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On-Orbit Checkout of Satellites
Final Report

Volume II
(Part 3 of On-Orbit Checkout Study)

Prepared by

Advanced Mission Analysis Directorate
Advanced Orbital Systems Division

15 May 1978

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.

Contract No. NASW-3099

Systems Engineering Operations
THE AEROSPACE CORPORATION

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STUDY BACKGROUND

- STUDY OBJECTIVES
  - / COMPARE ON-ORBIT CHECKOUT OPTIONS
  - / DESCRIBE THE BEST OPTIONS

- STUDY CHRONOLOGY
  - / FIRST STUDY (FY 76), CHECKOUT OF TECHNOLOGY DEMONSTRATION SATELLITE, STORMSAT, SMS/GOES
  - / SECOND STUDY (TRANSITION PERIOD), CHECKOUT OF LANDSAT AND ATREX
  - / THIRD STUDY (FY 77), DESCRIBE OPTIONS, SELECT BEST OPTIONS, AND DESCRIBE ON-ORBIT CHECKOUT TESTS TO SATELLITES STUDIED

EXAMPLE SATELLITES STUDIED

2

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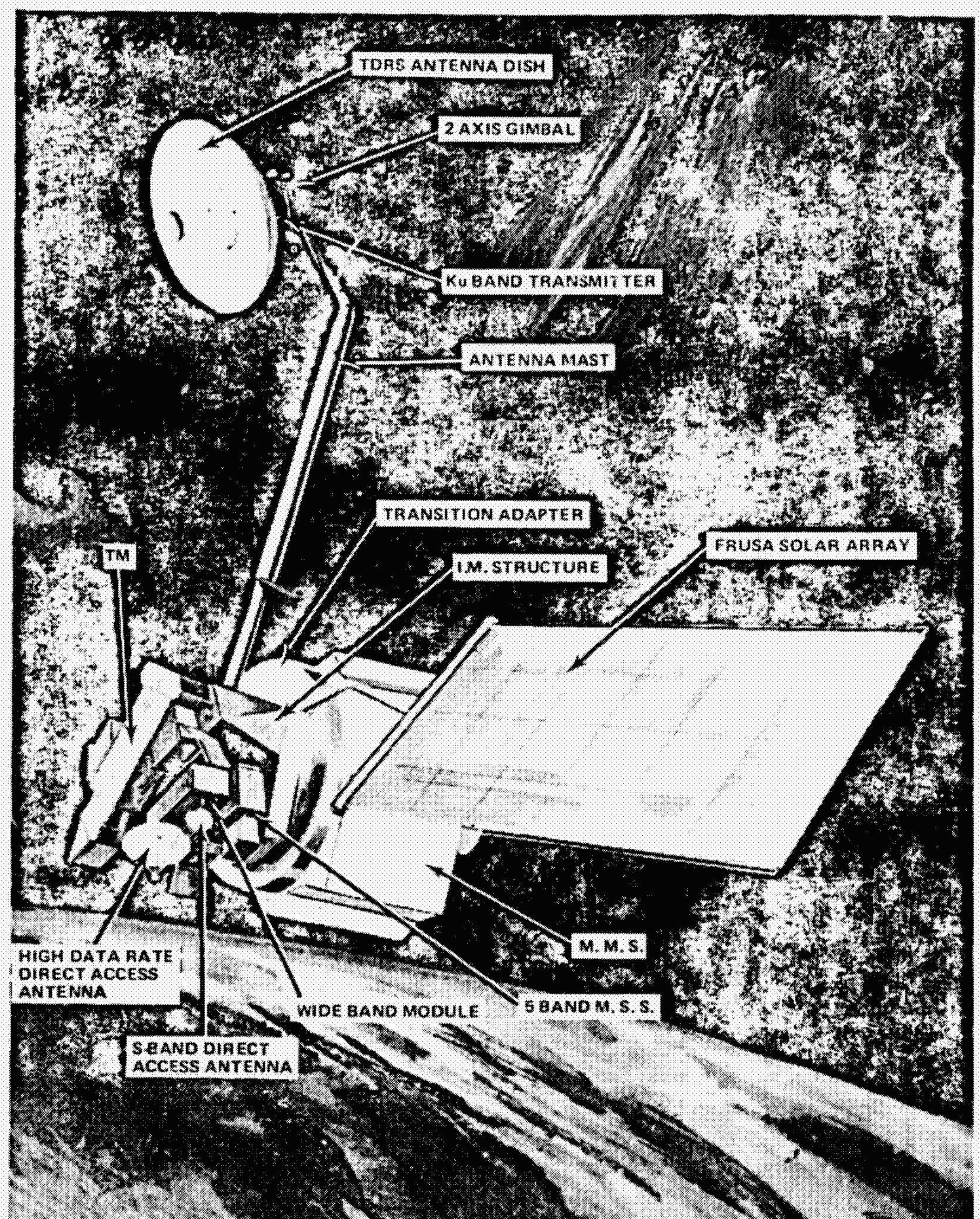
OPTIONAL BASELINE LANDSAT-D



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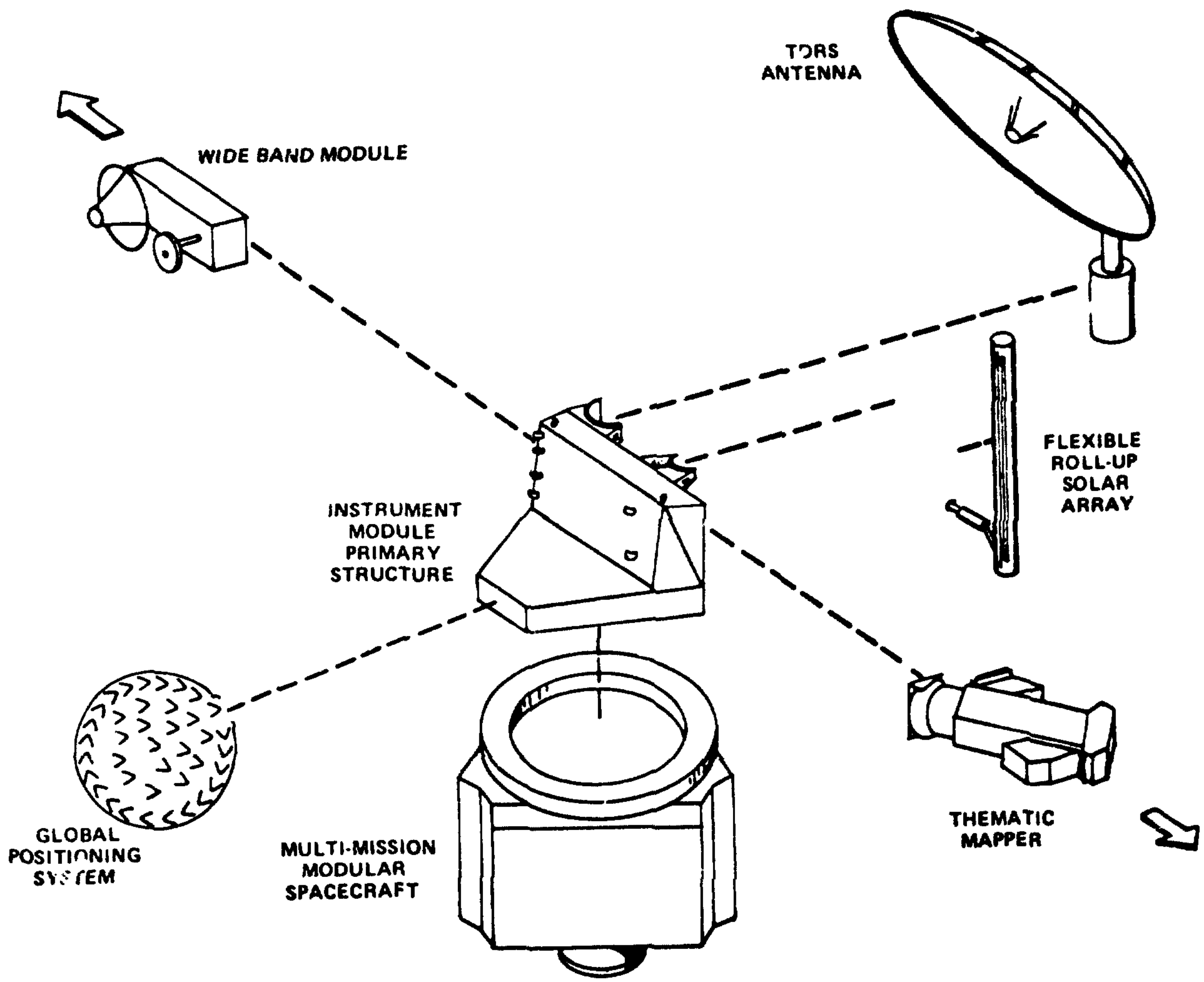
LANDSAT-D COMPONENT BREAKAWAY SCHEMATIC



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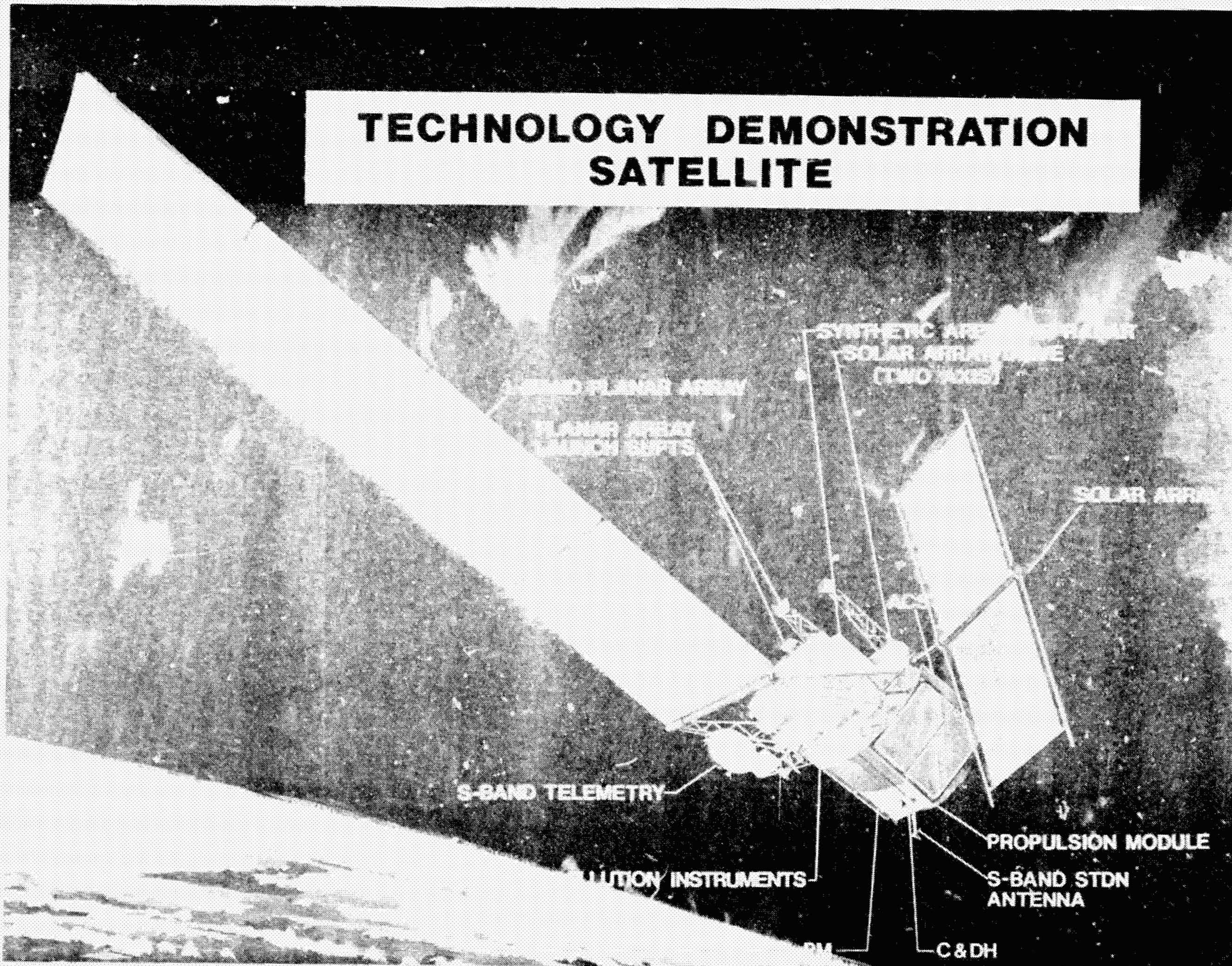
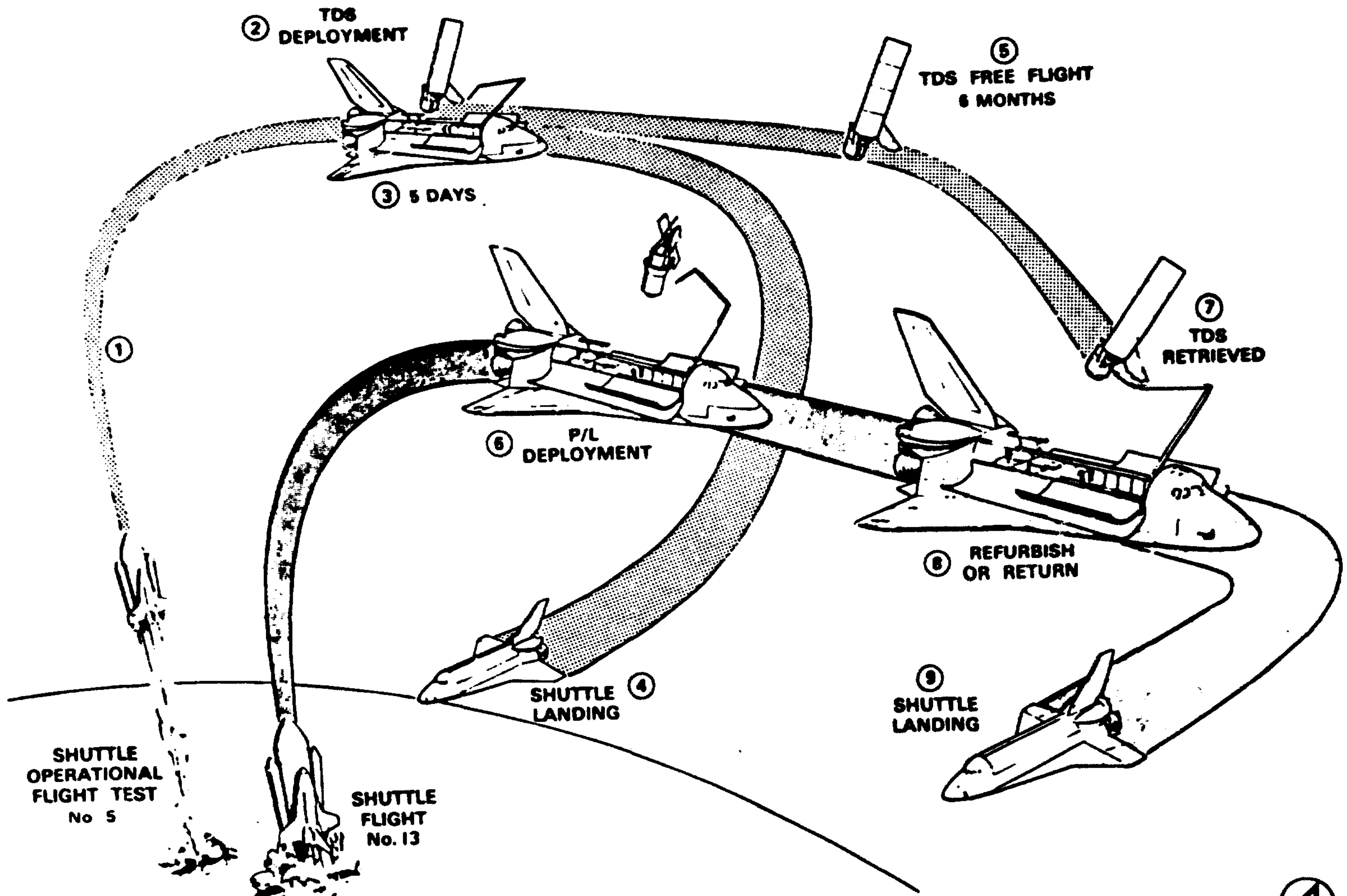
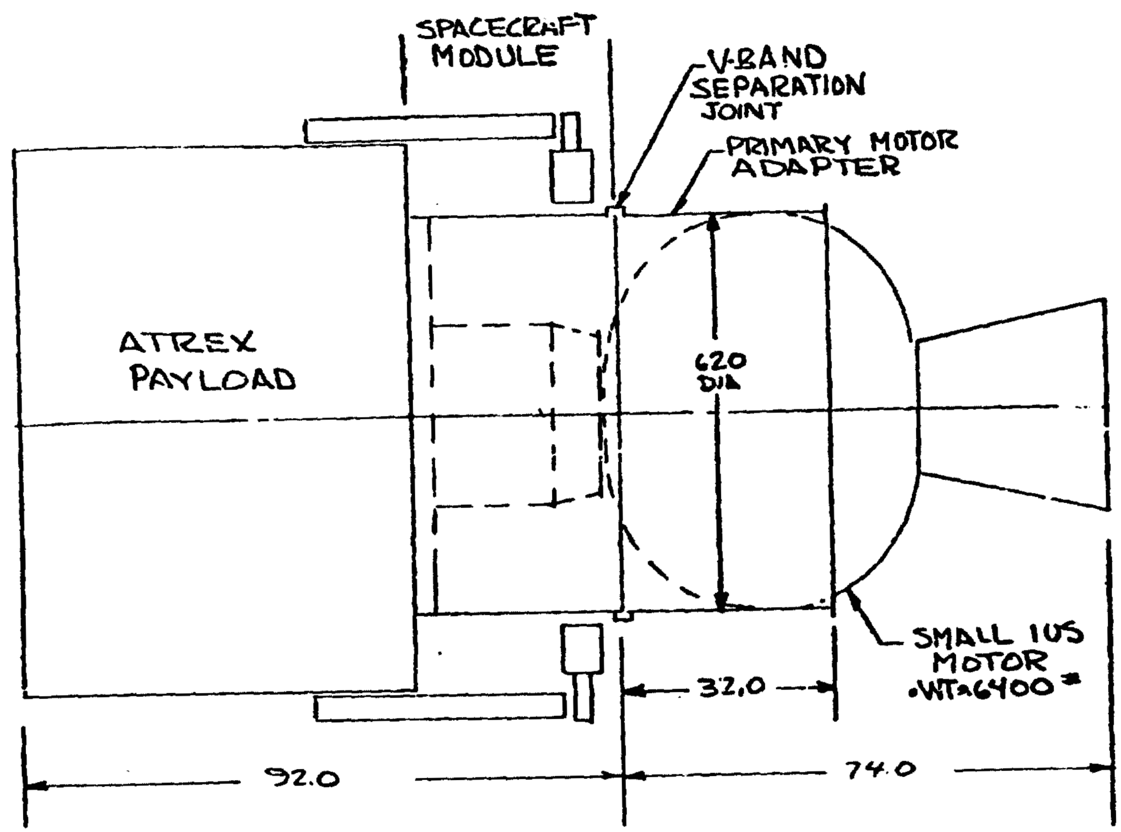

