in pitch (rotation in the orbit plane) by a variable speed momentum wheel. About transverse axes it is controlled by precession thruster firing, and by gyroscopic action. The only secular attitude change - the one revolution per orbit in pitch - is controlled with only infrequent unloading of the momentum wheel by thruster firing. This should minimize spacecraft-induced random orbit disturbances.

The selection of the FLTSATCOM bus for TOPEX is based on these considerations, and enhanced by its status as an ongoing program, with continuity planned for launches in the 1985-87 time period.

See Section 5 for a comparison of FLTSATCOM capabilities for TOPEX, and a discussion of the few modifications which may be necessary for that mission.

3.0 PROPOSED SPACECRAFT FOR TOPEX MISSION

Section 3.1.1 describes the FLTSATCOM bus as it is presently configured* and Section 3.1.2 as it is envisioned for the TOPEX application. The Propulsion Subsystem described in Section 3.2 is proposed specifically for the TOPEX mission and the modifications from the existing FLTSATCOM design are defined. All FLTSATCOM subsystem descriptions in Sections 3.3 through 3.6 refer to the existing designs (not modified for TOPEX). A discussion of modifications for the TOPEX mission is included in Sections 4 and 5.

3.1 FLTSATCOM BUS

3.1.1 The Present FLTSATCOM Configuration

The current mission of the FLTSATCOM spacecraft is to provide satellite communication capability for the Navy and other DoD users. The satellite consists of two hexagonal modules, antennas and solar arrays. The payload module houses the communication system which includes the UHF and SHF equipment and antennas. The spacecraft module (bus) includes all other subsystem equipment and the solar array drives. Figure 3.1-1 shows the spacecraft configuration.

The spacecraft's overall size when deployed is 43.4 feet between solar panel ends. Electronic equipment is housed in the spacecraft body which is a hexagonal prism 7.5 feet across flats. The parabolic transmit antenna is 16 feet in diameter and the receive antenna is an 18-turn helix approximately 12 feet long, mounted to the side of the parabolic transmit antenna. In the launch configuration, the spacecraft is folded to fit within the 10-foot diameter NASA standard Centaur fairing. The spacecraft weighs 4,170 pounds

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* The description of FLTSATCOM is Sections 3.1.1 and 3.3 through 3.6 as "presently configured" refers to Units 1 through 5, which have been built and launched. The FLTSATCOM units 6, 7, and 8 that are to be built and launched in 1985-87 will be somewhat different from Units 1 through 5:

- Unit 6 will be an exact copy of Unit 5 except that the existing solar cells are no longer available and will be replaced by more efficient cells.

- Units 7 and 8 will carry an additional EHF payload necessitating a more powerful AKM and the structure will be modified for both payload and motor accommodation.

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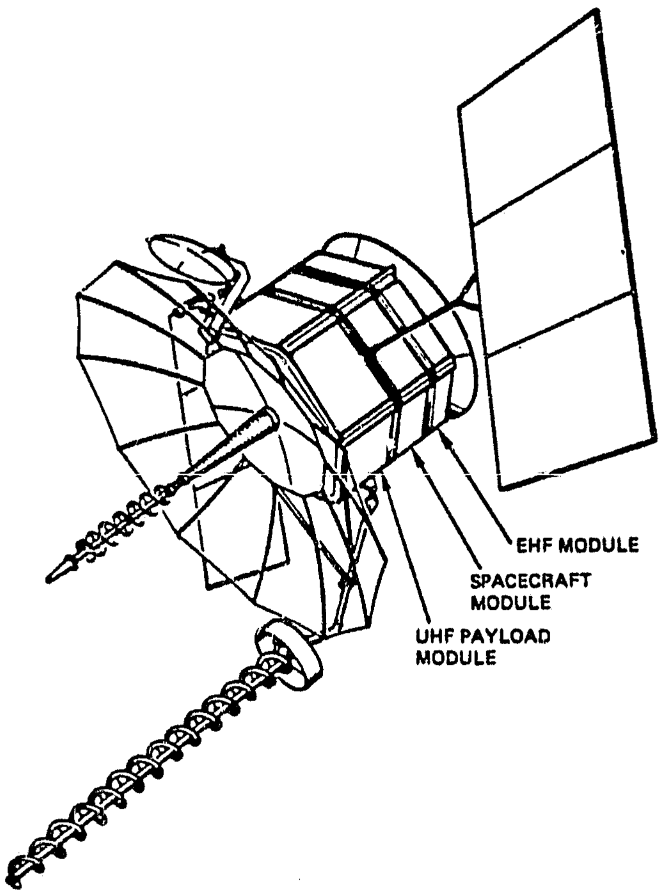

Figure 3.1-1. Orbit Configuration of FLTSATCOM 7 and 8

in the launch configuration with nearly half of this weight being the propellant in the STAR 37F solid rocket motor that is used for injection into synchronous orbit. The spacecraft is designed to operate in synchronous equatorial orbit and is placed in an elliptical transfer orbit by an Atlas Centaur boost vehicle launched eastward from the Eastern Test Range.

Once the spacecraft is injected into synchronous orbit, it is deployed and oriented relative to the Earth and the orbit plane. Spacecraft orientation is specified relative to the directions forward, south, and down which are the reference directions for the body X, Y and Z axes, respectively. On orbit, the spacecraft is oriented so that the +X axis is forward in the direction of flight. The solar array axis defines the Y axis of the spacecraft and the central axis of the downlink antenna defines the Z spacecraft axis.

Additional technical features of the spacecraft design are summarized in Figure 3.1-2. The spacecraft power budget is slightly over 1,200 watts. This power is provided by 22,632 2 x 4 cm solar cells that generate about 2 kW at beginning of life (BOL) but degrade due to the space environment to 1,436 watts at the 5-year design life point. The spacecraft UHF communications equipment operates in the 244 to 400 MHz frequency band. The spacecraft attitude is controlled on orbit by a combination of a body fixed momentum wheel and direct decomposition hydrazine jets. It points the communication antennas to within 0.25 degree of nadir. The spacecraft has a design lifetime of 5 years and the design incorporates complete electrical and mechanical redundancy.

Figure 3.1-3 provides the weight budget. The power budget is given in Figure 3.1-4.

3.1.2 The Envisioned TOPEX Satellite

The FLTSATCOM bus, adapted for use as the TOPEX Satellite, is shown in Figure 3.1-5. The principal features of this adaptation are:

- The solar arrays when deployed are canted at 45 degrees to the solar array drive axis. This accommodates the wider range of the sunline from the orbit plane: up to $\pm$86.8 degrees in the TOPEX orbit, compared with $\pm$23.4 degrees for FLTSATCOM.

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LAUNCH VEHICLE:	ATLAS/CENTAUR
POWER:	~ 1200 WATTS, EQUINOX, AFTER 5 YEARS
FREQUENCY BAND:	244 TO 400 MHz
ANTENNAS:	TRANSMIT – DEPLOYABLE PARABOLOID RECEIVE – DEPLOYABLE HELIX
TRANSPONDER:	CHANNELIZED LIMITING REPEATERS ON-BOARD SIGNAL PROCESSORS HIGH POWER, MULTICHANNEL, UHF TRANSMITTERS
ATTITUDE CONTROL:	BODY-FIXED MOMENTUM WHEEL 0.25 DEGREE POINTING ACCURACY (WORST CASE) COMPLETE ELECTRICAL AND MECHANICAL REDUNDANCY
SPACECRAFT DESIGN LIFETIME:	FIVE YEARS

Figure 3.1-2. Technical Features

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SUBSYSTEM	WEIGHT (LB_M)
STRUCTURE	326.4
INTEGRATION HARDWARE	18.5
THERMAL CONTROL	35.8
ELECTRICAL POWER AND DISTRIBUTION	719.1
ATTITUDE AND VELOCITY CONTROL	129.6
COMMUNICATIONS	491.3
TELEMETRY, TRACKING, AND COMMAND	55.7
REACTION CONTROL, DRY	64.7
DRY WEIGHT	1841.1
EXCESS PROPELLANT LOADED (MARGIN)	+46.2
DRY WEIGHT PLUS MARGIN	1887.3
AKM – FIRED CASE	135.3
DRY WEIGHT – IN ORBIT	2022.6
RESIDUAL FLUIDS	7.6
WEIGHT AT END-OF-MISSION	2030.2
RCS EXPENDABLES (REQUIRED)	180.6
AKM EXPENDABLES	1916.7
WEIGHT AT SEPARATION	4127.5
BOOSTER ADAPTER	43.0
WEIGHT AT LAUNCH	4170.5

Figure 3.1-3. FLTSATCOM Spacecraft Weight as of June 12, 1981. Summary (STAR 37F OIM)

SUBSYSTEM	ECLIPSE AVERAGE (WATTS)	SUNLIGHT UNATTENDED (WATTS)
TELEMETRY, TRACKING AND COMMAND	9.0	7.8
COMMUNICATIONS	880.5	880.5
ATTITUDE AND VELOCITY CONTROL	30.6	44.1
THERMAL CONTROL	4.3	17.0
REACTION CONTROL	17.5	40.0
ELECTRICAL POWER AND DISTRIBUTION	246.4	247.8
TOTAL	1188.3	1237.2

Figure 3.1-4. Power Summary at Equinox

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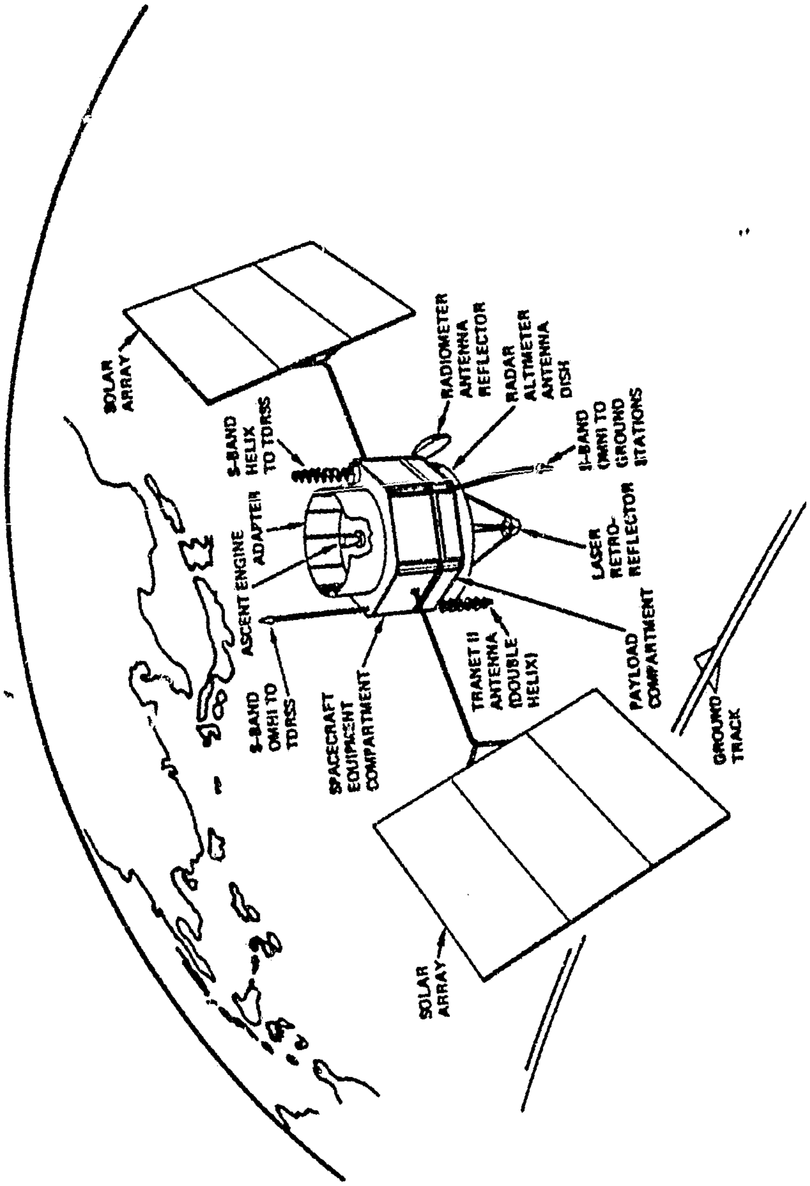

Figure 3.1-5. TOPEX Satellite Based On FLTSATCOM

- The RF payload and its antennas are removed from the nadir-facing side of the satellite, and replaced by TOPEX payload antennas -- the radar altimeter paraboloidal antenna, the radiometer offset paraboloidal reflector, and the TRANET II double helix antenna -- and the laser retroreflector.

- The S-band antenna which communicates with ground stations is moved to a corner of the payload module to avoid interference with TOPEX payload antennas, also on the nadir side.

- On the zenith side, S-band antennas are added for communication with TDRSS. Shown are an omni for low data-rate communication to any visible TDR satellite, and a higher-gain antenna for high data-rate transmission when a TDR satellite is close enough to the zenith.

- Also on the zenith side can be seen a 300-lbf thrust ascent engine.

Other features of the adaptation are internal and not shown in the figure:

- A recommended replacement of the two FLTSATCOM 22-inch diameter N_2H_4 propellant tanks by a single 39-inch diameter tank which occupies the space vacated by removing the solid apogee kick motor. This provides propellant for the added TOPEX ascent propulsion requirement as well as for the on-orbit attitude and velocity control requirements via FLTSATCOM's 0.1- and 1.0-lbf thrusters.

- The earth sensors of the attitude control subsystem are modified to compensate for TOPEX's lower altitude.

- The transponder and data system are replaced to provide TDRSS compatibility (rather than SGLS) and to handle the higher TOPEX data rates. An S-band power amplifier of $\sim$40 watts is added.

FLTSATCOM features directly applicable to TOPEX without significant modification are the structure and modular configuration, the electrical power subsystem, the S-band nadir-pointing omni antenna, the attitude control subsystem, and the part of the propulsion subsystem devoted to on-orbit attitude and velocity control. The approximate mass and power budgets for TOPEX will be as shown in Figures 3.1-6 and 3.1-7.

3.2 PROPULSION SUBSYSTEM

A blowdown, monopropellant hydrazine propulsion subsystem provides the impulse to transfer the satellite from the Shuttle delivery orbit to the mission altitude, and for maneuvers and attitude control in operational orbit. The propulsion subsystem is a modification of the existing FLTSATCOM subsystem. The modification replaces existing propellant tanks with a

Spacecraft Dry		1911
Structure	340	
Thermal Control	32	
Electric Power and Distribution	690	
Attitude and Velocity Control	127	
Telemetry Tracking and Command	86	
Integral Propulsion	175	
TOPEX Payload (Option 3) (209 kg)	461	
Propellant		760
For ΔV (Option 1, 677 m/s)	720	
For Attitude and Spin Control	24	
Unusable	16	
Spacecraft at Launch		2671
Adapter		120
Total		2791

Figure 3.1-6. TOPEX Mass, lbm (Approximate)

Subsystem	Power, Watts
Telemetry, Tracking, and Command	160
Attitude and Velocity Control	44
Thermal Control	17
Propulsion	20
Electrical Power and Distribution	190
TOPEX Payload (Option 1)	259
Total Required	690
Available From Array After 5 Years	1440
(Accounting for 45° Incidence Angle)	1140
Excess for Battery Charging	450

Figure 3.1-7. TOPEX Power Budget (Approximate)

larger, central tank, and adds a 1335 N (300 lbf) thruster for orbit boosting. The following sections describe TOPEX propulsion requirements, the subsystem design approach taken, the existing FLTSATCOM propulsion subsystem, and the modifications to be made for TOPEX.

3.2.1 Requirements

The propulsion subsystem must have the capacity to: (1) boost the satellite from Shuttle delivery orbit to mission altitude, and (2) provide on-orbit maneuvers which include orbit phasing, orbit repeat cycle, orbit maintenance, and inclination change (or margin). The ΔV requirement for item (1) above is specified as 550 m/s for Option 1 by paragraph E of the Statement of Work for Contract 956199. It is lower for Options 2 and 3. The ΔV requirement for item (2) above is 127 m/s per the JPL Phase A report for TOPEX. The maximum ΔV for the mission is then 550 + 127 = 677 m/s.

3.2.2 Design Approach

The existing FLTSATCOM bus incorporates a monopropellant hydrazine reaction control subsystem which delivers impulse for attitude, velocity and spin speed control, and momentum wheel unloading for a 7-year mission life. It also has a solid rocket apogee kick motor (AKM). The reaction control subsystem satisfies all the TOPEX requirements except for orbit boosting, which can be met by an existing 1335 N (300 lbf) thruster that has been flown on a classified program. The FLTSATCOM propellant tank capacity must be increased to carry the additional propellant needed for orbit boosting. The solid rocket AKM, however, is no longer needed. The space previously occupied by the AKM is then available for a larger hydrazine propellant tank.

Using the maximum ΔV requirement of 677 m/s, and a mission average specific impulse of 220 seconds for the monopropellant hydrazine thrusters, the maximum propellant requirement is 326 kg (720 pounds). The Shuttle RCS tank, at a 3:1 blowdown ratio, is rated at 346 kg (763 pounds) capacity. It, therefore, can hold all the required propellant for the TOPEX mission. Consequently, the two existing FLTSATCOM propellant tanks may be eliminated in favor of a single, central propellant tank for all mission phases. The Shuttle RCS tank is spherical, and is 39.2 inches in diameter. It readily fits into the space presently occupied by the solid rocket AKM.

An integral propulsion subsystem is preferable to a separate ascent propulsion module plus an on-orbit propulsion subsystem because many reaction control functions would otherwise have to be duplicated in the ascent module. The FLTSATCOM bus already provides all the requisite reaction control functions. The delivered performance of a monopropellant hydrazine orbit boost thruster yields weight margins that are very comfortable for the planned missions. Other candidates for the boost thruster included two stage solid rocket motors or a bipropellant thruster. Monopropellant was selected because of commonality with the existing reaction control subsystem, acceptable performance in the required energy regime, lower project cost and risk, and user familiarity.

3.2.3 Existing FLTSATCOM Propulsion Subsystem

The hydrazine propulsion subsystem on FLTSATCOM has demonstrated its capability to provide the specified mission performance in both spinning (transfer orbit) and three-axis stabilized modes of operation. The subsystem now provides ∿217,000 N-s (49,000 lbf-s) total impulse for the following functions:

- Spin-up and despin
- Pre- and post-AKM precession
- Acquisition and two reacquisitions
- Attitude control
- Wheel unloading
- Initial orbit correction and positioning
- Repositioning
- Stationkeeping

The subsystem was loaded with 104 kg (230 pounds) of hydrazine on its most recent flights.

The first use of the hydrazine subsystem is at initial separation from the launch vehicle when two high level thrusters (HLTs) are fired by the spacecraft sequencer to spin up the spacecraft to 62.5 rpm. The roll HLTs are then used to precess the spacecraft spin axis to the nominal AKM firing attitude. Upon injection into synchronous orbit, additional HLT firings are conducted to precess the spacecraft to the orbit normal attitude, and to sequentially conduct the required despin, and sun and earth acquisition maneuvers, respectively. The later maneuvers are conducted by firing all eight of the primary HLTs to provide active control in the pitch, roll and yaw axes.

Normal on-orbit control is provided by a combination of reaction wheels and thrusters. A body-fixed momentum bias wheel provides both active pitch control to maintain the required pointing accuracy and passive momentum wheels. In this normal on-orbit control mode, both the HLTs and low level thrusters (LLTs) are pulsed at a very low duty cycle. Sufficient time elapses between pulses to allow the catalyst bed to return to the prefiring temperature. The high number of bed ambient temperature pulses (up to 100,000 on the LLTs) necessitated the incorporation of electrically powered catalyst bed heaters to ensure the required catalyst bed lifetime.

Orbit correction, repositioning and east-west stationkeeping are performed with the ΔV HLTs. Active attitude control is maintained by the roll and pitch HLTs firing in pulse mode.

The propulsion subsystem schematic diagram is presented in Figure 3.2-1. Twenty thrusters are used to meet the system attitude and velocity control requirement with full redundancy and to satisfy all operational constraints. Impulse for spin/despin, precession, ΔV, acquisition, attitude control during ΔV and momentum wheel unloading is supplied by two redundant banks of eight HLTs which generate 5 N (1.0 lbf) maximum steady-state thrust. Two redundant banks of two LLTs, which generate 0.5 N (0.1 lbf) nominal steady-state thrust, provide impulse for normal-mode roll/yaw control.

The thrusters are positioned within the spacecraft as shown in Figure 3.2-2. Figure 3.2-3 summarizes subsystem components, suppliers, and weight.

3.2.4 Modifications for TOPEX Propulsion Subsystem

The following changes to the FLTSATCOM propulsion subsystem are made for TOPEX:

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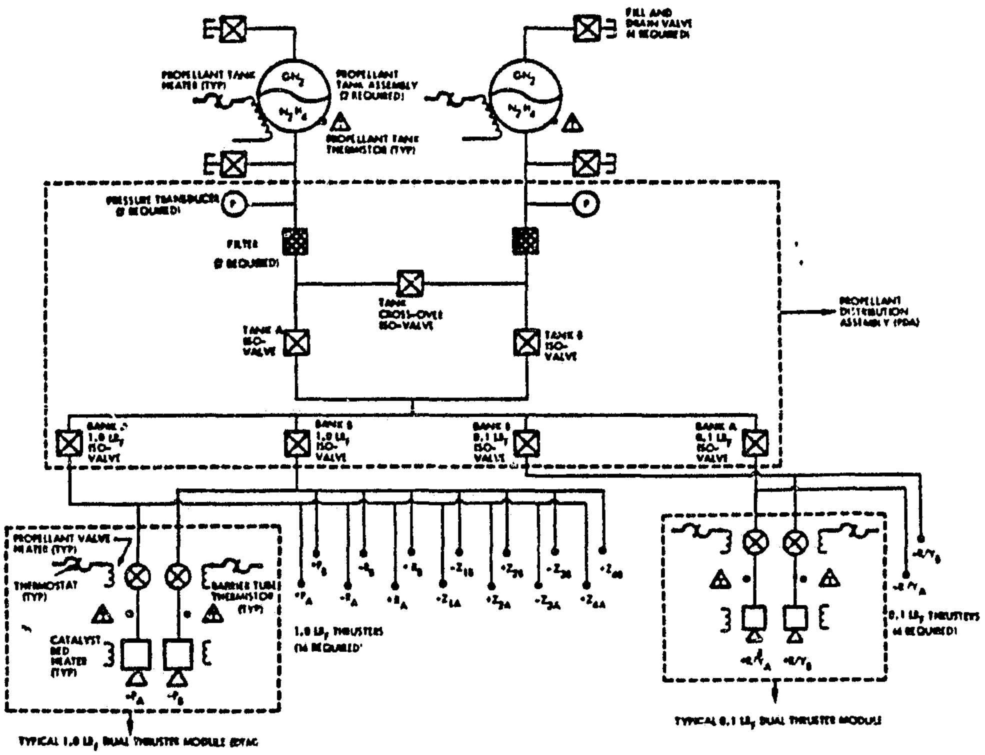

Figure 3.2-1. FLTSATCOM Hydrazine Propulsion Subsystem Schematic

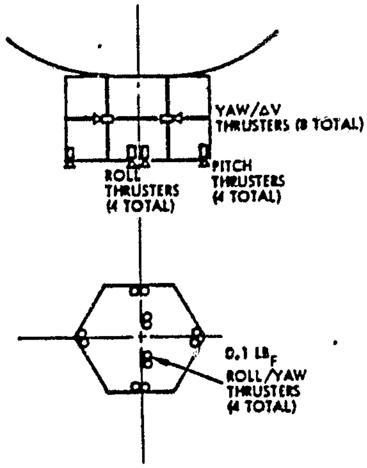

Figure 3.2-2. FLTSATCOM Thruster Positions

Component/Module	Quantity Per System	Supplier	Weight (lb) Unit	Weight (lb) Total
Propellant Distribution Assembly	1	TRW		6.7
Filter package	1	Wintec	1.1	
Pressure transducer	2	Statham	0.4	
Latching valve	7	Hydraulic Research	0.56	
HLT and LLT Dual Thruster Modules	10	TRW	1.7	17.0
HLT and LLT thruster	20	TRW	0.1	
Propellant valve	20	Parker-Hannifin and Allen Design	0.5	
Valve heaters	20	Tayco		
Thermostats	20	Sundstrand		
Thermistor	20	Fenwal		
Catalyst bed heaters	60	Tayco	0.1	
Fill and Drain Valve	4	TRW	0.15	0.6
Propellant Tank Assembly	2	Pressure Systems, Inc.	16.7	33.5
Tank diaphragm	2	TRW		
Line Heaters/Misc. Hardware	A/R	Tayco (heaters)		4.1
Total Weight (28.1 kg)				61.9

Figure 3.2-3. FLTSATCOM Propulsion Subsystem Components

(1) Replace the two propellant tank assemblies with the Shuttle RCS propellant tank.

(2) Add a 1335 N (300 lbf) thruster for orbit boosting.

(3) Implement the associated valving changes per the schematic diagram shown in Figure 3.2-4.

The Shuttle RCS propellant tank is furnished by Martin-Marietta. It has a dry weight of 34 kb (75 pounds). The 1335 N (300 lbf) thruster is supplied by Walter Kidde. It weighs 28 kg (62 pounds). It has previously been used on an Air Force classified satellite.

The additional equipment conveniently fits into the space vacated by the current FLTSATCOM solid AKM, which is no longer needed.

3.2.5 STS Services

The Space Transportation System (STS) interface with TOPEX should provide several services to the propulsion subsystem in the Shuttle orbiter. These include telemetry channels for monitoring propellant tank pressure and status of the isolation valves.

3.3 MECHANICAL SUBSYSTEM

Figure 3.3-1 lists the principal features of the existing FLTSATCOM structural design. Figure 3.3-2 and -3 show exploded views of the spacecraft structure. The principal load path is a central cylinder attached to the boost vehicle by a conical adapter section. The apogee kick motor (AKM) weighs slightly over a ton and is mounted inside the central cylinder. An annular Z ring carries the rocket motor weight during boost, transmits motor thrust during firing, and provides thermal isolation between the motor casing and the satellite interior. The two hydrazine tanks operate in the blow-down mode, and zero g feed is assured by bladders. Total propellant load capability is about 350 pounds of hydrazine. The longerons and stringers support the external spacecraft panels and loads are carried by the horizontal support platform and diagonal struts. The payload module is of similar construction.