TECHNOLOGY DEMONSTRATION
SATELLITE
SOLAR ARRAY
S-BAND TELEMETRY
PROPULSION MODULE
S-BAND STDN
ANTENNA
C & DH

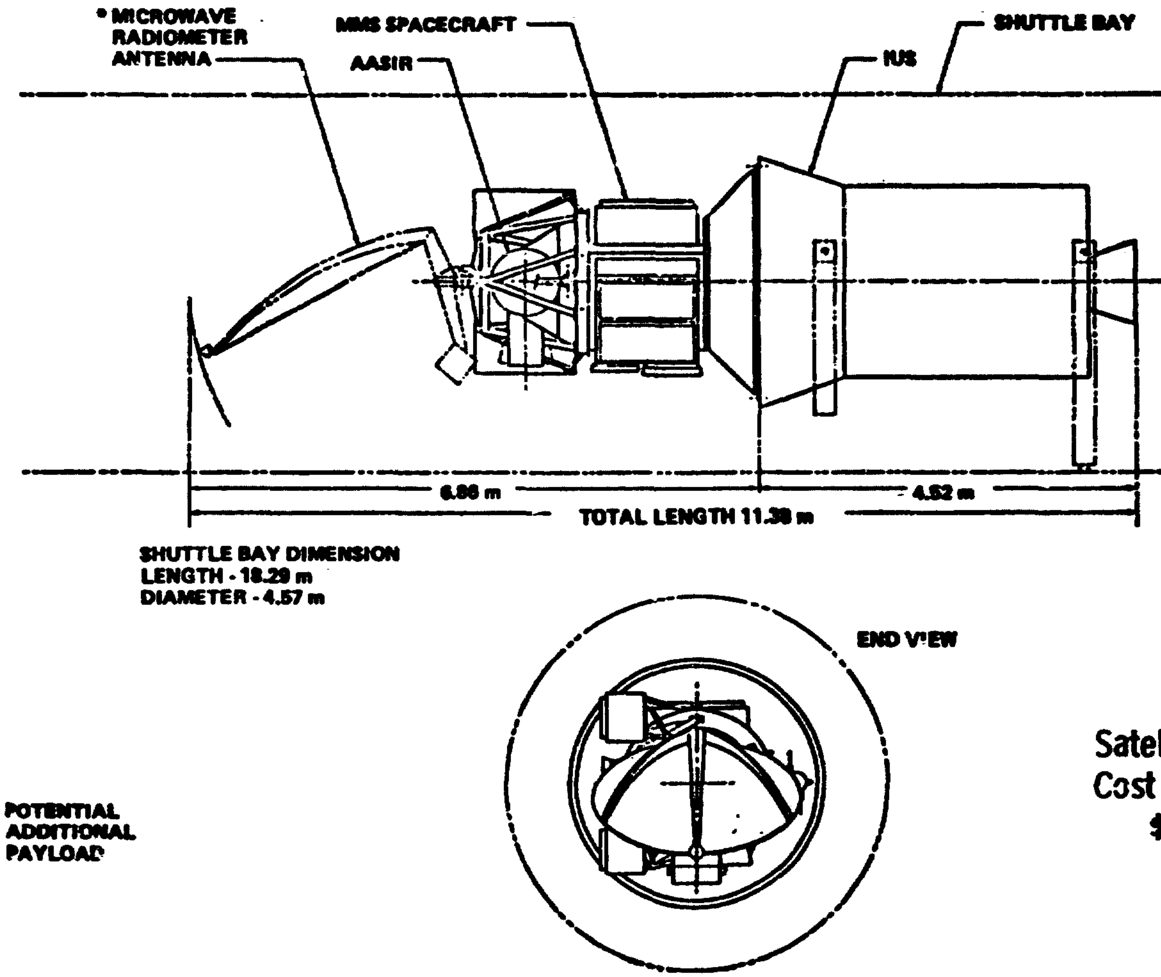
TDS MISSION PROFILE



ATREX/AEM SPACECRAFT AND SMALL IUS MOTOR PROPULSION MODULE



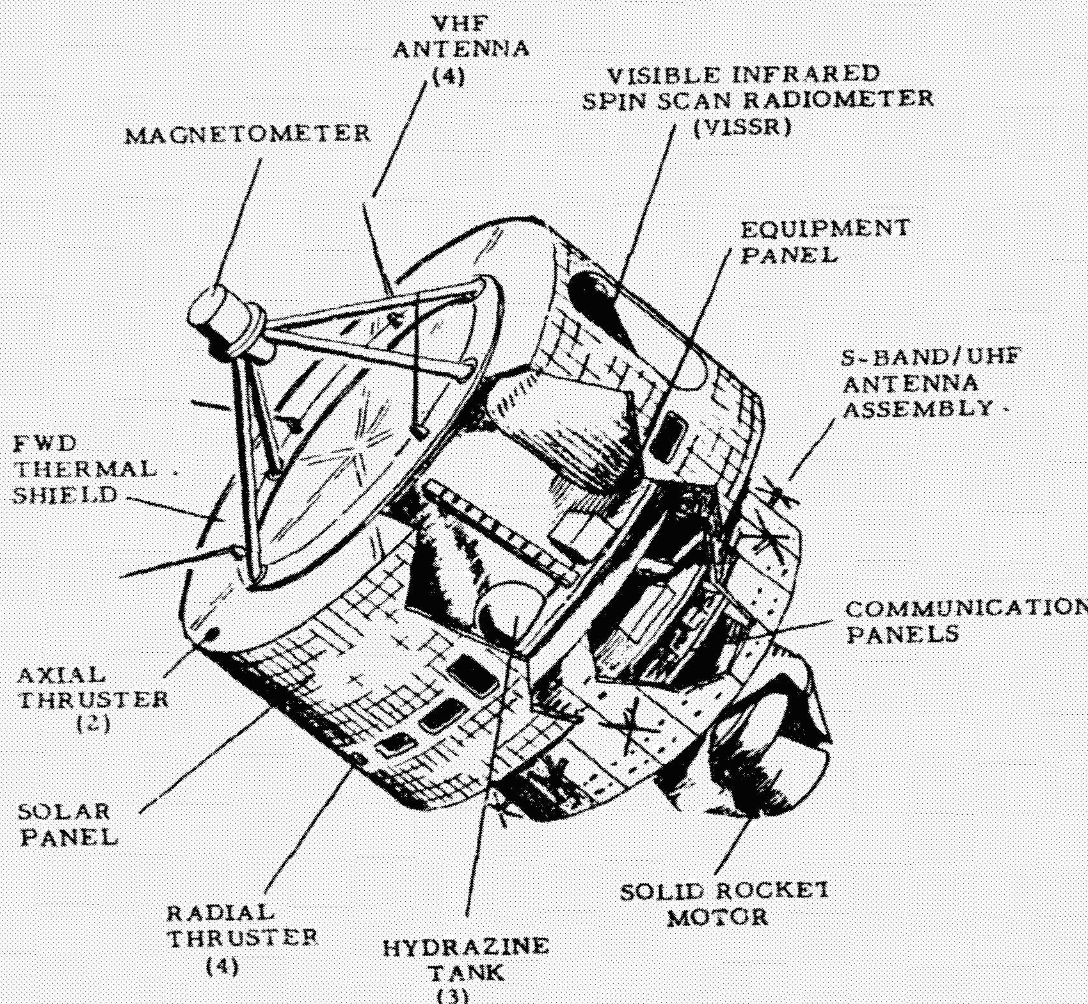
STORMSAT IN LAUNCH CONFIGURATION



* POTENTIAL ADDITIONAL PAYLOAD

Satellite Unit Cost Estimate $23M

SYNCHRONOUS METEOROLOGICAL SATELLITE (SMS)



CHARACTERISTICS

DIAMETER (MAX)	-	6 FT
HT. (OVERALL)	-	11.3 FT
WT. (LIFTOFF)	-	1379 LB
POWER (BOL)	-	200 WATTS
DESIGN LIFE	-	5 YEARS
ORBIT	-	SYNCHRONOUS EQUATORIAL

GROSS EARLY FAILURES ON SATELLITES

HISTORICAL DATA

EARLY SPACECRAFT FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION

Day Of Occur.	Anomaly	Cause	Mission Impact And Corrective Action	Traceable To:	Origin.	Program
1	Earth sensor data not producing credible or consistent attitude fits.	Spurious readings appear in time ranges associated with illumination and darkening of solar panel.	Use sun sensor magnetometer data for attitude determination in interim -- Sun shield added on S3-2. Major	Hardware (SC)	Design	53-1 (73-5)
1	Antenna B failed to fully deploy.		Use Antenna A. Mission compromised - Major	Hardware (TTC)	Design or Wkmsp	S3-3 (S74-2)
1	Mode 6 divergent	(Class) Design change on next vehicle.	Plenum pumped to above normal pressure by ground. CMD - Major	Hardware	Design	DSP Ph 1 Flt 1
2	High spacecraft compartment temperature.	Inadequate radiator area. Design change on next flight.	Restricted operation of selected equipment to reduce internal power dissipation. Major	Hardware	Design	DSP Ph 1 Flt 1
3	High level thruster freezing.	Inadequate heaters and insulation on thrusters. Additional heaters added on next launch.	Restricted operation to those times when thruster temperature $\geq 40^\circ F$. Major	Hardware (AP)	Design	DSP Ph 1 Flt 1
1	High level thruster freezing.	Inadequate heaters and insulation on thruster. Insulation and heaters added on subsequent vehicle.	Use restricted to diurnal periods when temperature is $> 40^\circ$ F. Major	Hardware (AP)	Design	DSP Ph 1 Flt 1

REFERENCE: The Aerospace Corporation Report No. ATR-78(7659)-1, Volume III, Standardization and Program Practice Analysis Final Report, Volume III, Spacecraft Data, 30 September 1977 (Analysis of 25 Flights on 12 Programs)

EARLY SPACECRAFT FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION (CONT'D)

Day Of Occur.	Anomaly	Cause	Mission Impact And Corrective Action	Traceable To:	Origin	Program
1	Unable to CMD.	Crypto box experienced difficulty in processing CMD.	Operational delay. Corrected by software procedures. Hardware, software, and system test changes on follow-on flights. Major	Hardware (TTC)	Design	DSCS-II Flight 1
1	Unable to CMD.	Crypto box experienced difficulty in processing CMD.	Operational delay. Corrected by software procedures. Hardware, software, and system test changes on follow-on flights. Major	Hardware (TTC)	Design	DSCS-II Flight 2

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EARLY SPACECRAFT FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION

MAJOR FUNCTIONAL IMPACT(1)

S/C & Anomaly Number	Date Detected S/C Hours	Failed/Affected Item	Project	Discussion of Anomaly	Action Taken
A-1	9/5/64 0	EP-1, EP-6 Spin Axis Boom	OGO	Marginal spring torque for boom deployment - prevented normal operation of ACS, omni-directional antenna, making it unusable, restricted playback of tape recorder data - orientation is spin axis fixed.	Spring redesigned; kick-off springs added on subsequent spacecraft. (Ref: Doc. No. 08174-6047-RO-000)
C-1	10/14/65 0	Attitude Control System Horizon Scanner	OGO	Horizon scanner locking on thermal gradients in earth's infrared image, caused depletion of gas supply. Fixed orientation of spin axis.	Spacecraft commanded to spin mode. Subsequent spacecraft redesigned to include new infrared filter. Bandwidth also reduced.
E-1	3/4/68 0	-Z Door Thermal Inculation	OGO	Temperature rose above expected levels (insulation degradation), excessive thermal opening.	Necessitated the operationa' cycling of four experiments located in that region.