The solar array substrate is 0.625-inch aluminum honeycomb with 0.005-inch facesheets. The backup structure and solar array booms are rectangular tubular aluminum. Thermal control of the spacecraft is accomplished

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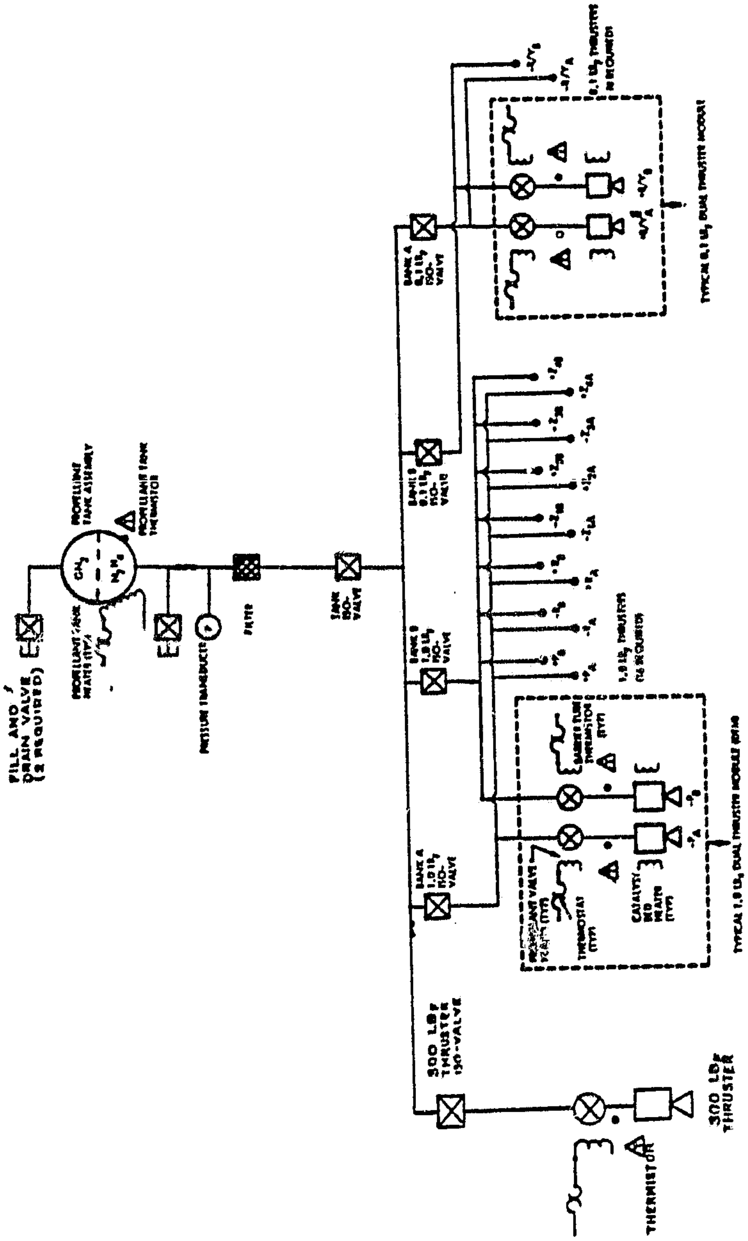

Figure 3.2-4. TOPEX Propulsion Subsystem Schematic

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PRIMARY LOAD PATH	CENTRAL CYLINDER 0.050 INCH MAG 0.7 INCH STIFFENERS
	AKM INSIDE CENTRAL CYLINDER "Z" RING MOUNT
SECONDARY STRUCTURE	HORIZONTAL PLATFORM — PROPELLANT TANKS
	LONGERON AND STRINGER FRAME
EQUIPMENT MOUNTING	EXTERNAL HONEYCOMB PANELS
TRANSMIT ANTENNA	0.750 Al RIBS CRES STAINLESS — Ag COMPOSITE BRAZED MESH
	Cu FACE SHEET HONEYCOMB CENTER DISH
	TUBULAR Al BIFILAR HELICAL FEED
RECEIVE ANTENNA	1.25 INCHES x 0.010 Al RIBBON HELIX
	FIBER GLASS STANDOFFS Al CENTRAL TUBE
	GFRP SUPPORT BOOMS
SOLAR ARRAY	0.625 INCH Al HONEYCOMB 0.005 FACE SHEET

Figure 3.3-1. Structural Features

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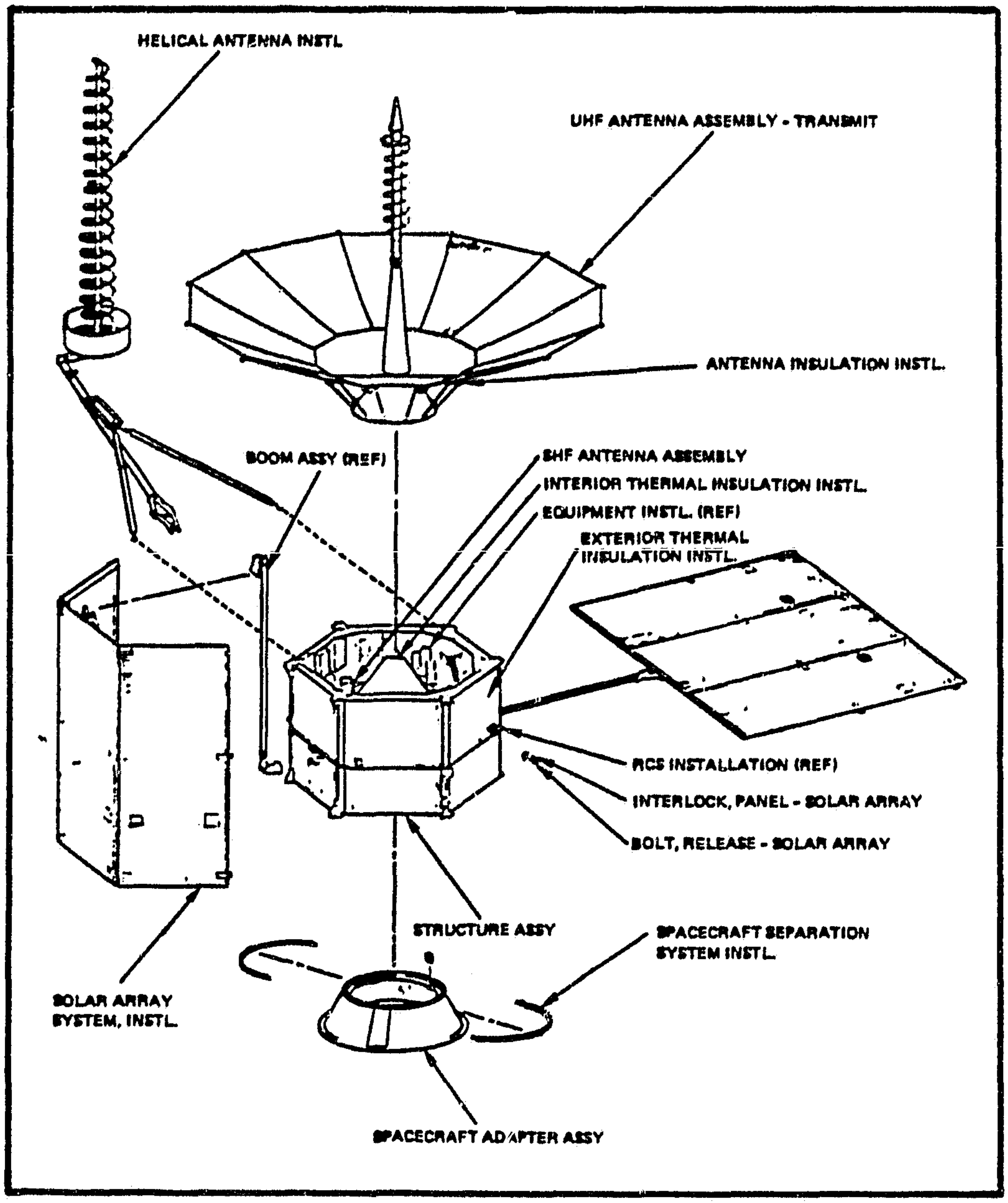

Figure 3.3-2. Spacecraft Structural Assembly

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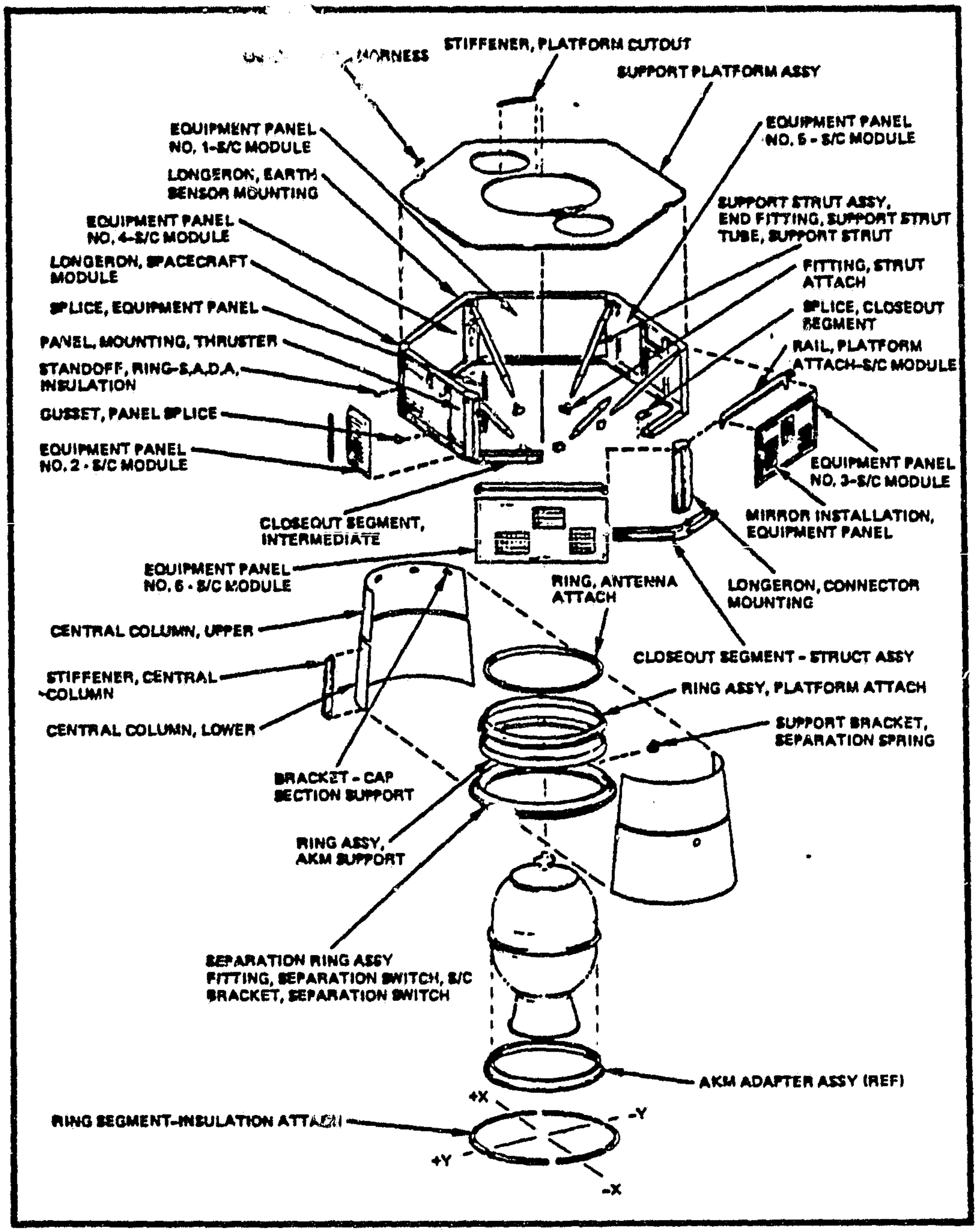

Figure 3.3-3. Equipment Compartment Structural Assembly

by radiation of heat directly from the spacecraft external panels. Second surface mirrors (SSM) bonded to the exterior surface of the honeycomb panels provide the required thermal emissivity while reflecting incident solar radiation. The panel areas that are not used as radiators are insulated with multilayer super-insulation.

3.4 POWER SUBSYSTEM

The electrical power subsystem of the FLTSATCOM consists of solar arrays, batteries, a power control unit, converters, power switching assemblies, distribution units and cabling. Functionally, these elements are arranged as shown in Figure 3.4-1, and the summary characteristics of the subsystem are shown in Figure 3.4-2.

When in sunlight the solar arrays power the main bus and provide current for charging the batteries. When in eclipse, the batteries power the main bus. The main bus voltage is unregulated, but user requirements are met via converters which regulate their output voltages. Heater and ordnance power are supplied from the main bus.

The solar array is comprised of six panels, three on each of two wings. A solar array drive mechanism rotates the wings about a common north-south axis to keep them facing the sun; with the orientation assumed by the spacecraft in geosynchronous orbit, the sunline deviates from the array normal by $\pm 23.4^{\circ}$ due to seasonal variation in the sun's declination.

There are 22,632 solar cells (2 x 4 cm each) in the array, 3,772 per panel. These are divided into a load section (19,872 cells, 3,312 per panel) and a charge section (2,760 cells, 460 per panel). This solar array provides FLTSATCOM with 1,256 watts at 29 volts (load section) plus 180 watts at 37 volts (charge section) at the end of a five-year mission.