REFERENCE: TRW Report No. 75-2286.148, Demonstrated Orbital Reliability of TRW Spacecraft, A Compilation and Analysis of the On-Orbit Reliability of TRW Spacecraft, and the Development of a New Prediction Modeling Procedure, December 1975

(1) Serious degradation of all (or most) mission functions or complete loss of a few mission functions or violation of intrinsic expectations of the project (e.g., reduction in life)

EARLY SATELLITE FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION - I

Reference: PRC Document PRC D-1864, Addendum to Reliability Data from In-Flight Spacecraft: 1958-1970

Index	Anomaly Time (Hours)	Anomalies			Corrective Action (If Known)
		Description	Cause	Mission Effect	
3	ϵ	Substantial and increasing signal degradation of filter wedge spectrometer.	Ice deposit on cooled balometer detector.	Loss of data.	New cooler design required for new applications.
10	ϵ	One of two tape recorders provided no output in playback.	Attributed to launch shock.	Loss of experiment data and operational flexibility.	

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EARLY SATELLITE FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION - II

Reference: PRC Document PR~ R-1453, "Reliability Data from In-Flight Spacecraft; 1958-1970"

Index	Anomaly Time (Hours)	Anomalies			Corrective Action (If Known)
		Description	Cause	Mission Effect	
19	ε	Transponder failed during launch.	Unknown	Complete inutility of the spacecraft.	
22	ε	Inoperable filter wedge spectrometer.	Ice deposit on cooled detector.	Loss of data.	
39	ε	Decrease in infrared interferometer spectrometer sensitivity.	Excessive bolometer & optics housing temperature as a result of earth albedo entering the optics housing.	About 40 percent of experiment data lost.	
40	ε	Intermittent and erratic transmitter operation from launch for about 3 weeks.	Frequency instability due to high voltages.	Loss of nearly half of theoretically possible experimental data.	
41	ε	Transponder degraded to 75% usefulness.	Improper adjustment to data loop due to a design deficiency.	Loss in payload utility of nearly 25%.	

EARLY SATELLITE FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION - III

Reference: PRC Document PRC R-1453, "Reliability Data from In-Flight Spacecraft; 1958-1970"

Index	Anomaly Time (Hours)	Anomalies			Corrective Action (If Known)
		Description	Cause	Mission Effect	
45	ϵ	Degradation of neon reference for the infrared interferometer spectrometer.	High radiation levels early in the mission, particularly over the So. Atlantic	Substantial experiment degradation.	
47	ϵ	Excessive spin rate subsequent to launch.	No despin mechanism provided.	Precluded receipt of useful data although spacecraft interrogated 50 times in about 6 months.	
50	ϵ	Failure of experimental transponder during launch	Unknown	Spacecraft completely unuseable.	
58	ϵ	Malfunctioning Faraday Cup experiment; abnormal response to ground commands.	Unknown	Majority of anticipated data lost from this experiment.	

EARLY SATELLITE FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION - IV

Reference: PRC Document PRC R-1453, "Reliability Data from In-Flight Spacecraft; 1958-1970"

Index	Anomaly Time (Hours)	Anomalies			Corrective Action (If Known)
		Description	Cause	Mission Effect	
84	10	The telemetry from the digital solar aspect indicator[1] gradualy decreased in pulse amplitude and disappeared.	Unknown	Loss of important engineering data.	
87	20	Spacecraft attitude stabilization attempt was unsuccessful; Vertistat booms were properly deployed but to no avail.	Basically unknown. Considered to be the result of gravity gradient, aerodynamic pressure & solar pressure "commutated" by rhythmic motion in Veristat booms, which in turn was caused by asymmetrical configuration, solar heating & spacecraft spin.	Significant degradation of data.	
96	47	One of two camer cameras indicated an inoperable shutter and a light leak.	A high current transient at camera[2] selection blew the unregulated shutter bus fuse.	Loss of capability.	

(1) The indicator operated sporadically for nearly a year.
(2) This camera was 2-1/2 years old prior to launch and the shutter had been operated about 5,000 times. Normal shutter life is claimed by the vendor to be at least 400,000 to 1,000,000 operations.

SUMMARY

EARLY SATELLITE FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATIONS

- 6 % OF SATELLITES FLOWN SUFFER GROSS EARLY FAILURE
- THERE APPEARS TO BE NO SIGNIFICANT CHANGE WITH TIME
- PROJECTED COST IN MILLIONS OF 1975 DOLLARS OF EARLY FAILURE

Project	Cost Per Payload Unit	Potential Savings ($M) For On-Orbit Checkout	
		Unit Saved	Average Flight(1)
TDS	22.0	13.4	0.80
STORMSAT + IUS	27.5	16.8	1.00
SMS + SSUS	9.0	5.5	0.33
ATREX	15.9	9.7	0.58
ATREX + SRM	35.5	21.6	1.30
LANDSAT D			

(1) If all early failures identified correctly and no false returns

EXAMPLE CASES OF INFANT MORTALITY LEADING TO ATREX SATELLITE RETURN FOR REPAIRS

(FAILURES ARE DETECTED BY ONE MEASUREMENT CONFIRMED BY ANOTHER)

- Failure to Extend
  - / Solar Arrays
  - / TDRS Antenna
- Failure to Uncover Optics of Star Tracker
- RCS Propellant/Pressurant Leakage
- Heater Failure
- Thermostat Failure
- Louvers Not Operating
- RCS Valve Malfunction
- Critical Command Circuit Open
- SRM Ignition Failure
- Antenna Switch Failure
- Diplexer Failure
- Transponder Failure
- Command Decoder Failure
- PCM Encoder Failure
- Tape Recorder and Antenna Steering Failure
- All-Sky Monitor Gross Failure
- Multiple Instrument Failures
- Electrical Power Out of Limits (Voltages, Currents)
- Star Trackers Inoperative
- Failure of a Non-Redundant Gyro Axis
- Failure of CPIU
- Failure to Transfer Orbiter Data
- Reaction Wheel Failure
- SRM TVC Actuator/Nozzle Failure
- Component Temperatures Grossly Abnormal
- Failure of Electromagnets
- Failure of Magnetometer

ON-ORBIT CHECKOUT SYSTEM LEVEL STUDIES

BACKGROUND FOR SUBSYSTEM TESTS RECOMMENDED FOR ON-ORBIT CHECKOUT

GROUND RULES

- SHUTTLE-LAUNCHED SATELLITES AND REPLACEMENT MODULES ARE ASSUMED TO HAVE BEEN CHECKED OUT PRE-LAUNCH

- VISIBILITY ON AND CONTROL OF CHECKOUT TESTING IS REQUIRED AT POCC

  / DISPLAY NUMERICAL DATA DERIVED FROM TESTS AND IDENTIFICATION INFORMATION

  / MANUAL CONTROL OF TESTS (INTERRUPT, REPEAT, STEP, SEQUENCE, ETC.

- TESTS ARE JUDGED BY EACH SUBSYSTEM SPECIALIST TO BE SUFFICIENT TO REACH THE CHECKOUT GOAL

BACKGROUND FOR SUBSYSTEM TESTS RECOMMENDED FOR ON-ORBIT CHECKOUT

TRADEOFFS

BASELINE	STUDY TRADE
Checkout goal is to identify at least 80 to 90 percent of infant mortality failures in order to maintain checkout benefits as high as possible. Check out all functions, all subsystems.	Consider cost reduction vs benefit reduction for less thorough checkout.
For satellite suffering from infant mortality failure, avoid satellite loss through inability to retrieve. Test all equipment needed to perform satellite retrieval while the payload is still attached to the orbiter.	Consider cost reduction vs benefit reduction for risking an occasional inability to retrieve. If testing all equipment is too expensive while the satellite is attached to the orbiter, consider alternative modes of retrieval and reduced testing.

FALSE ALARM PROTECTION APPROACH

- THE FALSE ALARM PROBLEM:
  - / PROTECT AGAINST CALLING A GOOD SPACECRAFT BAD AND RETURNING IT FOR REPAIR
- RECOMMENDED SOLUTION:
  - / TEST EQUIPMENT CHARACTERISTICS FOR MINIMUM FALSE ALARMS
    - SELF-CHECKING
    - HIGH RELIABILITY DESIGN
    - MAN/MACHINE INTERFACE ADEQUATE
  - / MORE THAN ONE FAILURE INDICATION THROUGH
    - BACKUP TESTS

      E. G., THRUSTER VALVE FUNCTION AFFECTS CATALYST TEMPERATURE AND SATELLITE ANGULAR RATES
    - DUAL MEASUREMENTS AND TELEMETRY PATHS

      E. G., DUAL THERMOCOUPLES AND PRESSURE TRANSDUCER ON PROPELLANT TANKS
  - / REHEARSALS OF ON-ORBIT CHECKOUT BEFORE FLIGHT
    - EXPERIENCE IN AVOIDING MISTAKES
  - / INSISTANCE ON HARD EVIDENCE OF SATELLITE FAILURE

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ON-ORBIT CHECKOUT OF INSTRUMENTS - LANDSAT D

THEMATIC MAPPER

Subsystem Element	On-Orbit Tests: For:	Measurements[1]: Primary	Measurements[1]: Backup	Payload and Test Location: Attached To Shuttle	Payload and Test Location: Standoff
Thematic Mapper	Aliveness of Sensor Channels, Bands 1-4	Response to Calibration Light	Response to Redundant Calibration Light	X	
Thematic Mapper	Aliveness of Bands 5 and 6 (Uncooled)	Electronic Signal Injection[2] Detector Bias Measurement	Detector Noise Measurement[3]	X	
Thematic Mapper[4]	Aliveness of Bands 5 and 6 and Cooldown[5]	Not Applicable[6] (Backup Test Only)	Detector Signal Full Cooldown Temperature		X
Thematic Mapper[4]	Aliveness of Bands 1-4	Quick-Look Images	Analog (Video) Signals		X
Thematic Mapper[4]	Sun Calibration	Response to Sun and to Built-In Calibration Light	Repeat Test on Another Orbit		X

(1) Data examined at Operational Control Center or experimenter's facility.
(2) If available from built-in test equipment.
(3) Feasibility needs study.
(4) Not recommended during checkout if Thematic Mapper is a serviceable module on orbit and a spare is available.
(5) Requires up to 5 days wait for outgassing to subside and then approximately 1 day for cooldown.
(6) Recommended as a backup test, only used if detector noise measurement test is either not feasible or fails.

ALTERNATIVE ON-ORBIT CHECKOUT MODES
PRIMARY ITEMS VARIED

- SPACEBORNE TEST EQUIPMENT AND INTERCONNECTIONS
- AUTOMATIC SEQUENCING BY COMPUTER IN ORBITER BAY OR ON THE GROUND IN THE PAYLOAD OPERATIONAL CONTROL CENTER
- LOCATION OF PAYLOAD DURING CHECKOUT TESTING
  - / ATTACHED TO SHUTTLE
  - / STANDING OFF FROM ORBITER
  - / COMBINATION OF THESE
- COMMAND, TELEMETRY, AND INSTRUMENT DATA R.F. LINKS
- ATTITUDE CONTROL SYSTEM TESTS WHILE ATTACHED TO ORBITER
  - / WITH AND WITHOUT TILT TABLE
  - / SATELLITE ON RMS
  - / ORBITER TO MMS INERTIAL REFERENCE UNIT MISALIGNMENT TESTS

ELAPSED TIME FOR TESTING WITH THE SATELLITE ATTACHED TO THE ORBITER

BACKGROUND INFORMATION

- TESTING WHICH IS FEASIBLE ONLY WITH THE SATELLITE ATTACHED TO THE ORBITER
  - / TESTS WHICH VERIFY THE FUNCTIONS OF SATELLITE EQUIPMENT REQUIRED FOR NORMAL PAYLOAD RETRIEVED ON RETRIEVABLE SATELLITE
    - E. G., TT&C CHECKOUT
    - E. G., CHECKOUT OF ACS EQUIPMENT REQUIRED TO STABILIZE THE SATELLITE IN A PLANNED RETRIEVAL ATTITUDE
      - EXPECTED TO REQUIRE 10 TO 20 MINUTES FOR STS PAYLOAD
  - / ALL CHECKOUT TESTS FOR A NON-RETRIEVABLE SATELLITE
    - FULL CHECKOUT WOULD REQUIRE 1 TO 3 DAYS
- TESTING WHICH MAY BE FEASIBLE ONLY WITH SATELLITE ATTACHED TO THE ORBITER
  - / E. G., "COOL" SATELLITE TESTING, EXPECTED TO REQUIRE UP TO 10 MINUTES PLUS COOL-DOWN TIME BEYOND ABOVE

ELAPSED TIME FOR TESTING WITH THE SATELLITE ATTACHED TO THE ORBITER

BACKGROUND INFORMATION (CONT'D)

- TESTING WHICH MAY BE ACCOMPLISHED WITH THE SATELLITE ATTACHED TO THE ORBITER OR STANDING OFF FROM THE ORBITER
  - / E. G., "WARM" SATELLITE TESTING
  - / ARGUMENTS FOR TESTING ATTACHED: AVOID RETRIEVAL IF EARLY FAILURE FOUND AND VERIFIED
  - / ARGUMENTS AGAINST TESTING ATTACHED:
    - SUBJECT PAYLOAD UNDER TEST TO ADDITIONAL (THERMAL) ENVIRONMENTS
    - EXTEND IN-BAY TIMELINE FOR PAYLOADS TO BE DEPLOYED SUBSEQUENT TO PAYLOAD UNDER TEST (AND HENCE SOAK TIMES AND THERMAL ENVIRONMENTS)
    - DEVOTES ADDITIONAL ORBITER TIME TO PAYLOAD UNDER TEST
- TESTING WHICH MAY BE ONLY FEASIBLE WITH SATELLITE STANDING OFF FROM ORBITER
  - / E. G., LOW ALTITUDE EARTH VIEWING HISTORICAL END-TO-END TESTS WITHOUT ARTIFICIAL STIMULI
  - / RCS OR PROPULSION THRUSTER VALVE TESTS
  - / TESTS REQUIRING EXPOSURE OF CONTAMINATION-SENSITIVE OPTICS

THERMAL CONSIDERATIONS AFFECTING TEST SEQUENCE ON ORBIT

Project	Probable Satellite Condition During Ascent	Satellite Positions Available, Payload Attached To Orbiter	Satellite Required On In Unelevated Position	Satellite Temperature When On-Orbit Checkout Is Initiated(1)	Normal Satellite Condition In Standby With All Equipment Operating(2)
Landsat	Off(3)	Horizontal, Elevated to Vertical	Yes(4)	Warm to Cool	Warm
ATREX	Off(3)	Vertical In-Bay (Not Elevated)	Yes	Warm to Cool	Warm
TDS	Off(3)	Horizontal, Elevated to Vertical	Yes(4)	Warm to Cool	Warm
Stormsat/IUS	Satellite Off(3) IUS On	Horizontal, Elevated to 60°	No	Warm	Warm
SMS(GOES)/SSUS	Satellite Off(3) SSUS Off(3)	Horizontal, Elevated	No	Warm to Cool	Warm

(1) Depends on remainder of cargo, satellite equipment on, launch conditions, time line on orbit (first out, second out, etc.).
(2) Outgassing period over.
(3) Except gyros (if required to operate during ascent), and turning on equipment on heaters required to keep the payload warm.
(4) For rate matching tests.

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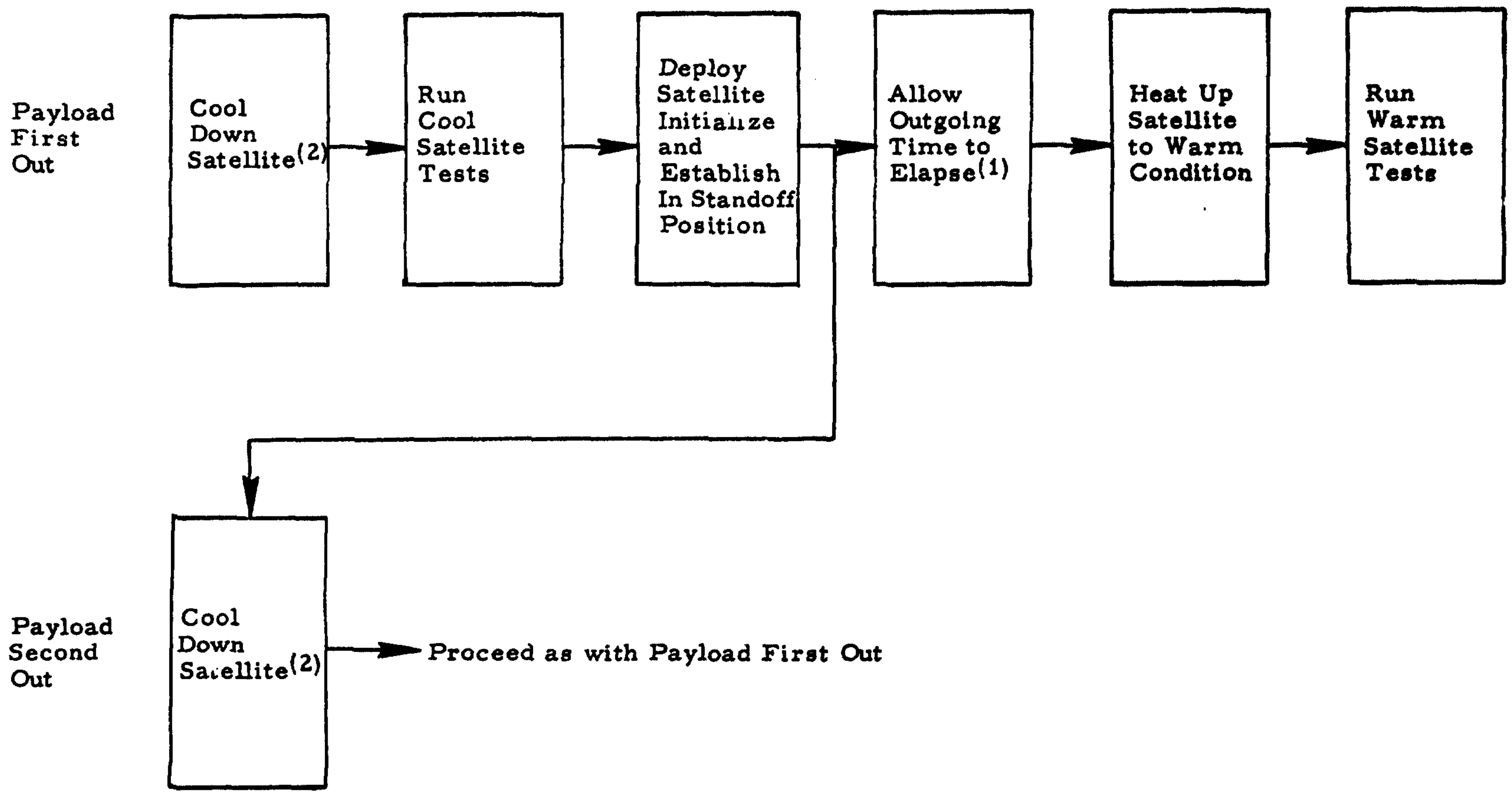
GENERALIZED TOP-LEVEL CHECKOUT FLOW ASSUMING NO EARLY FAILURES



(1) If required to present arcing and glow on high voltage satellite equipment, otherwise, hold in stand-off position while tests proceed.

(2) If necessary.

PRIMARY CHECKOUT OPTIONS - LANDSAT, A RETRIEVABLE SATELLITE

Option	Test Objectives	Spaceborne Test Support Equipment	Location/ Position Of Satellite Under Test(1)	Primary Test Links	Time Constraints: Successful Checkout	Time Constraints: Contin-gency	Comments
1	Identify 80-90% of Gross Early Failures	Stimulus SCSS(2)	Attached & Elevated / Standoff	Thru PDI Sat/TDRS / Sat/TDRS	?	Yes	Full Checkout Option(3)(4)
2	Identify 80-90% of Gross Early Failures	Stimulus OACE(5)	Attached & Elevated / Standoff	Thru PDI Sat/TDRS / Sat/TDRS	?	Yes	Full Checkout Option(3)(6)
3	Limit Checks	None	Attached & Elevated	Thru PDI	Nominal (~10 Min)	No	Minimal Checkout Option
4	Limit Checks(7) Initiate Landsat(8) + Additional Tests As Possible	None	Attached & Elevated / Standoff	Thru PDI Sat/TDRS / Sat/TDRS	2-3 Hours	Yes	Limited Duration Checkout Option(4)
5	Limit Checks(7), Command/ Response(7), Rate Matching(7), Initiate Satellite + Additional Tests As Possible	None	Attached & Elevated / Standoff	Thru PDI Sat/TDRS / Sat/TDRS	4-8 Hours	Yes	Limited Duration Checkout Option(4)(5)
6	Identify 80-90% of Gross Early Failures	None	Attached & Elevated / Standoff	Thru PDI Sat/TDRS / Sat/TDRS	?	Yes	Full Checkout Option(4)(5)

(1) Relative to orbiter.
(2) Spaceborne checkout support system
(3) When satellite attached to orbiter, all tests except R.F. tests done thru PDI, satellite/TDRS only used for R.F. tests.
(4) Ground-based automatic test sequencing at POCC.
(5) On-orbit automated checkout equipment
(6) Space-based automatic test sequencing with OACE.
(7) Prior to deployment.
(8) After deployment to standoff position.

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EL SEGUNDO, CALIFORNIA

LANDSAT, A RETRIEVABLE SATELLITE

STUDY RESULTS FOR PRIMARY CHECKOUT OPTIONS WITH EMPHASIS ON TESTING PRIOR TO DEPLOYMENT

Option	Test Objectives	Risks Of Undetected Early Failures	Risk Of Return Of Good Satellites	Estimated Test Duration Increment(1) (Hours)		Cost Estimate Increment(2) For Tests ($M)	Comments
				Attached	Standoff		
1	Identify 80-90% of Gross Early Failures	Acceptable (10 to 20%)	Minimum	22	2	0.42	Checkout Cost Benefits for a Fully Serviceable Satellite are Marginal(3)
2	Identify 80-90% of Gross Early Failures	Acceptable (10 to 20%)	Minimum	22	2	0.57	Checkout Costs are Marginal or Exceed Benefits(3)
3	Limit Checks	Significant (a) thru (g)	Significant	~10 Mins	0	No Estimate	Assurance of Retrievability Degraded. Checkout too Limited to be Worth the Effort
4	Limit Checks(4), Command/Resp.(4) R.F. Tests(4), Rate Matching(4), Initiate Landsat	Significant (a), (b), (c), (e)	Minimum	3	0	0.16	Incomplete Checkout
5	Limit Checks(4), Command/Resp.(4) R. F. Tests(4), Rate Matching(4), Thermal Tests(4), Initiate Landsat	Significant (a), (c)	Minimum	2	2	0.16	Incomplete Checkout
6	Identify 80-90% of Gross Early Failures	Acceptable (10 to 20%)	Minimum	22	2	0.16	Benefits Exceed Costs. Complete Checkout(3)

Note: (a) = Missing RCS leak tests; (b) = Missing thermal tests; (c) = Missing instrument tests; (d) = Missing command response testing; (e) = Missing isolation valve tests; (f) = Incomplete tests of extendables; (g) = Missing RF tests.

(1) After satellite/POCC communications are calibrated and test software and equipment checked out

(2) For a description of the "activity" covered with and without checkout, see Table

(3) R. F. link satellite/STDN tested in attached position

(4) Prior to deployment

TECHNOLOGY DEMONSTRATION SATELLITE, A RETRIEVABLE SATELLITE

PRIMARY CHECKOUT OPTIONS

Option	Test Objectives	Spaceborne Test Support Equipment	Location/ Position Of Satellite Under Test(1)	Primary Test Links(2)	Time Constraints: Successful Checkout	Time Constraints: Contingency	Comments
1	Identify 80-90% of Gross Early Failures	R. F. Stimulus SCSS	Attached & Elevated	Satellite/Test Equipment/ PDI	?	Yes	(3)
			Standoff				
2	↓	Stimulus SCSS	Attached & Elevated	PDI, Payload Interogator/ PDI	?	Yes	(3)(5), Replace R.F. Test Support Equipment Function With Payload Interogater
			Standoff	Payload Interogator/ PDI, Sat/ Gr'd. Sta.(4)			
3	↓	Stimulus SCSS	Attached & Elevated	PDI, Sat/ Ground Sta.	?	Yes	(3)(5), Replaces R.F. Test Support Equipment Function with Ground Station
			Standoff	Sat/Gr'd Sta.			
4	↓	R.F. Stimulus OACE	Attached & Elevated	Satellite/Test Equipment/ PDI	?	Yes	(6), With OACE Testing Can Proceed when Communications are interrupted
			Standoff				
5	↓	Stimulus OACE	Attached & Elevated	PDI, Payload Interogator/ PDI	?	Yes	(5)(6), Replace R.F. Test Equipment Function With Payload Interogator
			Standoff	PL Interogator /PDI Sat/Gr'd Sta.			
6	↓	Stimulus OACE	Attached & Elevated	PDI, Sat/ Ground Sta.	?	Yes	(6), Replace R.F. Support Equipment Function With Ground Station
			Standoff	Sat/Grd Sta.			
7	↓	None	Attached & Elevated	PDI, Payload Interogator/ PDI	?	Yes	(3), Delete All Spaceborne Test Support Equipment
			Standoff	Sat/Gr'd Sta.			

(1) Relative to orbiter.
(2) PDI = orbiter payload data interleaver which communicates payload data and commands through TDRS.
(3) Ground-based automatic test sequencing using POCC computers.
(4) For wideband data system.
(5) Duration of testing depends on visibility of ground station.
(6) Space-based automatic test sequencing with OACE.

ATREX, A RETRIEVABLE SATELLITE

STUDY RESULTS FOR PRIMARY CHECKOUT OPTIONS WITH EMPHASIS ON TESTING AFTER SATELLITE DEPLOYMENT

Option	Test Objectives	Risks Of Undetected Early Failures	Risk Of Return Of Good Satellites	Estimated Test Duration Increment (Hours)		Cost Estimate, Increment For Tests ($M)	Comments
				Attached	Standoff		
3	Limit Checks(1) Rate Matching(1) Command/Resp.(2) Instrument Tests(2) Thruster Tests(2) Extendible Tests(2)	Significant (a), (b)	Minimum	30 Minutes	4 Hours(1)	0.16	Incomplete Checkout
4	Identify 80-90% of Gross Early Failures	Acceptable (10 to 20%)	Minimum	8 Hours(1)(2)	18 Hours	0.16	Complete Checkout Benefits Exceed Costs

Note: (a) = Missing RCS leak tests; (b) = Missing thermal tests

(1) If outgassing period is required, it is completed before testing starts.

(2) Active test time increased to account for orbiter blockage of the ATREX/TDRS link.

ATREX, A RETRIEVABLE SATELLITE

PRIMARY CHECKOUT OPTIONS, GROUND-BASED AUTOMATIC TEST SEQUENCING USING POCC COMPUTERS

Option	Test Objectives	Spaceborne Test Support Equipment	Location/ Position Of Satellite Under Test(1)	Primary Test Links	Time Constraints		Comments
					Successful Checkout(2)	Contin- gency	
1	Limit Checks(3) Rate Matching(3)	None	Attached to Orbiter	Satellite/ TDRS	Nominal (~30 Min)	0	Minimal Checkout Option(4)
2	Limit Checks(3) Command/ Response(3) Rate Matching(3)	None	Attached	Satellite/ TDRS	0.5 - 2	0	Limited Duration Option(4)
3	Limit Checks Command/ Response Rate Matching + Additional Tests As Possible	None	Attached Then Standoff	Satellite/ TDRS	4 - 8	Yes	Limited Duration Option(4)
4	Identify 80-90% of Gross Early Failures	None	Attached Then Standoff	Satellite/ TDRS	?	Yes	Full Checkout Option(4)

(1) Relative to orbiter

(2) After satellite-to-ground communications are calibrated and any test equipment and software checked out

(3) Prior to deployment

(4) Active testing while ATREX is attached to orbiter is limited to times when TDRS is visible from ATREX, i.e., no interference by orbiter structure

STORMSAT/IUS, AS A NON-RETRIEVABLE PAYLOAD
PRIMARY CHECKOUT OPTIONS

Option	Test Objectives	Spaceborne Test Support Equipment	Location/ Position Of Satellite Under Test(1)	Primary Test Links	Time Constraints		Comments
					Successful Checkout	Contin-gency	
1	Identify 80-90% of Gross Early Failures	R. F. Stimulus SCSS	Attached & Elevated	Satellite/Test Equipment/ PDI	?	Yes	(2)
2	Identify 80-90% of Gross Early Failures	Stimulus CSS	Attached & Elevated	PDI, Sat/ Ground Sta. for RF Tests	?	Yes	(2), Delete R.F. Test Support Equipment
3	Identify 80-90% of Gross Early Failures	R. F. Stimulus SCSS	Attached & Elevated	Satellite/Test Equipment/ PDI	?	Yes	(3), With OACE Testing Can Proceed When Communications are Interrupted
4	Identify 80-90% of Gross Early Failures	Stimulus OACE	Attached & Elevated	PDI, Sat/ Ground Sta. for RF Tests	?	Yes	(3), Delete R.F. Test Equipment With OACE
5	Check Out Satellite Equipment Testable Without Test Support Equipment	None	Attached & Elevated	PDI, Sat/ Ground Sta. for RF Tests	?	Yes	(3), Delete All Spaceborne Test Support Equipment

(1) Relative to orbiter

(2) Ground-based automatic test sequencing using POCC computers

(3) Space-based automatic test sequencing with OACE

STORMSAT/IUS, AS A NON-RETRIEVABLE PAYLOAD
RESULTS FOR PRIMARY CHECKOUT OPTIONS

Option	Test Objectives	Risks Of Undetected Early Failures	Risk Of Return Of Good Satellites	Estimated Test Duration Increment (Hours)		Cost Estimate, Increment For Tests ($M)	Comments
				Attached	Standoff		
1	Identify 80-90% of Gross Early Failures	Could Not Reach Objectives, (1)(2)(3)(4) Significant Risks	Minimal	24	0	0.80	Incomplete Checkout. Costs Exceed Benefits
2	Identify 80-90% of Gross Early Failures	↓	Minimal	24	0	0.40	(1) - Incomplete Checkout. Net Benefits are Marginal.
3	Identify 80-90% of Gross Early Failures		Minimal	24	0	0.88	Incomplete Checkout. Costs Exceed Benefits.
4	Identify 80-90% of Gross Early Failures		Minimal	24	0	0.48	(1) - Incomplete Checkout. Net Benefits are Marginal.
5	Check Out Satellite Equipment Testable Without Test Support Equipment	Significant Risks (1), (2), (3), (4), (5), (6)	Minimal	24	0	0.10	(1) - Incomplete Checkout. Best Justified Option if IUS Not Retrievable.