There are three battery assemblies. Each consists of 24 NiCd battery cells of 24 ampere hour capacity. 22 of these cells are employed in series at a time, with the other two as backup. Electronic bypass at the cell level accommodates single cell failures.

The main bus is switched in the power control unit (PCU) to the various converters and to the electrical integration assembly (EIA). As the major power consumer on FLTSATCOM is the communications payload, most of the converters are dedicated to this payload.

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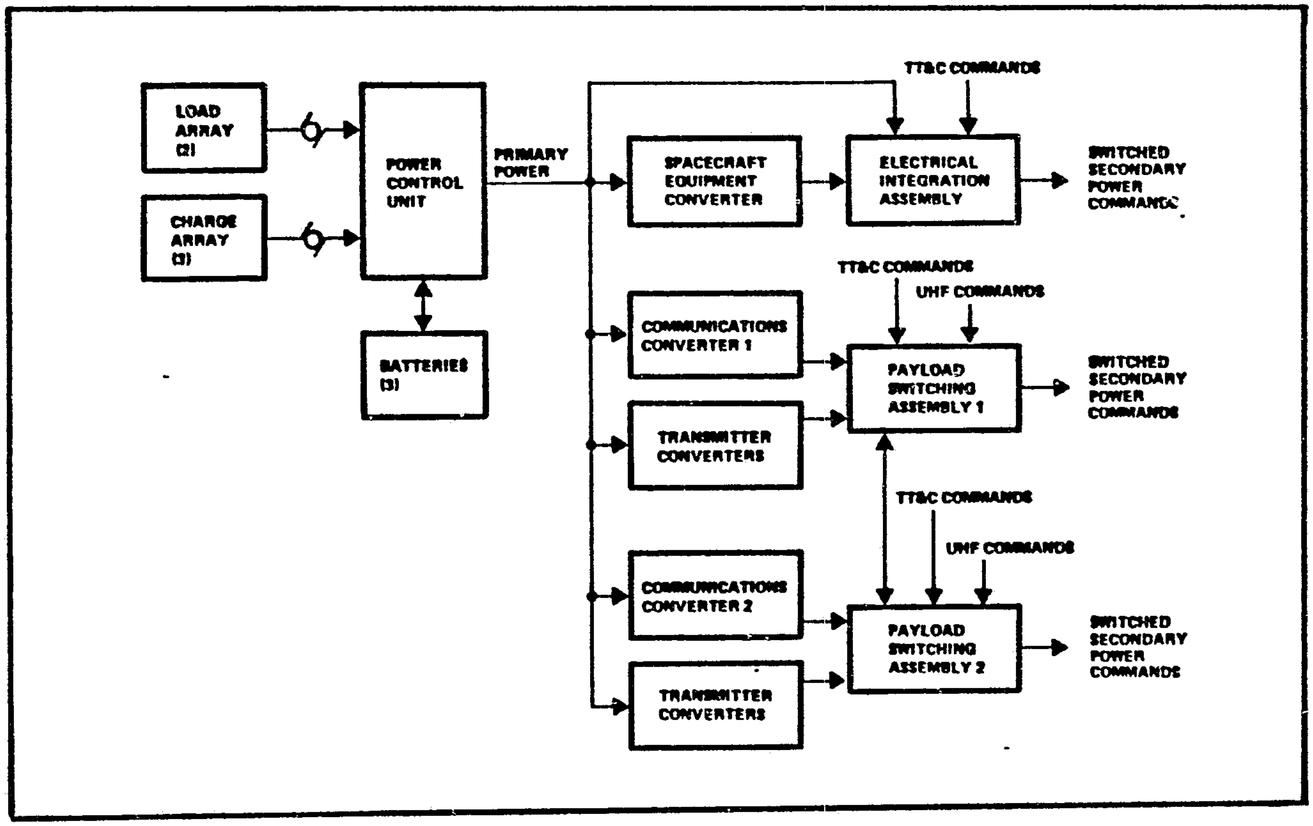

Figure 3.4-1. Electrical Power and Distribution Subsystem

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SOLAR ARRAY	22,632 2 CM x 4 CM 0.008 INCH NON P CELLS 0.006 INCH COVERGLASS
	2 KW BOL 1.2 KW EOL (7 YRS)
	SEPARATE BATTERY CHARGE STRINGS
	UNREGULATED BUS 20-70V
BATTERY	3 – 24 CELL 24 A HR NiCad BATTERIES
	CURRENT LIMITED CHARGE TO TEMPERATURE COMPENSATED VOLTAGE SWITCH TO TRICKLE
	ELECTRONIC BYPASS AT CELL LEVEL
SECONDARY POWER	3 MULTIVOLTAGE CONVERTERS SUPPLYING COMPONENT LOADS
	4 SINGLE VOLTAGE CONVERTERS FOR TRANSMITTERS
POWER SWITCHING/ FAULT ISOLATION	SWITCHING ASSEMBLIES IMPLEMENT RELAY SWITCHING OF SECONDARY POWER
	CONVERTER OSCILLATOR SHUT DOWN FOR SECONDARY POWER OVERLOAD
	FUSED PRIMARY POWER

Figure 3.4-2. Electric Power Subsystem Features

3.5 ATTITUDE AND VELOCITY CONTROL

FLTSATCOM has two different attitude control modes for the two phases of its mission. The first phase includes orbit transfer from low altitude to geosynchronous altitude and the firing of the apogee kick motor. For this phase the satellite is spin stabilized about its yaw (Z) axis, and the spin is initiated and terminated by firing one-pound yaw thrusters. The second phase is the on-orbit earth-pointing phase. This requires a slow rotation at one revolution per orbit about the pitch (Y) axis.

For the orbit transfer phase, spinning sun and earth sensors permit determination of the spin rate and the spin axis orientation. Spin rate is controlled by yaw thrusters, and spin axis orientation by the firing of precession pulses via pitch or roll thrusters. Attitude control electronics controls the firing of all thrusters. The launch sequence is shown in Figure 3.5-1. The subsystem block diagram is shown in Figure 3.5-2.

On orbit, pointing errors of the yaw (earth-pointing) axis are determined by scanning earth sensors sensitive to roll and pitch offsets. Stability of the slow rotation about the pitch axis is augmented by a pitch momentum wheel, and pitch errors are corrected by speed changes of this wheel. Pitch momentum unloading and roll error correction are effected by the firing of thrusters. The gyroscopic stability about the pitch axis makes active yaw control unnecessary. A sun sensor assembly provides information about the direction of the sunline and this data is used to periodically correct the solar array position and control the spacecraft during velocity correction maneuvers. The 1-lbf yaw thrusters can be used in a thrust aiding mode to impart horizontal velocity to the spacecraft. The equipment is fully redundant and capable of extensive cross-connection by ground command.

Figure 3.5-3 describes the on-orbit attitude control technique. The earth sensor is the scan-through type and operates in the long infrared (IR) region. The scan plane is offset 5 degrees from the equator so that the earth pulse is sensitive to both pitch and roll errors. The position of the earth pulse relative to the center of the scan provides the pitch attitude error and the length of the earth pulse measures the roll error. Each of the two sensors has two scan planes located ± 5 degrees from the

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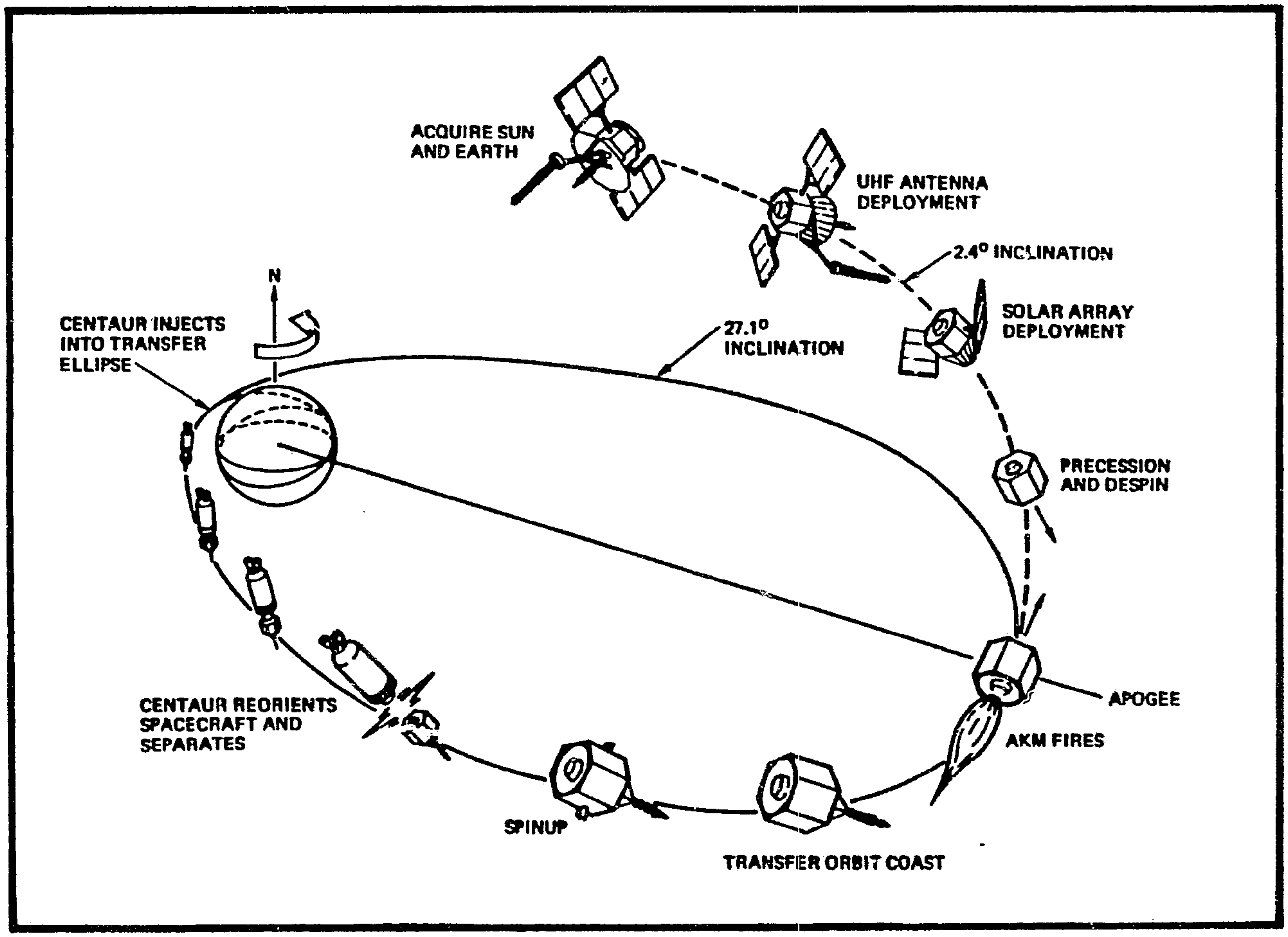

Figure 3.5-1. FLTSATCOM Mission Profile

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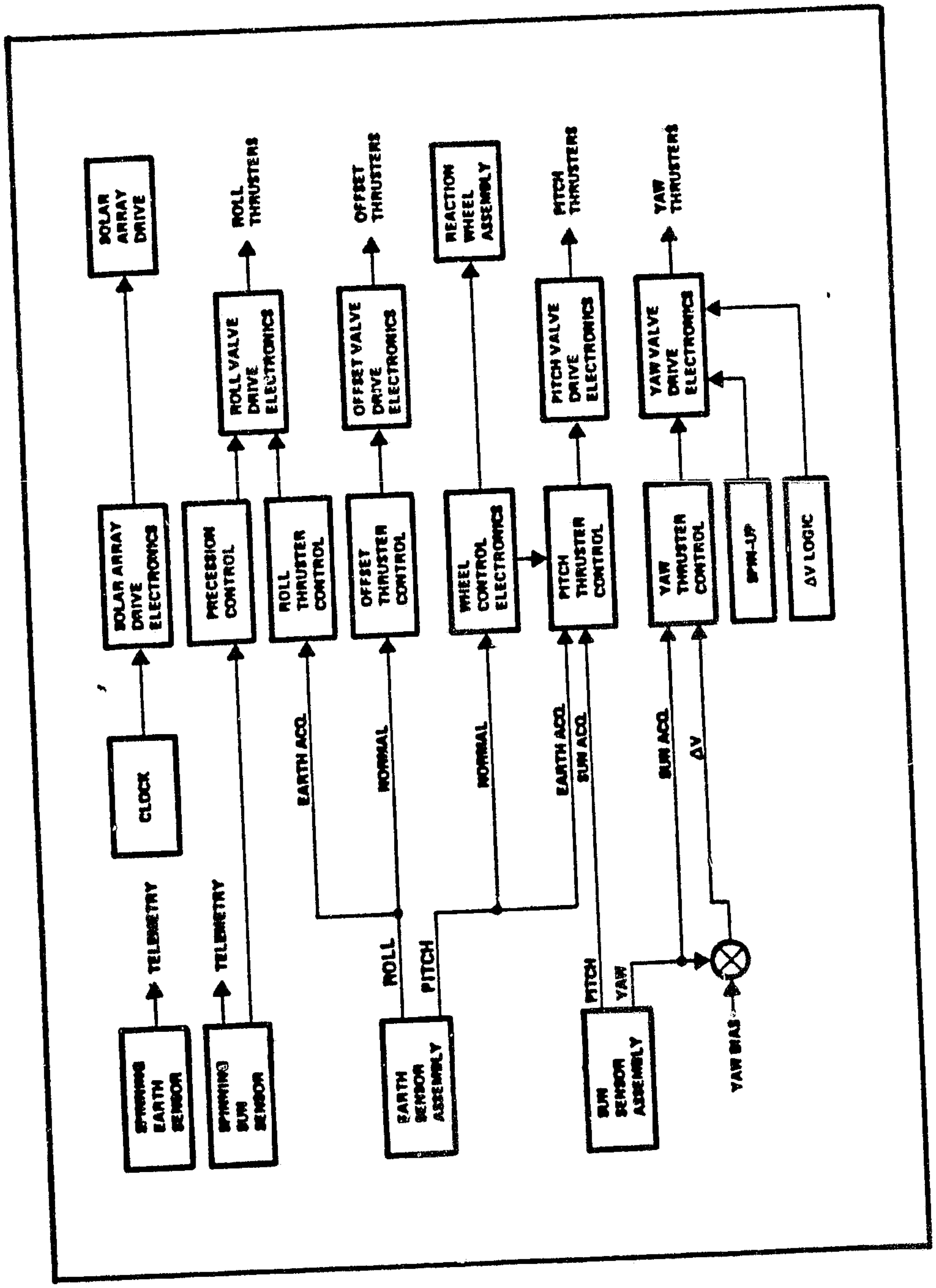