(1) Missing ACS end-to-end testing.
(2) Missing star tracker and fine sun sensor tests unless self-testing units are provided.
(3) Missing Stormsat RCS isolation valve tests.
(4) Missing Stormsat failures occurring after IUS ignition.
(5) Missing ACS electronics tests.
(6) Missing AASIR IR instrument electronics tests.

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SYNCHRONOUS METEOROLOGICAL SATELLITE (SMS)/GOES/SSUS
SMS IS ASSUMED MODIFIED TO BE COMPATIBLE WITH STS
PRIMARY CHECKOUT OPTIONS

Option	Test Objectives	Spaceborne Test Support Equipment	Location/ Position Of Satellite Under Test(2)	Primary Test Links	Time Constraints		Comments
					Successful Checkout	Contin-gency	
1	Identify 80-90% of Gross Early Failures	R.F. Stimulus OACE(3)	Attached & Elevated	Thru OACE/PDI	?	Yes	SMS/SSUS is Retrievable(4)
			Standoff	Thru OACE/PDI			
2	Identify 80-90% of Gross Early Failures	R.F. Stimulus OACE(2)	Attached & Elevated	Thru PDI, Sat/Ground	?	Yes	SMS/SSUS is Retrievable, High Inclination Parking Orbit. Overflies Wallops Island for RF Tests(4)
			Standoff	Sat/Ground			
3	Limit to Testing During Wallops Island Pass	None	Attached & Elevated	R.F. Satellite to Ground	5 Minutes (out of 24 hr. period)	Yes	High Inclination Parking Orbit, Overflies Wallops Island for Checkout Tests(5) SMS/SSUS Not Retrievable
4	Limit to Testing During Wallops Island Passes 24 Hours Apart	None	Attached & Elevated	R.F. Satellite to Ground	Two 5 Min Periods (out of 48 hr. period)	Yes	Same as Above
5	Limit to Attached Tests Without Test Equipment	None	Attached & Elevated	Thru PDI RF Sat/ Interrog/ PDI	?	Yes	SMS/SSUS Not Retrievable, SMS Shaded by Orbiter

(1) Including translator box, orbiter/SMS.

(2) Relative to orbiter.

(3) On-orbit automated checkout equipment includes telemetry, command computer, and tape recorder (see Reference

(4) Space-based automatic test sequencing with OACE.

(5) Ground-based automatic test sequencing using POCC computers.

SYNCHRONOUS METEOROLOGICAL SATELLITE (SMS)/GOES/SSUS
SMS IS ASSUMED MODIFIED TO BE COMPATIBLE WITH STS
STUDY RESULTS FOR PRIMARY CHECKOUT OPTIONS

Option	Test Objectives	Risks Of Undetected Early Failures	Risk Of Return Of Good Satellites	Estimated Test Duration Increment(1) (Hours) Attached	Estimated Test Duration Increment(1) (Hours) Standoff	Cost Estimate Increment(2) For Tests ($M)	Comments
1	Identify 80-90% of Gross Early Failures	Acceptable (3)	Minimum	24 Hours	5 Minutes	0.9	Testing Costs Much Larger Than Potential Benefits
2	Identify 80-90% of Gross Early Failures	Acceptable (3)	Minimum	24 Hours	5 Minutes (out of 24 hr period)	0.9	Testing Costs Much Larger Than Potential Benefits
3	Limit Checks, Command/Response Tests Only	Significant (a), (b), (c), (d), (3)	Minimum	5 Minutes (out of 24 hr period)	0	No Estimate	(4), Incomplete Checkout, Requires Larger Upper Stage and Probably a Dedicated Shuttle Flight
4	Limit Checks, Command/Response Tests, Leak Tests, Thermal Tests	Significant (c), (d)	Minimum	Up to 48 hr period	0	No Estimate	Same as Above
5	Limit Checks, Command/Response Tests, Leak Tests, Thermal Tests, RF Tests(5)	Significant (c), (d), (3)	Minimum	24 Hours	0	0.2	Incomplete Checkout

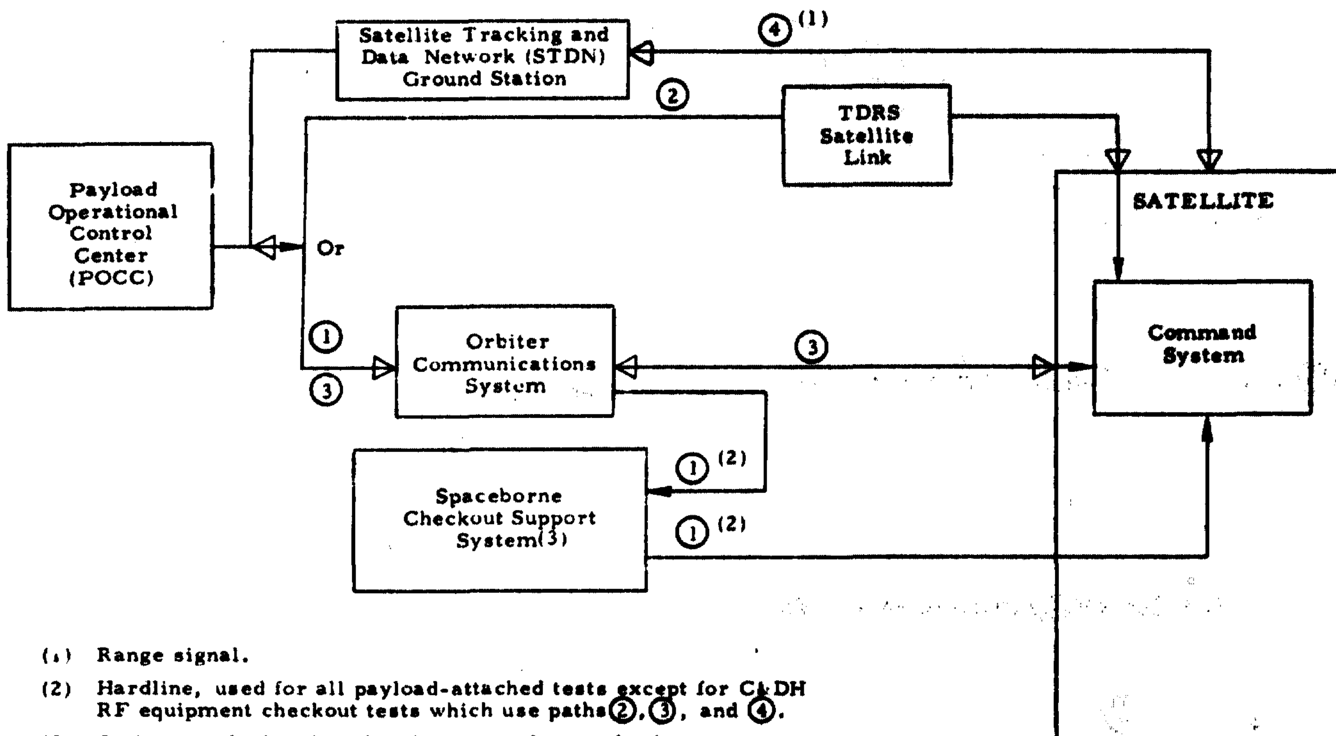
Note: (a) = Missing RCS leak tests; (b) = Missing thermal tests; (c) = Missing instrument tests; (d) = Missing ACS isolation valve tests

(1) Outgassing period (if any) elapses before testing begins. Communications links tested and test equipment (if any) checked out before testing begins.
(2) For assumptions used in making cost estimates, see Reference 1.
(3) Missing SMS failures occurring after SSUS ignition.
(4) Payload specialist controls payload temperatures or thermostats provided.
(5) Limited to S-band testing through orbiter payload interrogator.

SUMMARY OF PAYLOAD RETRIEVABILITY AND PAYLOAD TEST LOCATION CASES

Payload	Summary Results In Table No.	Checkout Studied For: Retrievable Payload	Checkout Studied For: Non-Retrievable Payload	Employing Checkout Testing: Prior To Deployment	Employing Checkout Testing: After Satellite Deployment
Stormsat/IUS	7-3	Yes		Yes	
	7-4	Yes			Yes
	7-5		Yes	Yes	
Technology Demonstration Satellite	7-6	Yes		Yes	
	7-7	Yes			Yes
SMS/GOES/SSUS	7-8	Yes		Yes	
	7-8		Yes	Yes	
Landsat D	7-9	Yes		Yes	
	7-10	Yes			Yes
ATREX	7-12	Yes		Yes	
	7-13	Yes			Yes

COMMAND (UP-LINK) SYSTEM FOR ON-ORBIT CHECKOUT
LANDSAT D ATTACHED TO ORBITER

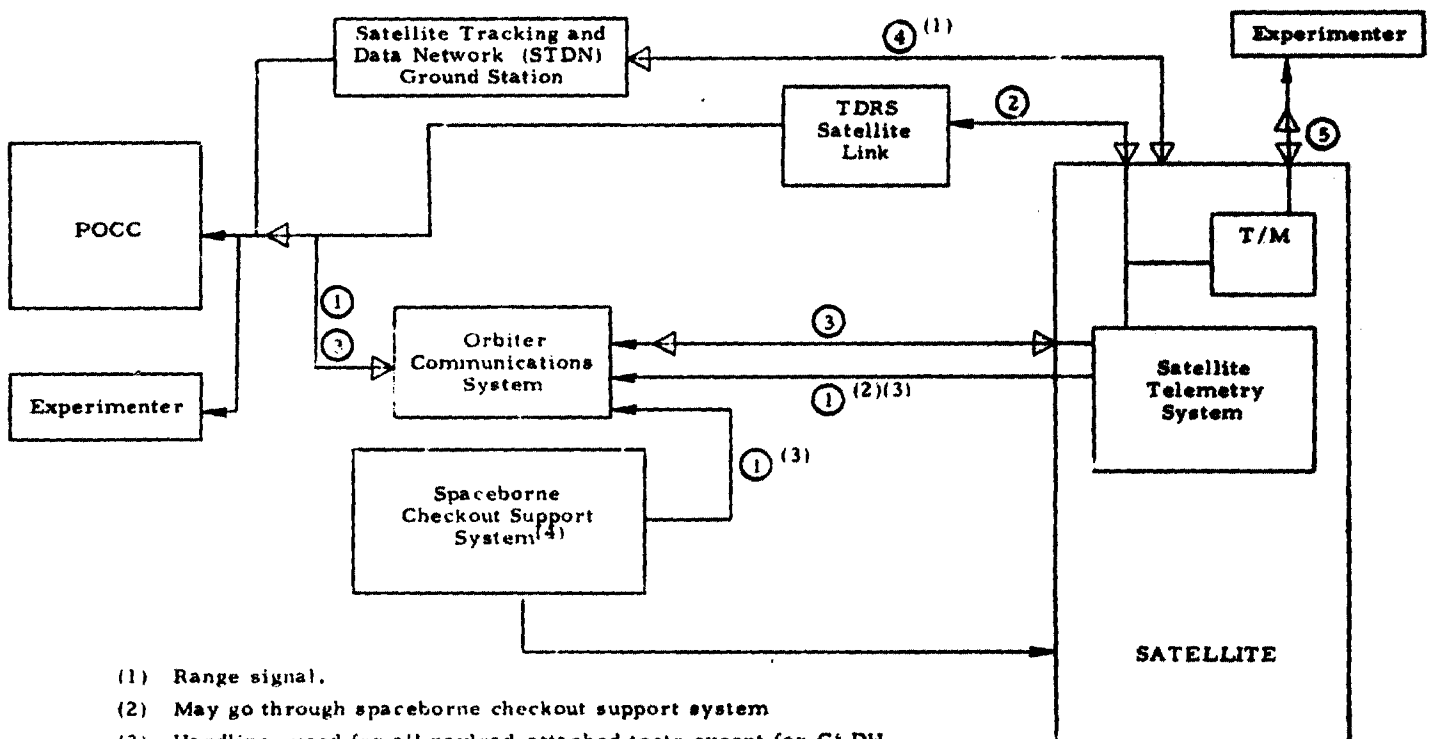


(1) Range signal.

(2) Hardline, used for all payload-attached tests except for C&DH RF equipment checkout tests which use paths ②, ③, and ④.

(3) Options studied with and without spaceborne checkout support equipment (SCSE). When SCSE is not included the hardline goes directly to the satellite.

TELEMETRY (DOWN-LINK) SYSTEM FOR ON-ORBIT CHECKOUT
LANDSAT D ATTACHED TO ORBITER



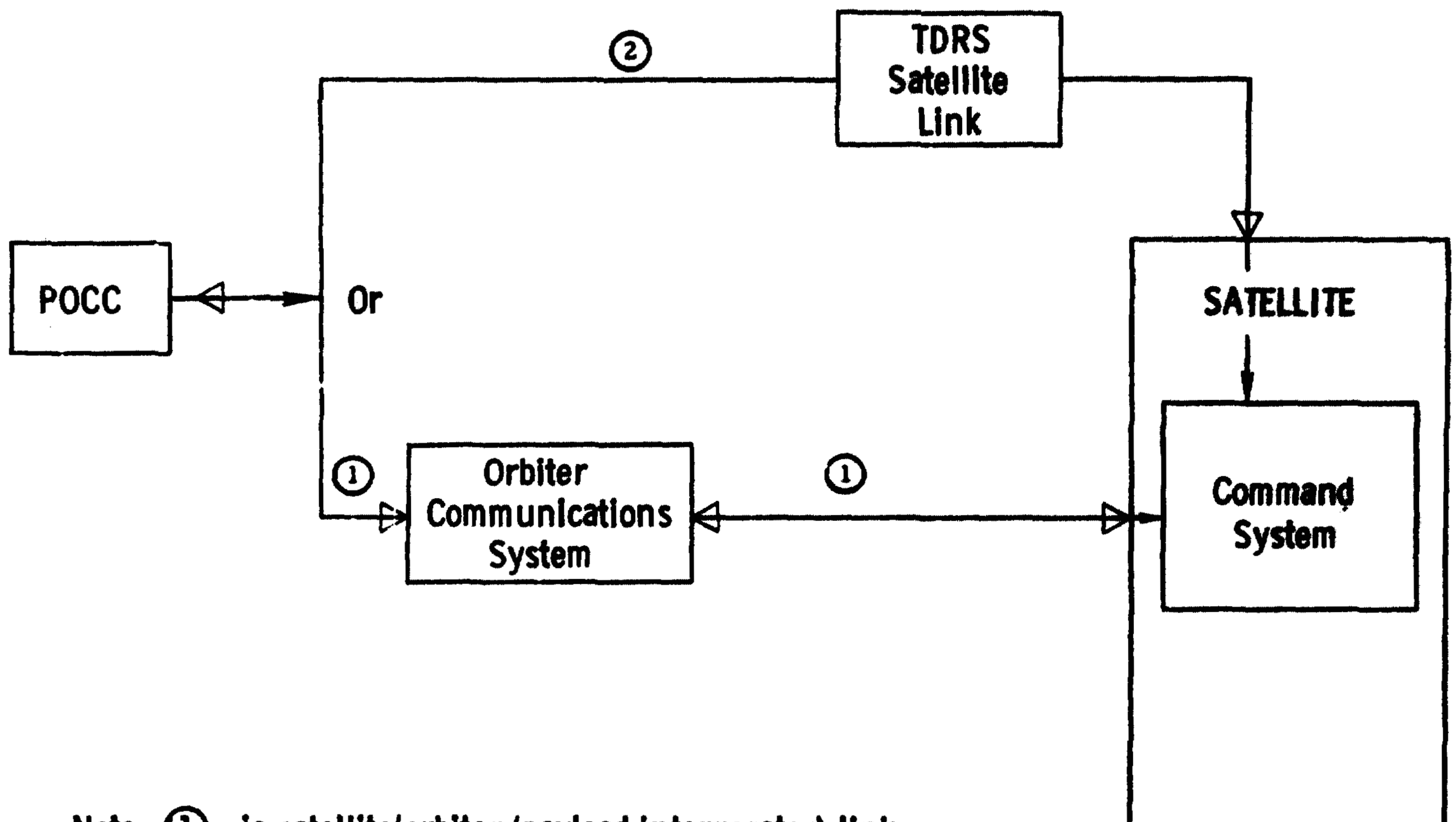
(1) Range signal.

(2) May go through spaceborne checkout support system

(3) Hardline, used for all payload-attached tests except for C&DH RF equipment checkout tests which use paths ②, ③, and ④.

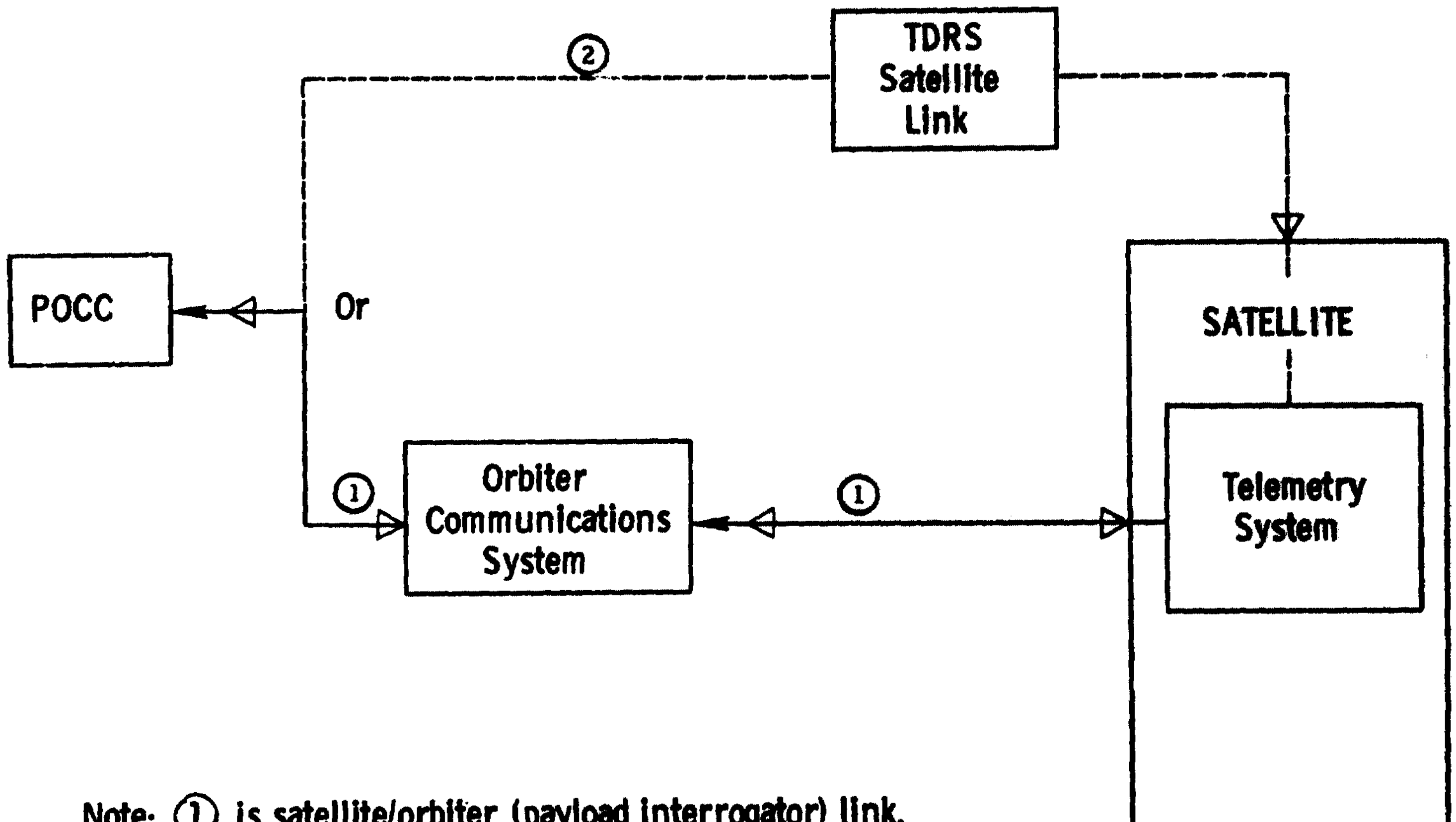
(4) Options studied with and without spaceborne checkout support equipment (SCSE).

COMMAND (UP-LINK) SYSTEM FOR ON-ORBIT CHECKOUT
LANDSAT D STANDING OFF FROM ORBITER



Note: ① is satellite/orbiter (payload interrogator) link.

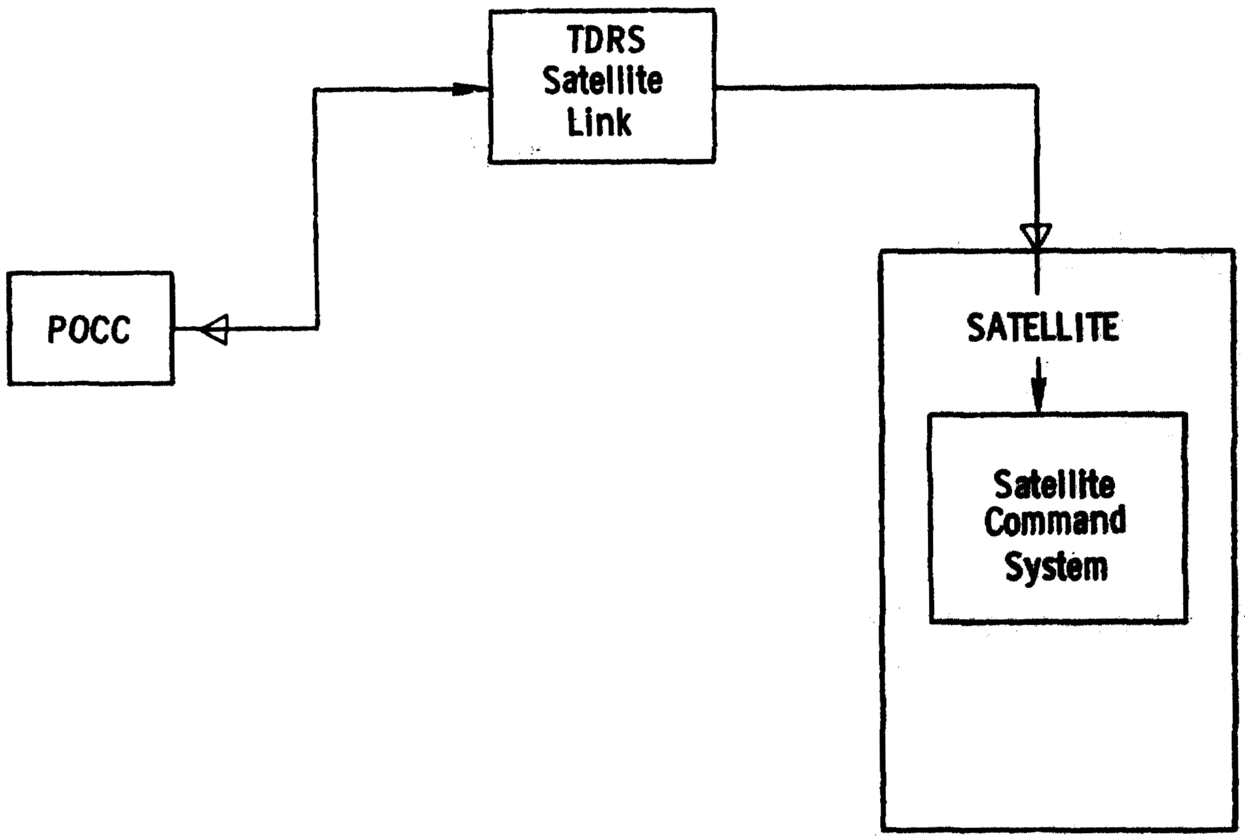
TELEMETRY (DOWN-LINK) SYSTEM FOR ON-ORBIT CHECKOUT
LANDSAT D STANDING OFF FROM ORBITER



Note: ① is satellite/orbiter (payload interrogator) link.

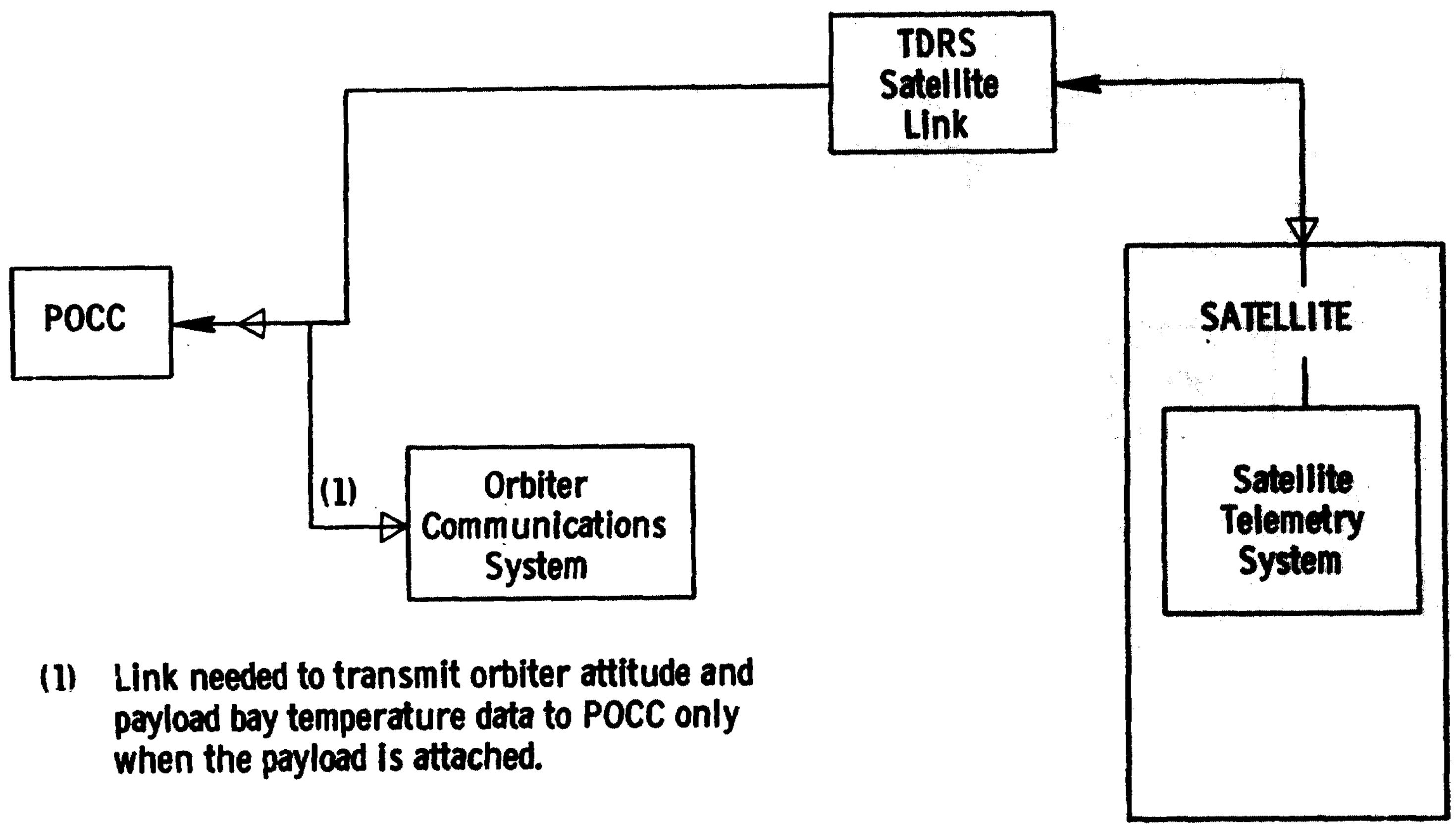
COMMAND (UP-LINK) SYSTEM FOR ON-ORBIT CHECKOUT

ATREX SATELLITE ATTACHED OR ORBITER OR STANDING OFF FROM THE ORBITER



TELEMETRY (DOWN-LINK), SYSTEM FOR ON-ORBIT CHECKOUT

ATREX SATELLITE ATTACHED OR ORBITER OR STANDING OFF FROM THE ORBITER



(1) Link needed to transmit orbiter attitude and payload bay temperature data to POCC only when the payload is attached.