Figure 3.5-2. Attitude and Velocity Control Subsystem

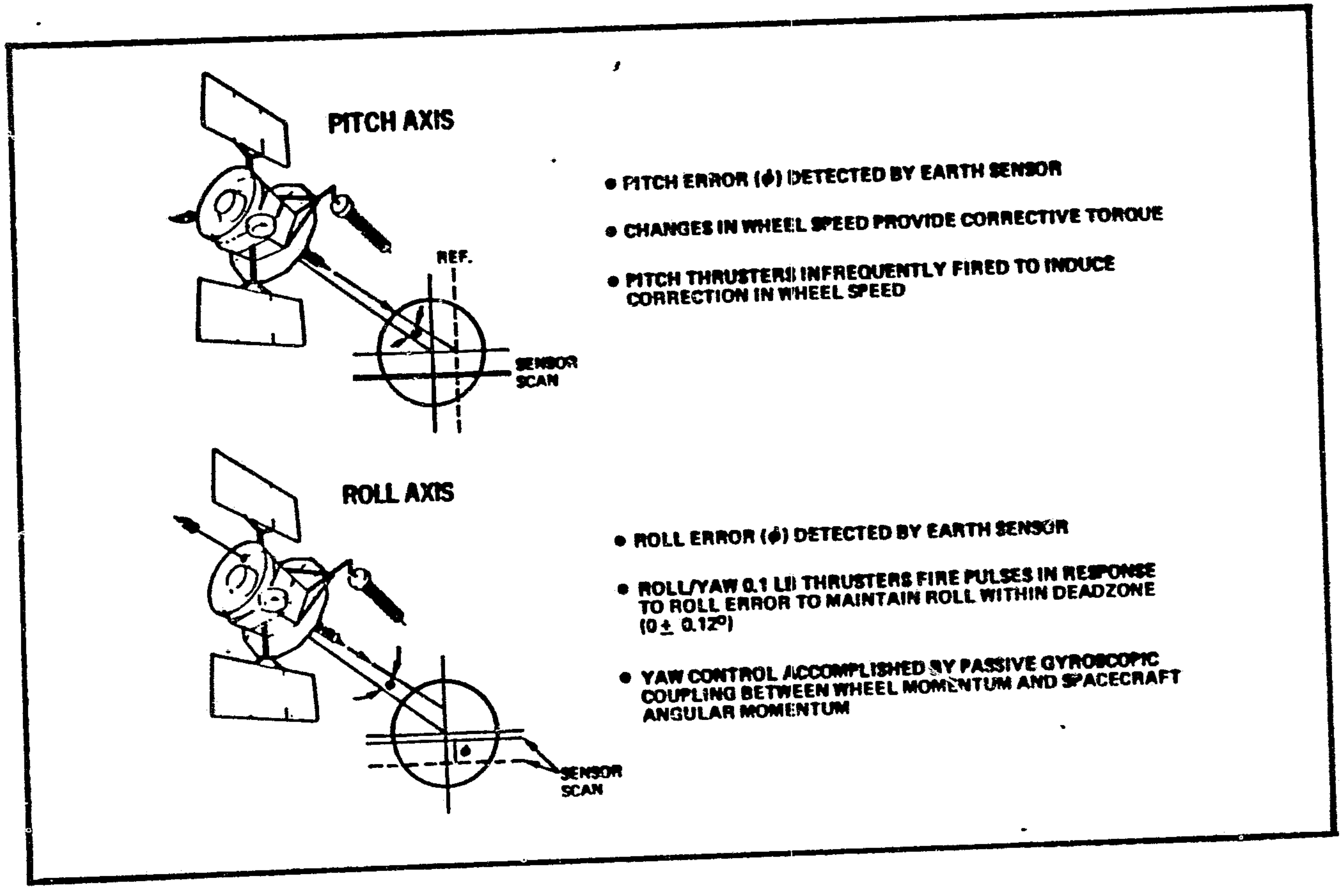

Figure 3.5-3. On-Orbit Attitude Control

spacecraft X and Z plane. These scan planes are selectable on command to avoid interference from the sun and moon. The measured pitch error is processed in the control system to modulate the speed of the reaction wheel which is oriented along the Y body axis. Torques generated by this modulation hold the pitch error close to zero. Secular pitch momentum build-up is corrected by the 1-lbf pitch thrusters. The reaction wheel speed is biased so that it operates between 2,000 and 4,000 rpm and always produces a component of momentum along the Y body axis. The roll control system uses the roll output of the earth sensor to fire a 20 msecond pulse from the 0.1-lbf thrusters. This pulse is fired when the roll error exceeds its dead-band value of 0.12 degree and imparts a nutation to the spacecraft due to interaction with the spacecraft momentum. The attitude control electronics fires a second pulse 1,000 seconds after the first pulse which cancels the nutation at close to zero roll error. The roll control system fires approximately 100 pulses of the 0.1-lbf thrusters per day. The timing logic prevents nutation build-up and the bias momentum of the pitch wheel, together with a small yaw offset component of the 0.1-lbf thruster alignment provides the cross-coupling between roll and yaw axes necessary for yaw stability.

3.6 TELEMETRY, TRACKING AND COMMAND (TT&C) SUBSYSTEM

Figure 3.6-1 summarizes the TT&C features of the existing FLTSATCOM spacecraft. The TT&C functions utilize the SGLS S-band system, Channels 11 and 13. The command system is a 1000 baud FSK system and includes PRM ranging tones and coherent turnaround of the uplink carrier to provide range rate. The individual commands are 32 bits and are encrypted. The telemetry system uses PSK modulation on a 1.024 MHz subcarrier and can operate at either 250 or 1,000 bps. Within the spacecraft, the commands are routed to the 36 user addresses by the S-band command unit and at these user addresses, further decoded to accomplish the individual command functions. A total of 977 commands are used, approximately half of these commands are needed for ascent operations, and most of the remaining commands for redundancy control. During normal operation, only 58 commands are needed. The telemetry consists of 184 main frame words and 965 subcom words. At the high data rate the main frame is sampled each 0.512 second and the subcom sampled at 1/64th of this rate. The various measurements

RF LINK	SGLS CHANNELS 11 AND 13	
MODULATION	COMMAND	PCM/FSK 1000 BPS
	TELEMETRY	PCM/PSK ON 1.024 MHz SUBCARRIER 250/1000 BPS
	RANGING	PCM/PRN COHERENT RANGE RATE
COMMANDS	38 USERS 977 COMMANDS	
	478 ASCENT OPERATIONS 58 NORMAL MODE	
	443 REDUNDANCY CONTROL	
TELEMETRY	184 MAIN FRAME	965 SUBCOM
	28/240 ANALOG	144/674 BILEVEL
	12/51 DIGITAL	

Figure 3.6-1. Telemetry and Command Features

are categorized as analog, bilevel, or digital as shown in Figure 3.6-1. Figure 3.6-2 is the TT&C subsystem block diagram.

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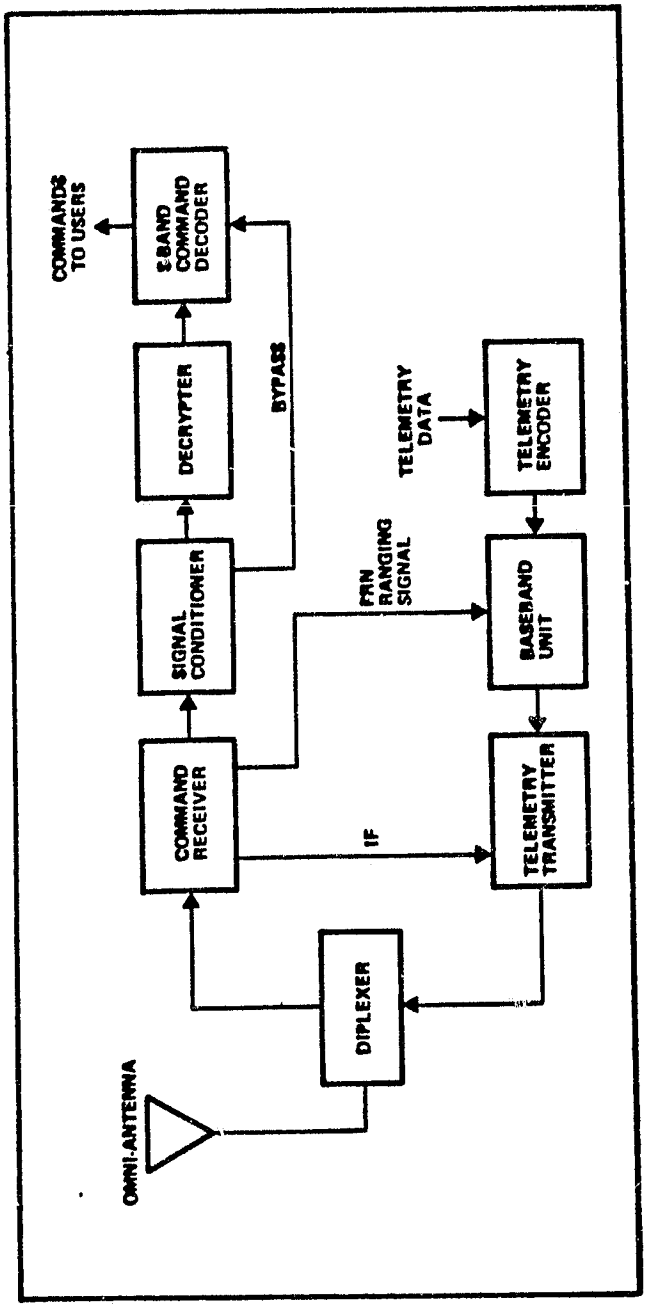

Figure 3.6-2. Spacecraft Command and Telemetry

4.0 FLTSATCOM/LAUNCH VEHICLE COMPATIBILITY

The FLTSATCOM dynamic envelope is such that it can not be accommodated by the Delta Launch vehicle without using a new hammerhead 10-foot fairing; therefore, for TOPEX it is assumed to use the Space Shuttle Vehicle (SSV).

4.1 THERMAL AND DYNAMIC ENVELOPE

As presently configured, FLTSATCOM without communication payload antennas occupies a cylindrical volume 9.3 feet in diameter and 10 feet in length. The allowable payload envelope in the SSV cargo bay is 15 feet in diameter and 60 feet in length which provides a margin of 80% in length not including any TOPEX ASE. This ample margin allows for companion payloads to be carried by the SSV (depending upon the particular STS mission) and for additional instruments on the FLTSATCOM bus should it be desirable to expand the baseline TOPEX payload instrumentation.

4.2 WEIGHT

SSV capabilities to deliver cargos into orbit depend upon program variables. Some limitations exist for discrete inclinations between 56° and 70°; these limitations are still under study by NASA. Since TOPEX is to be delivered by SSV at 63.4° inclination, it will be necessary to verify SSV capability with JSC during the detailed design phase. However, in view of FLTSATCOM's modest weight it is expected that full compatibility with SSV constraints will exist.

4.3 STRUCTURAL INTERFACE

FLTSATCOM is attached to the launch vehicle adapter by a conical flange at the station of the AKM nozzle. Two options are available for attaching the FLTSATCOM bus via the same flange to the SSV: (1) the bus can be supported directly on bridges at the sides of the cargo bay (longerons) and/or the bottom of the cargo bay (keel); or (2) the bus can have its own support structure which, in turn, is attached to the cargo bay. Option (1) necessitates the design of additional structure which FLTSATCOM will have to carry into the observation orbit. The weight penalty makes this option unattractive. To implement option (2), a number of existing cradle and pallet designs offer potential candidates; among these are the IUS cradle (Boeing), the Space Test Rack (GE), the GRO cradle (TRW), the FDI cradle

(Rockwell), the SSUS-A, the Multi-Mission Spacecraft (MMS) cradle, and the Spacelab and OFT pallets. It will be the task of detailed design to define the optimum, cost-effective cradle configuration for this application.

4.4 POWER AND SIGNAL INTERFACES

Selected components of the FLTSATCOM bus will require power during the prelaunch, launch and ascent (to the SSV orbit) phases of the mission. It will also be necessary for commands to be loaded to the spacecraft while it is still attached to the SSV. The minimal power requirement (a few watts) is well within the SSV capability of 315 W. Power conditioning and distribution will be accomplished by the Power Control Unit. The signal interface provided by the SSV is compatible with the FLTSATCOM TT&C subsystem. The spacecraft cradle will provide the physical location for the power/signal interfaces in the form of an appropriate connector panel.

4.5 HEAT REJECTION

The FLTSATCOM bus does not require active cooling and, therefore, an interface with the Active Thermal Control Subsystem (ATCS) of the SSV is not required.

4.6 ENVIRONMENTS

FLTSATCOM subsystems and components have been qualified to natural and induced environments commensurate with the pre-launch, launch/ascent and post-liftoff phases of an Atlas-Centaur vehicle launch. These qualification environments exceed in severity the corresponding environments in the cargo bay during a SSV launch. In the TOPEX application, those FLTSATCOM components which are modified can, therefore, be qualified by similarity, resulting in considerable cost savings to the program.

4.7 SAFETY

It will be the task of the detailed design to assure compliance with safety requirements applicable to SSV payloads. Allowable meterials, propagation of possible failure, the detection of and safing against potential hazards are key considerations to be considered.

5.0 SUMMARY OF FLTSATCOM CAPABILITIES VS TOPEX REQUIREMENTS

This summary is divided into three sections: requirements which are met by the FLTSATCOM bus as it exists or with very minor modifications, requirements which are not met and call for specific changes, and requirements for which changes are undetermined.

5.1 REQUIREMENTS MET BY FLTSATCOM

5.1.1 Space for Payload; Modularity

FLTSATCOM readily provides prime space for the TOPEX payload, space for nadir looking payload antennas, and a module for payload electronics. The adaptation of the spacecraft system to TOPEX, in this respect, consists merely of removing FLTSATCOM's complement of payload antennas and installing TOPEX antennas; of removing FLTSATCOM payload transponders and installing TOPEX electronics.

The shape and size of the payload module -- a hexagonal prism 7.5 feet across flats -- is about ideal for TOPEX's largest payload, Option 1, with a 2-meter radar altimeter dish; space remains around the periphery for smaller antennas. There is no conflict by spacecraft components with the field of view of payload antennas.

5.1.2 Structure

As the form of the modules satisfies the payload requirements, the structural design also has adequate margin. The heaviest TOPEX payload, Option 3, is somewhat lighter than the removed FLTSATCOM payload. In addition, the liquid ascent propulsion engine gives a much gentler ride than the solid apogee kick motor it supplants.

5.1.3 Mass

The total mass of the satellite is reduced, partly by payload reduction and partly by lower propulsive requirements (see Section 3.1). Because of the Shuttle launch, total satellite mass is not critical. However, the mass reduction gives a greater structural strength margin, and it is compatible with a propulsion system which is easily integrated into the satellite.

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5.1.4 Power

The power subsystem can be flown as is, and it will satisfy all TOPEX payload power requirements and spacecraft needs. (The canting of the arrays to 45° to the array drive axis is not a power subsystem change; it is a minor change in the local array deployment mechanism.) See Section 3.1.2 for the estimated power budget for TOPEX.

5.1.5 Propulsion

The 20 0.1- and 1.0-lbf thrusters are suitable as is for the TOPEX mission. Their number, their locations, their thrust levels, their minimum pulse duration, and their electrical control all appear to be satisfactory. The increase in hydrazine propellant capacity and the addition of a 300-lbf engine are associated with the functions of ascent propulsion, from the Shuttle orbit to the TOPEX orbit. The integrated propulsion subsystem handles both functions: ascent and on-orbit attitude and velocity control.

5.1.6 Attitude Control

The only change foreseen in the attitude control subsystem for the TOPEX satellite is to change the mounting angle and scan of the earth (horizon) sensors, because the earth as seen from the satellite now subtends an angle of 112 to 125 degrees (depending on which TOPEX mission option is selected) rather than 17.4° in the case of the geosynchronous FLTSATCOM.

For the integrated propulsion system which also provides ascent propulsion, the electronics must be augmented to control the firing of the 300-lbf engine.

The pointing accuracy of FLTSATCOM, 0.25°, would have to be reevaluated in the light of the earth sensor changes. If it remains the same, then FLTSATCOM meets the TOPEX pointing accuracy requirements for all instruments in Options 2 or 3, but falls short of the radar altimeter requirement of 0.15° in Option 1.

5.1.7 Lifetime

FLTSATCOM has a design life in orbit of five years. The performance to date of satellites 1 to 4 gives no indications of falling short of that requirement. FLTSATCOM satisfies the TOPEX requirement for a three-to-five year mission.

5.2 REQUIREMENTS NOT MET BY FLTSATCOM

5.2.1 Command and Data

The command and data handling characteristics of FLTSATCOM, part of its TT&C system, are deficient in several regards relative to the TOPEX mission:

- The FLTSATCOM transponder is compatible with SGLS (Air Force ground terminals), not with TDRSS and NASA ground terminals.
- The downlink bit rate of 1000 b/s is far short of the 480 kb/s of TOPEX.
- FLTSATCOM does not satisfy the TOPEX requirement for $\geq$ 512 stored commands.

For these reasons, the command and data systems will be replaced for TOPEX.

5.2.2 Telecommunications

The S-band telecommunications equipment is also part of FLTSATCOM's TT&C system (not part of the RF payload). It is deficient in several regards relative to the TOPEX requirements:

- As noted above, the transponder is not compatible with TDRSS and NASA ground terminals. This affects both the RF and data aspects.
- Antenna(s) must be added on the zenith side for communications upward to TDRSS.
- An S-band power amplifier must be added.

An order-of-magnitude estimate is that a 40-watt S-band power output will support communications to TDRSS at the rate of 48 kb/s via an omni antenna (hemispherical) with gain $\geq$ -1 dBi, or at 480 kb/s if the antenna gain is $\geq$ +9 dBi.

Assuming the addition of the 40 W power amplifier, this suggests several methods of meeting TOPEX's data requirements:

1) Playback at the low data rate (48 + 2 kb/s) can be handled upward to TDRSS or downward to ground stations using omni antennas, at any time the receiving station is visible from the satellite.

2) Playback at the high data rate (480 + 2 kb/s) is possible by the medium gain ($\geq$ +9 dBi) antenna to TDRSS by either of two approaches:

   a) whenever a TDR satellite is visible, if the antenna is steerable toward TDRSS.

   b) whenever a TDR satellite is overhead ±15 degrees, if the antenna is fixed and pointing toward the zenith. (This happens at least four times each day.)

3) Playback at the high data rate (480 + 2 kb/s) is possible by nadir-directed omni antenna to ground stations whenever they are visible.

The scenario for orbital operations is not defined adequately enough at this time to choose between 2a and 2b. What we have illustrated in Section 3.1.2 shows the zenith-facing omni antenna of 1 and a fixed zenith-facing helix per 2b.

5.2.3 Launch Vehicle Compatibility

While FLTSATCOM, as configured for TOPEX, has a mass compatible with a Delta launch, it is too big to fit within the 8-foot Delta fairing.* Thus the STS, the other launch vehicle candidate, must be employed.

FLTSATCOM has been built for launch by the Atlas Centaur vehicle. If it is to be launched by the Shuttle, certain changes will have to be made for compatibility:

- The physical attachment must be to ASE carried in the Cargo bay.
- This attachment must satisfy STS structural criteria, and it must provide for tilt out and separation of the satellite from the Cargo Bay.
- Data and electrical power interfaces with the Shuttle must be met.
- All Shuttle safety requirements must be reviewed for compliance.

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* However, a 10-foot fairing, now planned for the Delta launch vehicle by McDonnell Douglas, would be large enough for FLTSATCOM.

5.3 UNDETERMINED CHANGES TO MEET REQUIREMENTS

5.3.1 Data Storage

Because of the pattern of relatively low (6 to 15 kb/s) rates of acquisition of TOPEX data, but moderate (48 kb/s) to high (480 kb/s) playback rates, a data storage device, probably a tape recorder, is implied. FLTSATCOM does not carry a recorder, so this requirement calls for an addition. However, until the data return scenario is better defined and the options of Section 5.2.2 are resolved, the required data storage capacity can not be estimated.

5.3.2 Thermal Control

The adaptation of FLTSATCOM to the TOPEX mission will be accompanied by significant changes in thermal patterns:

- During eclipse seasons, TOPEX eclipses will not be as long as FLTSATCOM's but they will occur more often and for a larger fraction of each orbit.
- An RF payload dissipating some 700 watts is replaced by the TOPEX payload dissipating at most 250 watts.
- The total power developed by the solar array is reduced at some sunline orbit-plane angles by a factor of cos 45°, because of the canting of the array.

A future analysis will be necessary to determine what modifications, if any, are necessary to accommodate these changes.

5.3.3 Area to Mass Ratio

The TOPEX requirement is that the spacecraft area to mass ratio be $\leq 0.01\ m^2/kg$ for Option 1, and $\leq 0.02\ m^2/kg$ for Options 2 and 3. For FLTSATCOM employed as the TOPEX satellite, the estimated ratio is $0.019\ m^2/kg$ (worst orientation of solar array), $0.004\ m^2/kg$ (best orientation), or $0.014\ m^2/kg$ (effective average over one orbit). This is an inherent characteristic of the FLTSATCOM configuration, and it is not likely that changes could be made to give significant reductions.

6.0 COST AND AVAILABILITY

The results of Tasks 1 through 5 of the study, presented in preceding sections of this report, describe the technical features of our proposed existing FLTSATCOM spacecraft design and its direct applicability to the TOPEX mission requirements. This section includes the programmatic results of Task 6 of the study, consisting of cost estimates for budgetary and planning purposes and an assessment of availability of the described design based on the continuing production of FLTSATCOM during the schedule span planned for TOPEX.

The key groundrules on which the cost estimates are based are listed in Figure 6-1 and the cost estimates by JPL WBS element are presented in Figure 6-2. It is especially important to note that while these estimates are derived from an existing, on-going program, the accuracy is dependent on the scaling from a multiple unit production activity to a single unit build, with its attendant proportionately larger non-recurring elements. Additionally the possible efficiencies of coordinating activities between the FLTSATCOM and TOPEX projects are dependent on the precise relative timing of their schedules.

With respect to availability, TRW received a contract in January 1982 for long lead items in preparation for manufacture of FLTSATCOM flight units 6, 7 and 8. These units are presently scheduled for delivery in June 1985, February 1986 and October 1986. All of the components for the integral propulsion subsystem have proven flight heritage and are expected to be readily available in this same time frame. Thus JPL is assured of the availability of this recommended design for the 1984 start to 1987 launch schedule planned for TOPEX.

Items Included in the Cost Estimate:

- The existing FLTSATCOM design without the propulsion subsystem (hydrazine "blowdown" system, thrusters, and apogee kick motor) and without the communications payload (distinct from the telemetry, tracking and command subsystem which remains).

- An integral propulsion subsystem based entirely on hydrazine thrusters (substituted in place of the combined hydrazine, solid AKM subsystem).

Items Not Included in the Cost Estimate:

- Modifications or additions to any subsystem other than propulsion that may be required to meet TOPEX-unique mission requirements.

- Any modifications required to interface with the TOPEX payload.

- Any modifications for STS launch compatibility, including STS associated ASE.

- Any TOPEX payload and payload integration and test activities.

- Ground operations support after launch.

Programmatic Factors:

- TOPEX contract for one flight unit conducted by separate project office (independent of FLTSATCOM project).

- Costs estimated in constant 1982 dollars, without including ICOM, fee or economic price adjustment (EPA) to the actual period of performance.

- A separate WBS element for satellite integration and test, exclusive of payload associated costs, has been added within WBS element B (Flight Equipment).

- Program sharing of ground support equipment is assumed on the basis of planned launch schedule compatibility so no cost is included for duplicating existing FLTSATCOM GSE.

- Integration and test software for the basic FLTSATCOM is assumed to be unchanged so no cost is included for software.

Figure 6-1. Key Groundrules for TOPEX Budgetary and Planning Cost Estimates

JPL WBS Element	Estimated Cost (M$)
A. Management	2
B. Flight Equipment	
i. Structures (including thermal)	4
ii. Telecommunications	2
iii. Electrical Power	13
iv. Propulsion	4
v. Guidance and Control	8
vi. Airborne Support Equipment*	0
vii. Integration and Test (not including payload)	5
C. Ground Support Equipment*	0
D. Software*	0
Total (without ICOM, fee or EPA)	38

* Refer to Figure 6-1 for assumptions related to these WBS elements

Figure 6-2. TOPEX Budgetary and Planning Cost Estimates (constant 1982 dollars)

APPENDIX A

TOPEX REQUIREMENTS

The major requirements of the TOPEX mission are excerpted from Exhibit 1 of the Statement of Work for Contract No. 956199 as follows:

- III. Mission Options (from page 2 of Exhibit 1)
- Tables 1 to 5:

    TOPEX Options Satellite Mission Characteristics

    TOPEX Payload Support Requirements

    Command Unit Performance

    TOPEX Data Formats

    TOPEX Telecommunications Data Rates

In addition, summaries of the payload mass and power requirements are prepared:

- TOPEX Payload Mass Requirements (Table A-1)
- TOPEX Payload Power Requirements (Table A-2)

III. MISSION OPTIONS

Three potential options have been identified for TOPEX. All of the options share the following characteristics:

- Three-year mission with two-year extended mission option.
- Ten-day repeat circular orbit at 63.4° repeating within one kilometer.
- Orbit eccentricity <0.001.
- Shuttle launch from WSMC to 150 n.mi. with 63.4° inclination. or Delta Launch from WSMC to the observational orbit with 63.4° inclination.
- Payload Operations Control Center (POCC) and support at JPL.
- Telecommunications and operational orbit determination via TDRSS.
- Altitude measurement within 2 cm.
- Time tag resolution less than 4 μs with rollover >8 years.
- FY84 Project Start - late 1987 launch.