ON-ORBIT CHECKOUT SUBSYSTEM LEVEL STUDIES

COMMUNICATIONS AND DATA HANDLING

LANDSAT PRE-DEPLOYMENT CHECKOUT

TT&C SYSTEM

LANDSAT = MULTIMISSION MODULAR SPACECRAFT

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INSTRUMENTATION MODULE

LANDSAT TT&C CHARACTERISTICS

MMS COMMUNICATIONS AND DATA HANDLING SUBSYSTEM

Transponder	S-Band STDN/TDRSS, Transponder Output Power at Antenna Port 1.0, 2.5, 5.0 Watts, Prelaunch Selectable
Command Rates	2 KBPS (Shuttle/STDN). 125 and 1 KBPS Selectable (TDRSS)
Real-Time Telemetry Rates	1, 2, 4, 8, 16, 32, 64 KBPS
Tentative Selection	16 KBPS
Telemetry Formats	2 Selectable Prior to Launch, Plus In-Orbit Programmable Capability; All Formats Contain 890 Data Word Maximum
Stored Data Dump/Mission Data Source	2.048 MBPS Maximum, 1.024 MBPS Coded Data
On-Board Computer	18 Bits Per Word. 32K Words of Memory, Baseline Expandable to 64K Words. 5 Microsecond Add Time
Data Storage	Standard Option of 10^8 and 10^9 Bit Tape Recorders
TLM Minor Frame	1024 Bits (128 Words)
Subcommutators	128
Major Frame Cycle	8.192 Seconds

Preliminary Command and Telemetry Lists Available

LANDSAT TT&C CHARACTERISTICS

INSTRUMENTATION DOWNLINKS

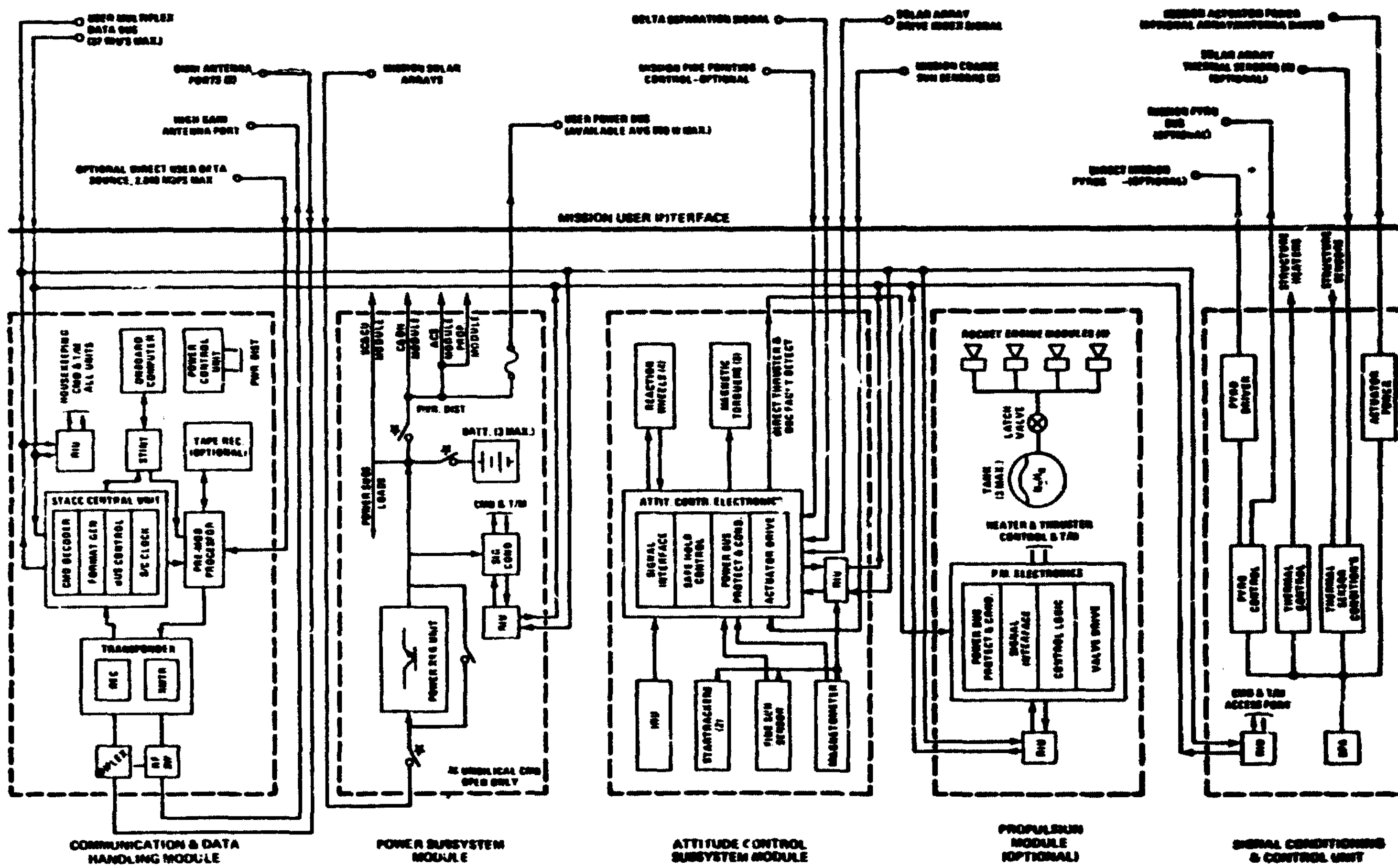
- TDRSS KU BAND
  - / 120 MBPS FOR THEMATIC MAPPING (TM)
  - / 15 MBPS FOR MULTI-SPECTRAL SCANNER (MSS)

OR

- X BAND
  - / 120 MBPS FOR THEMATIC MAPPING
  - / REQUIRES DEDICATED STATION
- S BAND
  - / 15 MBPS FOR MSS
- NO COMMAND OR TELEMETRY LISTS AVAILABLE

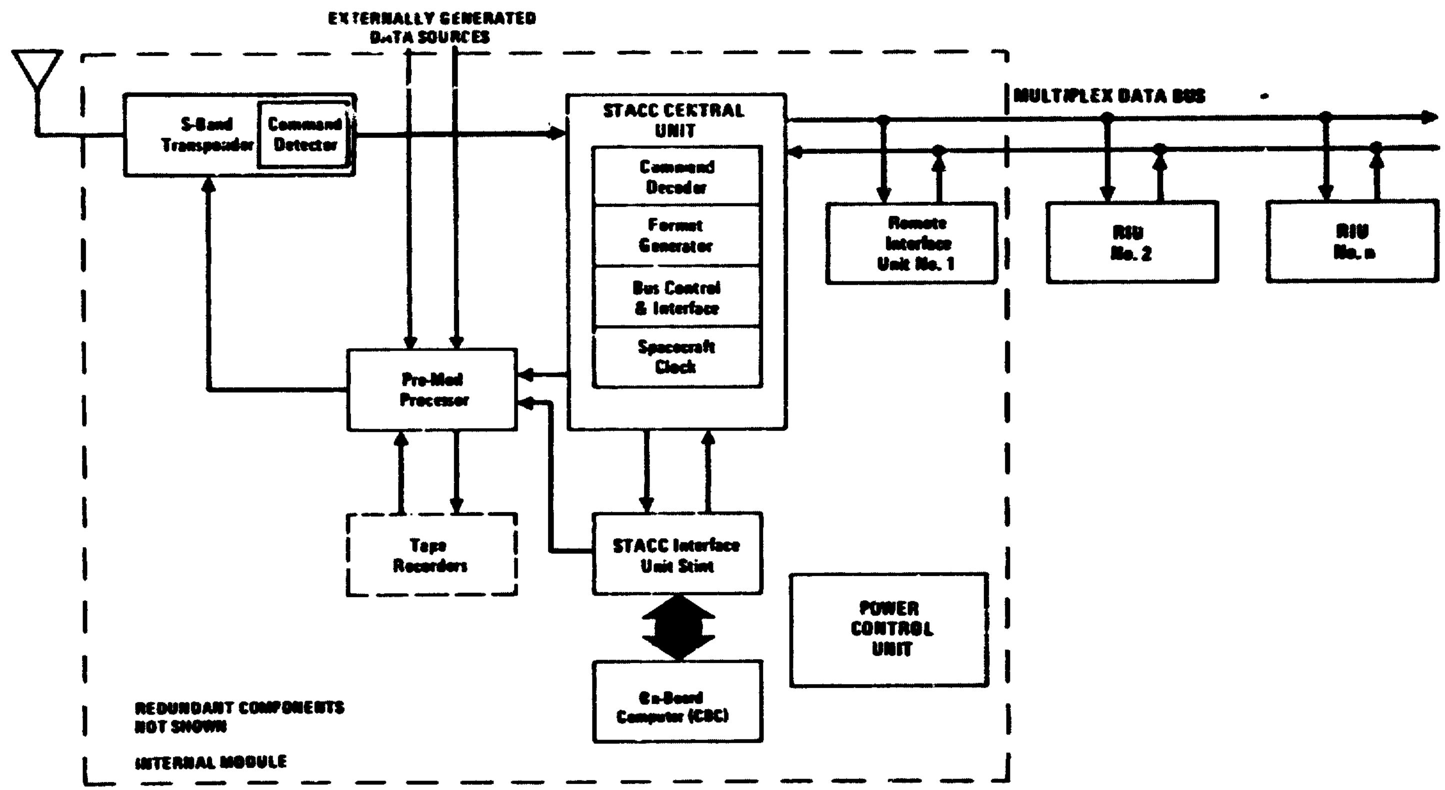
UNCLASSIFIED

MMS SYSTEM BLOCK DIAGRAM

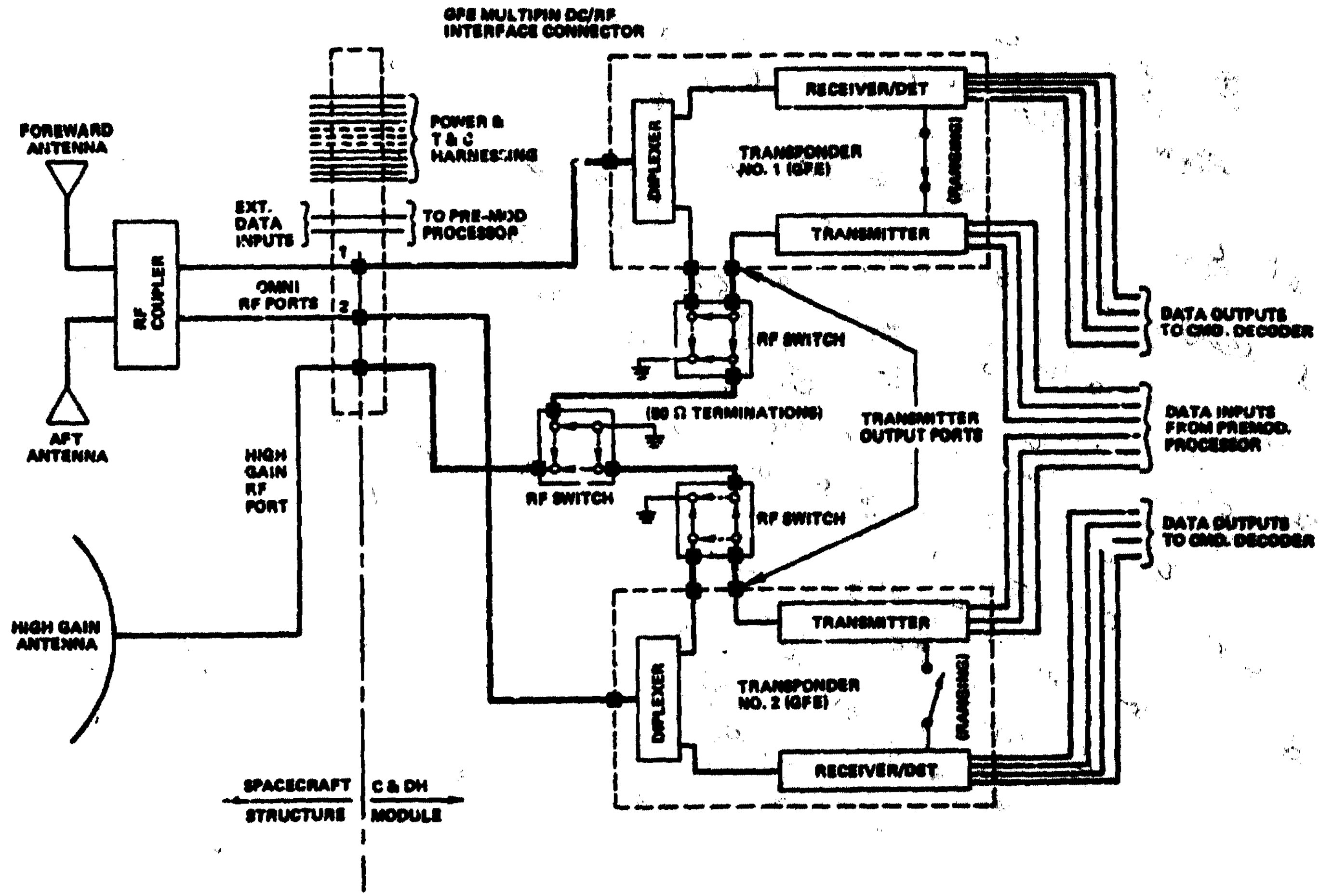


UNCLASSIFIED

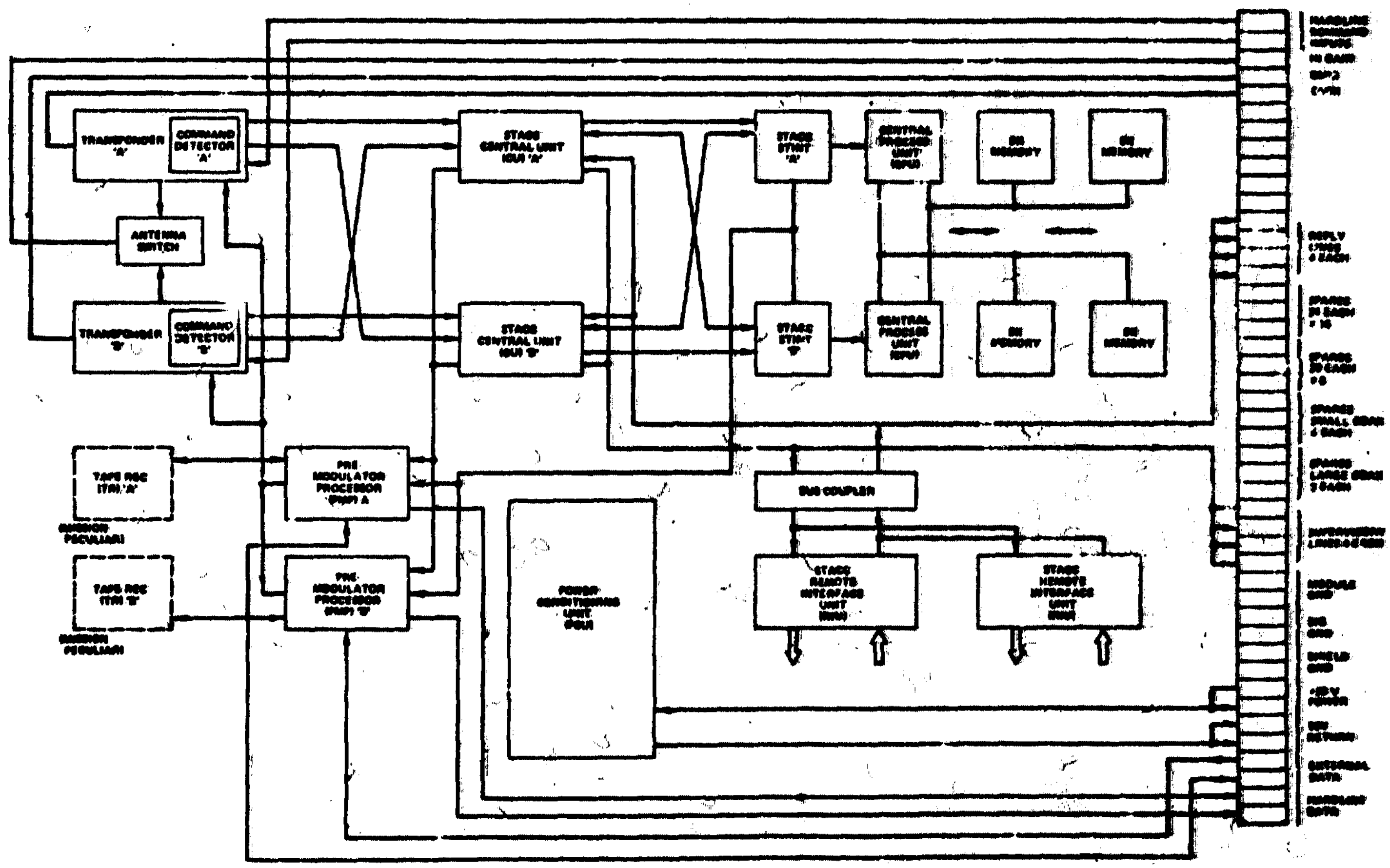
SIMPLIFIED BLOCK DIAGRAM OF THE TT&C SUBSYSTEM