The different options are further characterized as shown in Table 1.

III. Mission Options (from page 2 of Exhibit 1)

	Option 1	Option 2	Option 3
Payload	TOPEX dual freq altimeter TOPEX 2-channel radiometer Laser retroreflector TRANET II	Improved SEASAT alt Same Same Same	TOPEX Ku-band altimeter Same Laser calibration target Same SERIES GPS receiver
Tracking	Laser prime TRANET II backup	TRANET II prime Laser backup	SERIES prime TRANET II backup
Mission	1334 km orbit (nominal) >30 days avg between maneuvers	1000 km orbit (nominal) $\geq$20 days avg between maneuvers	800 km orbit (nominal) $\geq$10 days avg between maneuvers
Configuration	Area/mass $\leq 0.01\ m^2/kg$	Area/mass $\leq 0.02\ m^2/kg$	Area/mass $\leq 0.02\ m^2/kg$

Table 1. TOPEX Satellite Mission Characteristics

PARAMETER		OPTION 1	OPTION 2	OPTION 3
Altimeter				
Mass and Volume:	Signal processor	31 kg, 0.044 cu.m.	24 kg, 0.088 cu.m.	31 kg, 0.044 cu.m.
	RF (less ant)	59.5 kg, 0.252 cu.m.	48 kg, 0.152 cu.m.	59.5 kg, 0.252 cu.m.
	Cabling	3.5 kg	2 kg	3.5 kg
Power Demand		199 W, 24-32 VDC	120 W, 24-32 VDC	120 W, 24-32 VDC
Timing Signal		5 MHz (0.8 V p-p)	5 MHz (0.8 V p-p)	5 MHz (0.8 V p-p)
Commands:	Relay	20 at 1 per sec. 100 ms duration 20-32 V amplitude	20 at 1 per sec 100 ms duration 20-32 V amplitude	20 at 1 per sec. 100 ms duration 20-32 V amplitude
	Data	16 bit parallel, 1 kbps 20 ms (enable), 50 ms data TTL compatible	10 bit parallel, (TBD) kbps 20 ms (enable), 50 ms data TTL compatible	16 bit parallel, 1 kbps 20 ms (enable), 50 ms (data) TTL compatible
Data Outputs:	Rates	8 bit, 7496 (Ops) or 13920 (Calib) Bps	8 bit, 7496 (Ops) or 13920 (Calib) Bps	8 bit, 7496 (Ops) or 13920 (Calib) Bps
	Chirp Modulator	Linear FM	Linear FM	Linear FM
	Center Freq.	13.7 GHz (main), 5.45 GHz (Iono.)	13.5 GHz	13.7 GHz
	Bandwidth	2.34 to 600 MHz	320 MHz	2.34 to 600 MHz
Antenna:	Type	2 m., parabolic	1 m., parabolic	1 m., parabolic
	Pointing Control	Nadir centered within 0.15°	Nadir centered within 0.25°	Nadir centered within 0.25°
	Knowledge	Within 0.05°	Within 0.10°	Within 0.10°
Thermal Control:	Operating	0 to 35°C	0 to 35°C	0 to 35°C
	Non-operating	-20°C to +60°C	-20°C to +60°C	-20°C to +60°C

Table 2. TOPEX Payload Support Requirements

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PARAMETER		OPTION 1	OPTION 2	OPTION 3
Radiometer				
Mass and Volume:	Instrument Antenna/Feed	14kg, (TBD) cu.m. 4.5kg, 50 cm. hyperb.	14kg, (TBD) cu.m. 4.5kg, 50 cm hyperb.	14kg, (TBD) cu.m. 4.5kg, 50 cm hyperb.
Power Demand		20 w, 24-32 VDC	20 W, 24-32 VDC	20 w, 24-32 VDC
Timing Signal		5 MHz	5 MHz	5 MHz
Commands		Relay closure	Relay closure	Relay closure
Data Outputs		16 bits, (TBD) and 100 bps 20.3 and 31.4 GHz	16 bits, (TBD) and 100 bps 20.3 and 31.4 GHz	16 bits, (TBD) and 100 bps 20.3 and 31.4 GHz
Calibration:	Cold source Pointing Warm source	Skyhorn, UVI covered Normal to sun line Internal	Skyhorn, UVI covered Normal to sunline Internal	Skyhorn, UVI covered Normal to sunline Internal
Antenna:	Type Pointing*	50 cm. offset hyperb. Alt. boresight within 0.25°	50 cm. offset hyperb. Alt. boresight within 0.25	50 cm. offset hyperb. Alt. boresight within 0.25°
	FOV (half angle)	10° conical	10° conical	10° conical
Thermal Control:	Operating Non-operating	15-35°C > 15°C	15-35°C > 15°C	15-35°C > 15°C
Radio Metric Tracking				
Mass and Volume		53 kg, (TBD) cu.m.	53 kg, (TBD) cu.m.	83 kg, (TBD) cu.m.
Power Demand		40 w, 24-32 VDC	40 w, 24-32 VDC	60 w, 24-32 VDC
Timing Signal		Self contained	Self contained	Self contained
Commands		Relay closures	Relay closures	Relay closures
Data Output:	Rates	50 bps (housekeeping)	50 bps (housekeeping)	750 bps (housekeeping/data)

* Altimeter pulse limited footprint must lie entirely within radiometer footprint

Table 2. TOPEX Payload Support Requirements (cont'd)

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PARAMETER	OPTION 1	OPTION 2	OPTION 3
Radio Metric Tracking			
Antenna Type	Double Helix	Double Helix	Omni and Double Helix
Pointing	Nadir centered within 5°	Nadir centered within 5°	Nadir centered within 5°
FOV half angle	60° Nadir centered (down)	60° Nadir centered (down)	100° (up), 60° (down) Nadir axis
Thermal Control: Electronics Op	-15 to +50°C	-15 to +50°C	-15 to +50°C
NonOp	-20 to +60°C	-20 to +60°C	-20 to +60°C
Laser Retroreflector			
Mass and Volume	25 kg, 50° apex half angle pyramid x 70 cm base	13.6 kg, Torus: d=0.100m, D=1.15m, mounted around altimeter antenna	13.6 kg, Torus: d=0.100m, D=1.15m, mounted around altimeter antenna
Data Output	Housekeeping (temp)	Housekeeping (temp)	Housekeeping (temp)
Pointing	Nadir ± (TBD)°	Nadir ± (TBD)°	Boresighted with Altimeter antenna
FOV half angle	55° conical, Nadir centered	55° conical, Nadir centered	55° conical, Nadir centered
Thermal Control: Overall	-50 to + 40°C	-50 to + 40°C	-50 to +40°C
Cross Cube Δ	< 2°C	< 2°C	< 2°C

Table 2. TOPEX Payload Support Requirements (cont'd)

Function	Value
Command data rate	1 kb/s uplink
Real time command execution rate	1 per second
Command storage capacity	At least 512 commands
Stored command time resolution	1 second
Rollover	6 days

Table 3. Command Unit Performance

Data Format	Content	Mission Phase	Data Rate (kb/s)	Playback (kb/s) Low Rate	Playback (kb/s) High Rate
Launch & Ascent (L&A)	S/C and PM high rate engineering data. May be recorded for low rate playback.	Launch, STS Orbit, Ascent, Orbit Insertion	6	48	N/A
Orbit Adjust (OA)	Satellite high rate engineering data.	Orbit Maneuver	6	48	N/A
Housekeeping (HKPG)	Real time monitor during TDRSS access and for command verification. Low rate engineering, memory readout and selected sensor data. On TDRSS I channel except during orbit adjust or STS launch.	On Orbit	≤2	N/A	N/A
Waveform Sample (WFS)	Global altimetry data. Height , partial waveform other sensor & low rate engineering data.	On Orbit	8	48	480
Waveform Burst (WFB)	High rate sampling of height and waveform data.	On Orbit	15	N/A	480

Table 4. TOPEX Data Formats

	High Rate (kb/s)	Low Rate (kb/s)
Downlink		
TDRSS Q-channel	480	48
TDRSS I-channel	2	2
Ground Direct Q-channel	480	N/A
Ground Direct I-channel	2	N/A
Uplink		
TDRSS Command Channel	1	N/A

Table 5. TOPEX Telecommunications Data Rates

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TRW

TRW 40180.000
P241.4.82.14-3152
7 May 1982

California Institute of Technology
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Attention: Mr. Stephen P. Dombrowski
Senior Contract Negotiator

Subject: Contract No. 956199, Request for
Engineering Support
TOPEX Satellite Option Study

Reference: (1) S. P. Dombrowski, JPL, letter to G. M. Grujich, TRW, dated 28 April 1982.

(2) TRW Final Report, TOPEX Satellite Option Study, submitted to JPL on 12 March 1982.

In response to the reference (1) letter, TRW provides its answers to the JPL questions pertaining to the reference (2) Final Report.

The answers are based on four sources, cited in the Introduction, in addition to the reference (2) Final Report. It should be understood, however, that some of the questions posed by JPL were addressing TOPEX mission-unique requirements which were not the subject of the current study phase. In order to answer those questions, it would be necessary that JPL expand the study effort under the contract.

Should you require further technical clarifications, please address them to Dr. W. Dixon or Dr. R. Schilling who can be respectively reached at AC 213, 536-2222 or 535-5044. All contractual questions or correspondence should be addressed to the undersigned at AC 213, 535-6441 or Mail Station R5/1220.

TRW Inc.

G. M. Grujich

G. M. Grujich
Contracts Management
Space and Technology Group

GMG:clm

Attachment: As stated

cc: R. A. Neilson
JPL Technical Manager

TRW RESPONSE TO JPL QUESTIONS ON USE OF FLTSATCOM SPACECRAFT FOR TOPEX

INTRODUCTION

TRW provided its final report under the TOPEX Satellite Option Study contract on 12 March 1982. JPL responded to it on 28 April 1982 with questions seeking clarification and/or supplemental data.

The TRW answers, which follow, are based on the following sources in addition to the stated final report:

a. The FLTSATCOM Attitude and Velocity Control System, H. L. Mork, August 22, 1975.

b. Fleet Satellite Communications Spacecraft, TRW, June 1976.

c. FLTSATCOM System Effectiveness Program Plan, TRW, January 3, 1977.

d. Environmental Specification for FLTSATCOM, TRW, December 19, 1975.

Copies of the preceding four documents are enclosed since they provide background data in greater detail than the answers to specific questions.

Please note that the work statement requirements of the study focussed only on the identification and description of existing spacecraft designs. Consequently, only top level concepts for TOPEX-required modifications and unique hardware have been developed at this time. Thus, some of the questions posed by JPL, which address TOPEX mission-unique requirements, cannot be answered at this time since they require additional TOPEX-specific design study effort.

Also, please note that each TRW answer immediately follows the corresponding JPL question. The Q/A pairs are grouped by topic and sequentially ordered to match the list of questions received from JPL.

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SYSTEMS ENGINEERING

Q1. The cost basis appears to exclude the following items: new telecommunications subsystem, new command and data handling subsystem, modifications to the attitude control subsystem, new tape recorder, payload integration and thermal integration. Please comment.

A1. The cost basis does exclude the items listed in this question. This is one of the groundrules in Figure 6-1 of the TRW final report (page 6-2): Modifications or additions to any subsystem other than propulsion that may be required to meet TOPEX-unique mission requirements are not included in the cost estimate.

ATTITUDE DETERMINATION AND CONTROL

Q1. IRU parameters and thruster cutoff strategy to achieve the necessary ΔV accuracy are not defined. Please clarify.

A1. This strategy would be developed as part of the detail design of the modifications to the existing FLTSATCOM AVCS. See Reference "a" for additional detail on the existing subsystem design.

Q2. Describe the satellite nadir pointing concept; its hardware implementation; and the effects of gravity gradient, drag and solar pressure on hardware sizing.

A2. The on-orbit pointing control provided by the existing FLTSATCOM AVCS is described in Section V of Reference "a" (pages 7-10) and the hardware implementation in Section VI (page 10). Determination of the effects listed in the question for the TOPEX altitudes would be part of the detail design of the AVCS modifications.

Q3. Describe the solar array pointing concept, its hardware implementation, and the effects of that approach on satellite area to mass ratio.

A3. The concept and hardware implementation for the solar array drive assemblies are described in Section VI of Reference "a" (Page 10). The area to mass ratio effect is given in Section 5.3.3 of the TRW final report (page 5-5).

Q4. Describe the TDRS pointing concept, its hardware implementation and the satellite-imposed location and pointing constraints.

A4. This concept and hardware implementation would be developed as part of the detail design of the AVCS modifications.

Q5. Describe the orbit correction maneuver concept and its hardware implementation to satisfy TOPEX requirements.

A5. The concept and hardware implementation would be developed as part of the detail design of the AVCS modifications.

COMMAND AND DATA HANDLING

Hardware implementation of the C&DH is omitted. Please clarify sufficiently to answer the following questions:

Q1. Will the C&DH satisfy requirements stated in JPL Report 1633-1, the TOPEX Phase A Report?

Q2. What data storage approach is anticipated for TOPEX: what is its hardware implementation; what is the system design and hardware heritage; and what is the data storage capacity?

Q3. Will the data storage solution satisfy requirements stated in TOPEX Phase A Report?

Q4. How is the electronics protected from the radiation environment at 1000 and 1334 km altitude?

A1. through A4. The design and hardware implementation of the C&DH subsystem would not be based on existing FLTSATCOM equipment and thus would be the subject of a new subsystem design activity.

COMMUNICATIONS

Q1. Will TDRS Multiple Access or Single Access be used? Which frequencies?

Q2. Please provide link analysis for low and high rate communications with TDRS. What link margins will be available.

A1. and A2. The design and hardware implementation of the communications subsystem would not be based on existing FLTSATCOM equipment and thus these topics would be the subject of a TOPEX subsystem design activity.

COMMUNICATIONS - Continued

Q3. How is the helix (Option 2) pointed? What is the predicted pointing error? How long a period is ±15°? Long enough to playback the tape recorder?

A3. Under Option 2a, Section 5.2.2 of the TRW final report, helix steering would be by a method not yet determined. Open loop (controlled by a program stored on-board the spacecraft) and closed loop (homing on a signal received from TDRS) are candidates.

Under Option 2b, the helix would be zenith pointing, fixed to the TOPEX bus. Assuming communication to be possible when TDRS is within ±15° of the zenith, the duration of communications depends on the mission option and the actual phasing of sub-TOPEX paths with the sub-TDRS point. For mission option No. 1, the longest communication time (corresponding to coinciding sub-orbital points) is ~7.7 minutes. On rare occasions, with bracketing misses of the sub-TDRS point by the TOPEX, communication time would just shrink to zero. Considering the four times each day that this geometry is met, communications visibility will total 30.8 minutes per day maximum, or 24.2 minutes per day average. Tape recorder playback rates have not been investigated, and the amount of data to be returned via the 480 kb/s link has not been specified, so we have reached no conclusion as to tape recorder adequacy.

Q4. How is gross antenna blockage and RFI managed?

A4. On the envisioned TOPEX satellite configuration, Fig. 3.1.5 of the TRW final report, "gross antenna blockage" is avoided by having no antenna intrude into the field of view of any other spacecraft or experiment antenna. Nor does any other component intrude into the field of view of any antenna, with the possible exception that the solar array at certain clock angles might conflict with the zenith-directed omni. Details for the resolution of possible conflict has not been worked out. RFI for TOPEX was not addressed in the study.

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COMMUNICATIONS - Continued

Q5. How is power converted and regulated?

Q6. Does integration or size of the new telecom subsystem present any problems?

Q7. What is the telecom subsystem power profile? Will one receiver be on at all times?

Q8. Is the 40W amplifier a TWT or an SSA?

Q9. Is the 40W amplifier a single unit or is it two amplifiers coupled? If coupled, what interface problems are there?

Q10. Is an antenna available for communication during ascent?

Q11. How much power is required for TOPEX ground communications? How is the power cut back from 40W?

Q12. Which antenna is used for commanding TOPEX via TDRS? What is the margin?

Q13. What is the telecom subsystem parts heritage?

A5. through A.13. The design and hardware implementation of the communications subsystem would not be based on existing FLTSATCOM equipment and thus these topics would be the subject of a TOPEX subsystem design activity.

POWER

Q1. What is the predicted solar array degradation and contributing elements for the basic 3-year TOPEX mission and for the 5-year extended mission?

A1. The solar array output is expected to decrease by about 25% during the initial five year operation of FLTSATCOM at its synchronous location. Degradation for the TOPEX orbits would be predicted as part of the TOPEX spacecraft design activity. Figure 3.1-7 of the TRW final report (page 3-9) assumed 25% degradation of the FLTSATCOM 1 through 5 arrays and shows a sufficient margin after five years for battery charging under the worst case orbital eclipse fraction of 0.35. The FLTSATCOM 6, 7 and 8 arrays that TOPEX would use (see footnote on page 3-1 of the TRW final report) produce 10% more power than the original arrays. After five years they will supply an additional 115 watts margin, including 45° array angle effect, above the 1140 watts shown in Figure 3.1-7.

POWER - Continued

Q2. What is the breakdown of the electrical power and distribution budget (190W) of Figure 3.1-7?

A2. A detailed breakdown of the existing FLTSATCOM EPDS power budget is given on page 30 of Reference "b". A more detailed breakdown of Figure 3.1-7 for TOPEX would be developed in the TOPEX spacecraft design activity.

Q3. What is the battery reconditioning sequence of FLTSATCOM? Is the same system assumed for TOPEX?

A3. Reconditioning is initiated by ground command for all FLTSATCOM batteries during the 15 days preceding eclipse season. The charge control system provides two modes for reconditioning. Both include a slow (approximately 4 days) discharge followed by a 15 to 24 hour recharge. One mode automatically terminates at 18 ±1 volt, whereas the other mode permits discharging to a battery level of 1 volt or less.

Orbital Experience on other spacecraft programs and battery life cycle tests extending over simulated mission durations of 10 years or more show that the benefits of reconditioning are greatly increased by discharging to near zero voltage and that is the mode preferred for normal FLTSATCOM operation.

In either case, however, the ground operations are much the same and begin with disconnecting the battery to be reconditioned from the system and placing it in the discharge mode selected for use. The battery voltage and current may, but need not be, monitored during automatic discharge since the on-board charge control system automatically terminates the discharge at the proper level. Subsequent recharge is performed under automatic control regardless of the discharge mode used.

The discharge circuit includes two separate channels. One channel provides the discharge with automatic stop at 18 volts while the second channel automatically stops at a preselected lower level. If both channels are used simultaneously for the reconditioning process, the discharge time will be reduced by a factor of two. However, in this case, the reconditioning discharge automatically terminates at the 18 volt level.

This existing FLTSATCOM hardware implementation could be used for TOPEX. Suitable change would be made in the operational profile of the reconditioning process to account for the more frequent eclipse cycling of TOPEX.

POWER - Continued

Q4. How is redundant switching accomplished (e.g., ground command, on-board logic)?

A4. Redundant switching is accomplished throughout the FLTSATCOM spacecraft by use of 131 ground commands (see table at bottom of page 20, Reference "b").

Q5. How are energy storage, distribution and switching accomplished to initiate pyro devices?

A5. Except for the batteries, no energy storage devices (e.g., capacitor banks) are used to initiate pyro devices. Each pyro device is operated by a dedicated transistor switch controlled by an arm/safe relay in the load path and an ordnance fire relay controlling the transistor base circuit.

Q6. What is the estimated range of battery depth of discharge?

A6. The range of battery depth of discharge for FLTSATCOM at its synchronous location is 70% to 75%. No estimate was prepared for the TOPEX orbits.

Q7. What are the key technical problems in meeting Shuttle safety requirements for power and pyro electronics?

A7. Specific concepts for meeting STS safety requirements would be developed in the TOPEX spacecraft design activity.

PROPULSION

Q1. What satellite mass is assumed for TOPEX?

A1. The mass of the TOPEX satellite at launch was estimated to be approximately 2671 lbm (see Figure 3.1-6 of the TRW final report, page 3-8, for more detail).

Q2. Please supplement the mass detail in the attached equipment list.

A2. More detailed subsystem weight breakdowns for the existing FLTSATCOM are given in Reference "b" (total system on page 8, AVCS on page 26, EPDS on page 30, RCS on page 33 and structure on page 38). The TOPEX weight estimates were not developed in greater detail than shown in Figure 3.1-6 of the TRW final report, page 3-8.

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CONFIGURATION/MECHANICAL

Q1. What is the TOPEX payload configuration in FLTSATCOM?

A1. A concept for the configuration of the external TOPEX payload elements is shown in Figure 3.1-5 of the TRW final report, page 3-6. The internal electronics housings would mount on the honeycomb panels of the payload module replacing the existing FLTSATCOM payload which is mounted as shown on pages 6 and 11 of reference "b".

Q2. How will the FLTSATCOM structure be impacted by Shuttle launch loads (as opposed to the more benign Atlas Centaur loads)?

A2. Specific impact of the STS launch environment, if any, would be determined during TOPEX detail design. However, the Atlas-Centaur qualification environments (see Section 4.1 and 4.2 of Reference "d") exceed the corresponding environments predicted for STS launch.

Q3. What mechanical ASE is required for integration with the Shuttle? Cost?

A3. A number of existing cradle and pallet designs are available for use as mechanical ASE for TOPEX (see Section 4.3 of the TRW final report, page 4-1 for examples). Selection of a specific unit would be part of the detail design activity.

Q4. What additional mechanical equipment is required to integrate the TOPEX payload into FLTSATCOM (e.g., structure, temperature control, devices, cabling)?

A4. The TOPEX payload would require a new wiring harness for integration with the FLTSATCOM payload module. Identification of mounting bracket requirements, if any, would be a detail design activity.

Q5. What are cabling weights accounted in the mass summary?

A5. Cable weights were not separately estimated for the TOPEX. The EPDS harness assembly in the existing FLTSATCOM weighs a total of 160 lbs.

Q6. What is the Shuttle launch weight (including ASE)?

A6. The launch weight of TOPEX, including adapter, was estimated to be approximately 2791 lbm (see Figure 3.1-6 of the TRW final report, page 3-8, for more detail).

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COST AND PROGRAMMATIC

Q1. What qualification is assumed in the cost and availability estimates? Any TOPEX unique test or analysis? Analogy to FLTSATCOM?

A1. The cost estimate assumes the existing FLTSATCOM qualification program, described in Sections 4.1 and 4.2 of Reference "d", is applicable to TOPEX. Any additional payload or STS imposed qualification requirements were not included.

Q2. Would the TOPEX payload be expected to meet the satellite at a standard interface or would individual sensors be interfaced with the bus?

A2. The payload interface concept would be the subject of a detailed trade-off study to identify the optimum approach.

Q3. What is the hardware base for the FLTSATCOM GSE: Please comment on the feasibility of its use (hardware and/or software) in a POCC environment for flight operations.

A3. FLTSATCOM Units 1 through 5 utilized an IBM 1800 based system for telemetry processing. An upgrade of that computer system is planned for FLTSATCOM 6 through 8. Uplink and downlink is based on Space/Ground-Link Systems (SGLS) communications. The remaining GSE (e.g., for attitude control, power test etc.) uses standard hardware. Requirements for operation in a POCC environment have not been established.

Q4. Are there any TOPEX unique requirements which, if relaxed, would significantly lower the cost?

A4. FLTSATCOM currently meets the 0.25° pointing requirement of payload options 2 and 3 but not the 0.15° requirement of option 1. The ability to meet 0.15° has not been determined, and thus this tighter requirement for Option 1 could have a cost effect.

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RELIABILITY/QUALITY

All Reliability, PM&P and Quality Assurance aspects of the FLTSATCOM program are controlled by Reference "c", the "FLTSATCOM System Effectiveness Program Plan," specifically Part 2. Reliability; Part 3. Parts, Materials and Processes; and Part 4. Quality Assurance Plan.

Q1. What formal reliability program was in place for FLTSATCOM? To what specifications?

A1. The FLTSATCOM reliability program is specified by Part 2 of Reference "c".

Q2. What was the single point failure policy for the design?

A2. The single-point failure policy is described in Part 2, Section 5.2.3 of Reference "c", page 2-21.

Q3. Does each design comply with current Shuttle safety requirements (such as fracture mechanics)?

A3. The FLTSATCOM design has not been subjected to a rigorous assessment of compliance with STS safety requirements.

Q4. What electronic parts screening program was in place? To what specification?

A4. The FLTSATCOM parts screening program is specified by Part 3, Section 5.5.4 of Reference "c", page 3-36.

Q5. What materials and process control program was in place? To what specification?

A5. The FLTSATCOM materials and process control program is specified by Part 3, of Reference "c".

Q6. Is formal documentation available to support hardware qualifications?

A6. Formal documentation supporting the FLTSATCOM qualification would be available for a TOPEX project.

Q7. What formal quality assurance program was in place? To what specificattions?

A7. The FLTSATCOM quality assurance program is specified by Part 4 of Reference "c".

Q8. How will payload mechanical alignments be made and verified?

A8. The concept for meeting payload mechanical alignment requirements would be developed as part of the design activity. The present FLTSATCOM alignment is consistent with the 0.25° pointing control.

RELIABILITY/QUALITY - Continued

Q9. Will the payload temperature controls be satisfied?

A9. Thermal accommodation of the payload would be part of the detail design activity. However, the TOPEX payload power dissipation is less than the FLTSATCOM payload and it is expected that the existing FLTSATCOM thermal design concept, utilizing tailored passive radiators combined with distributed active, thermostatically controlled heaters, can accommodate the TOPEX payload requirements.