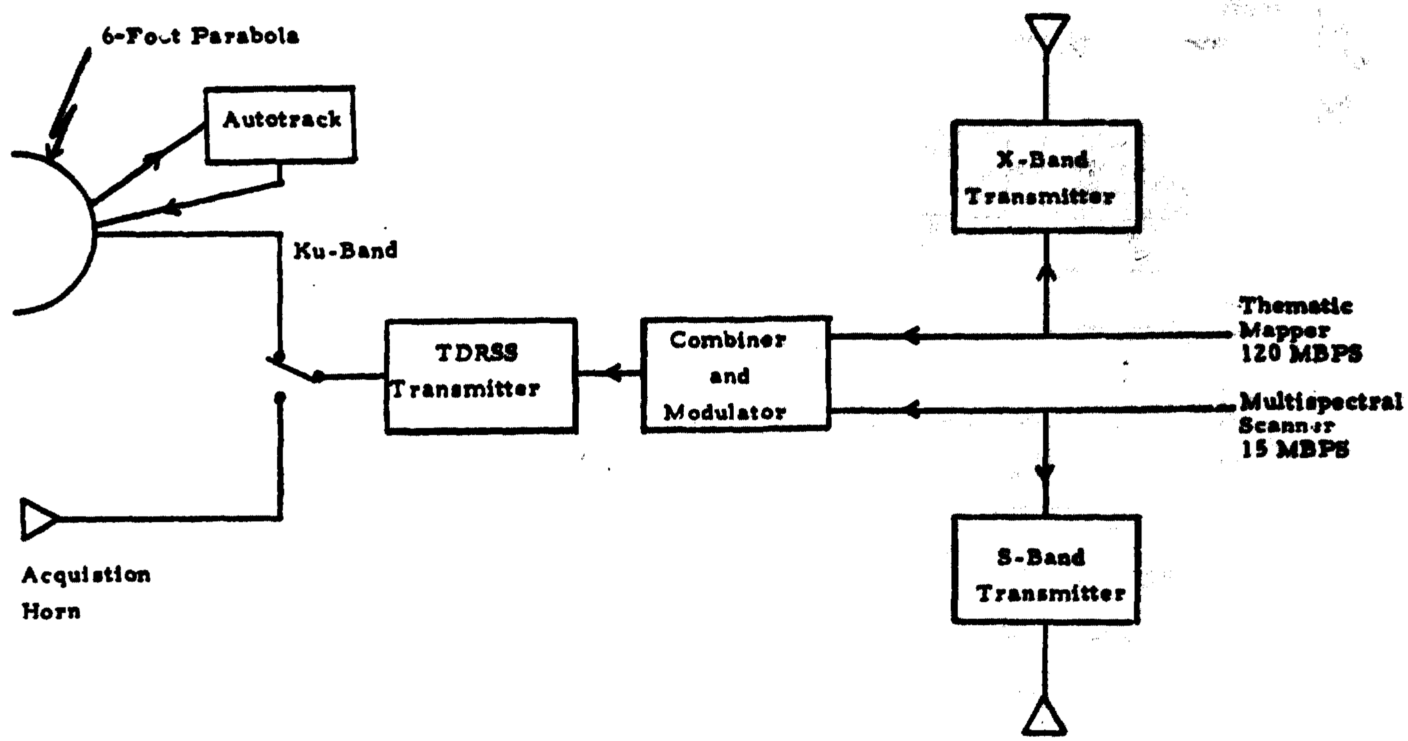
MMS RF EQUIPMENT



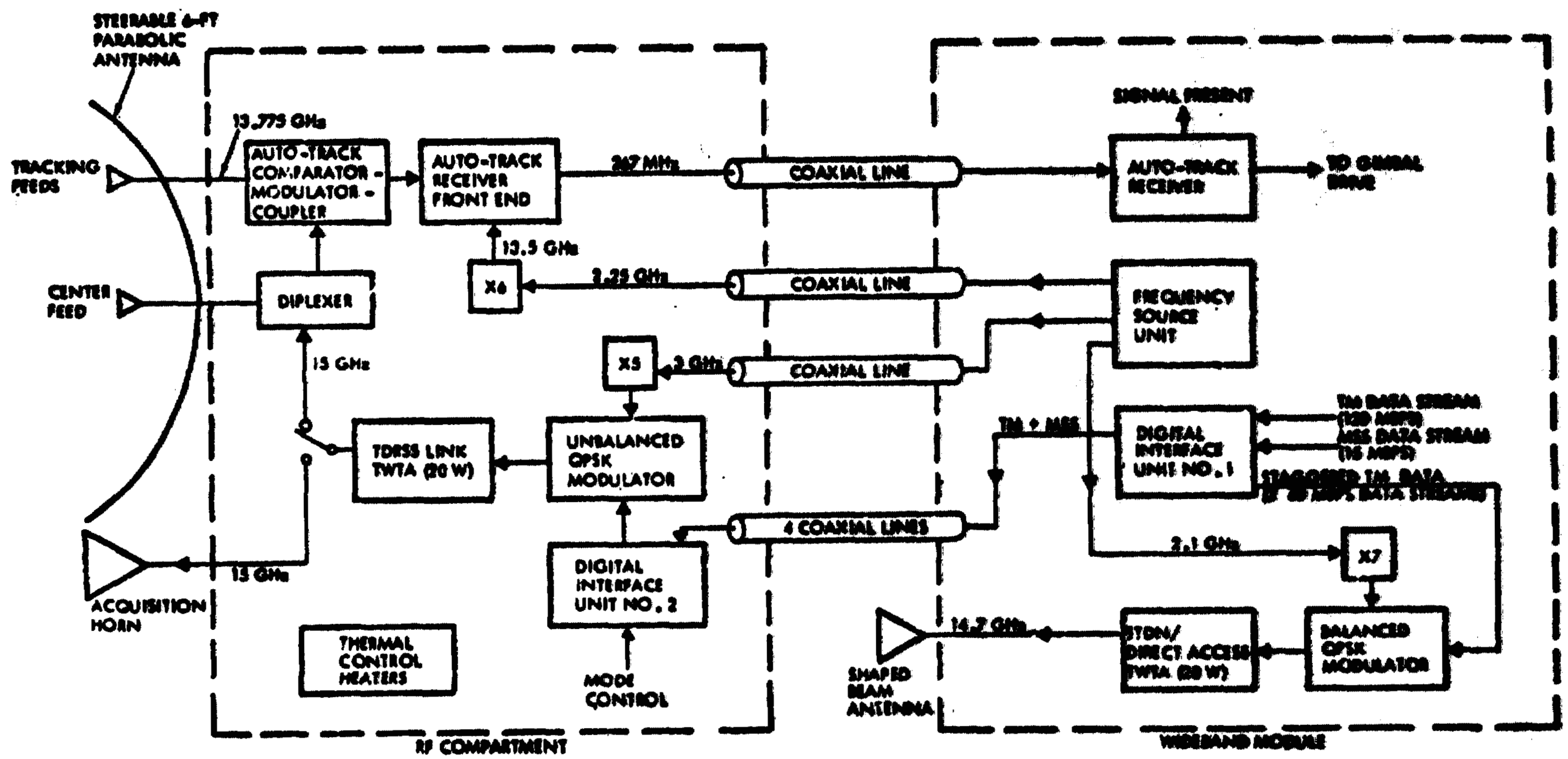
C&DH SUBSYSTEM BLOCK DIAGRAM (SHOWING MODULE INTERFACE)



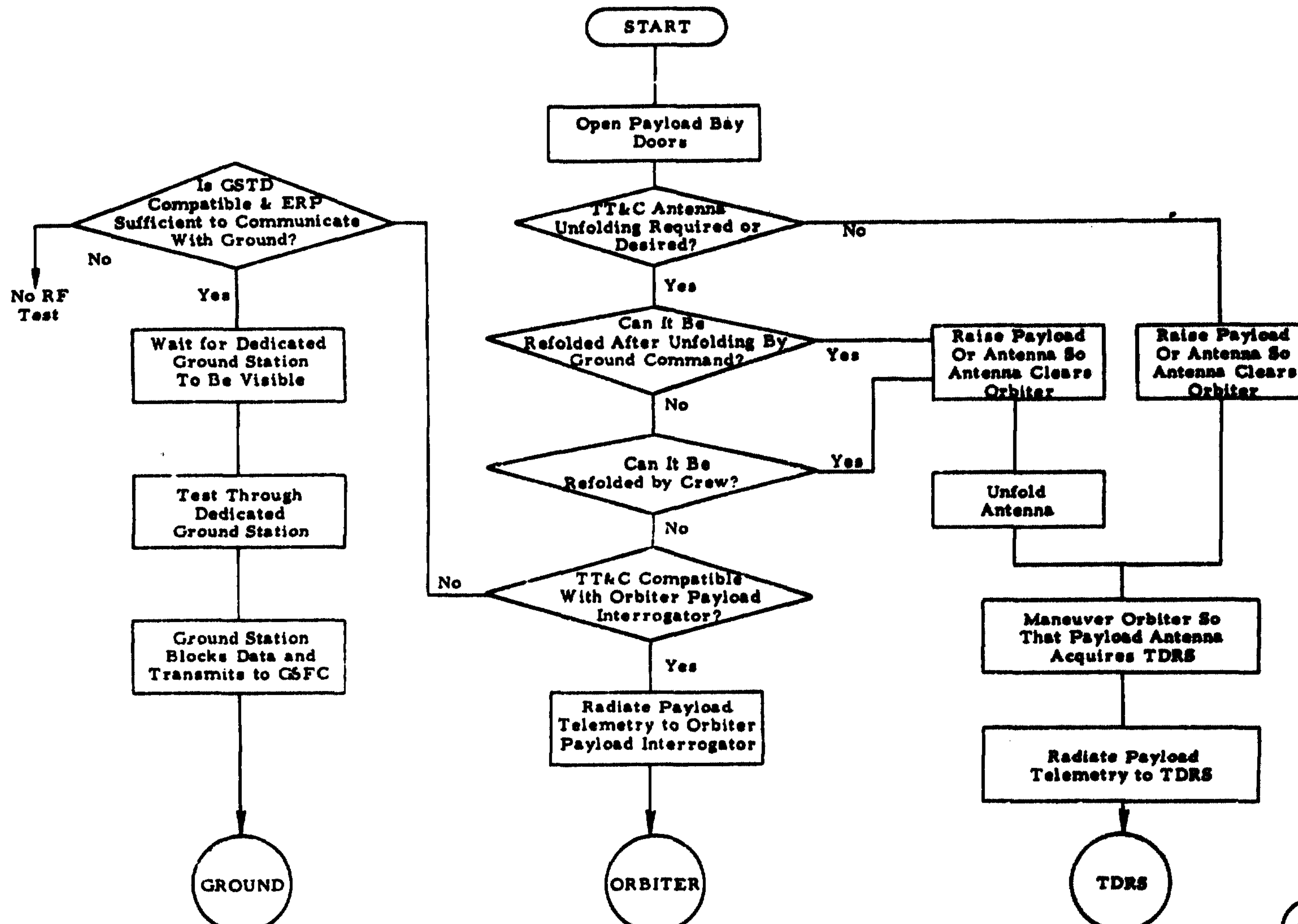
LANDSAT D MISSION-PECULIAR COMMUNICATION



LANDSAT D CONFIGURATION



TT&C RF TESTING FOR LANDSAT OR ATREX TDRS LARGE DISH EQUIPMENT
TESTING PRIOR TO DEPLOYMENT - I



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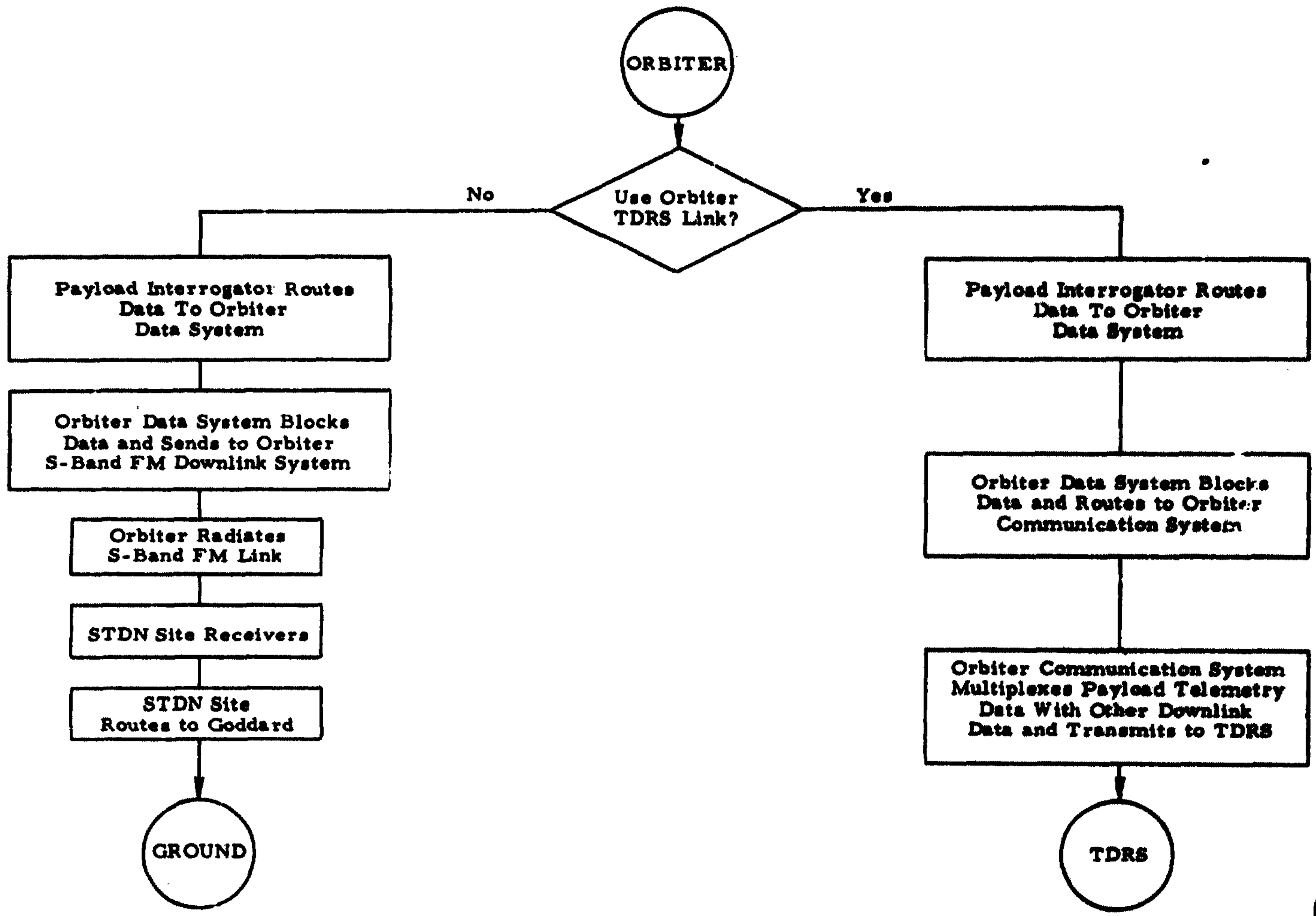
TT&C RF TESTING FOR LANDSAT OR ATREX TDRS LARGE DISH EQUIPMENT
TESTING PRIOR TO DEPLOYMENT - II



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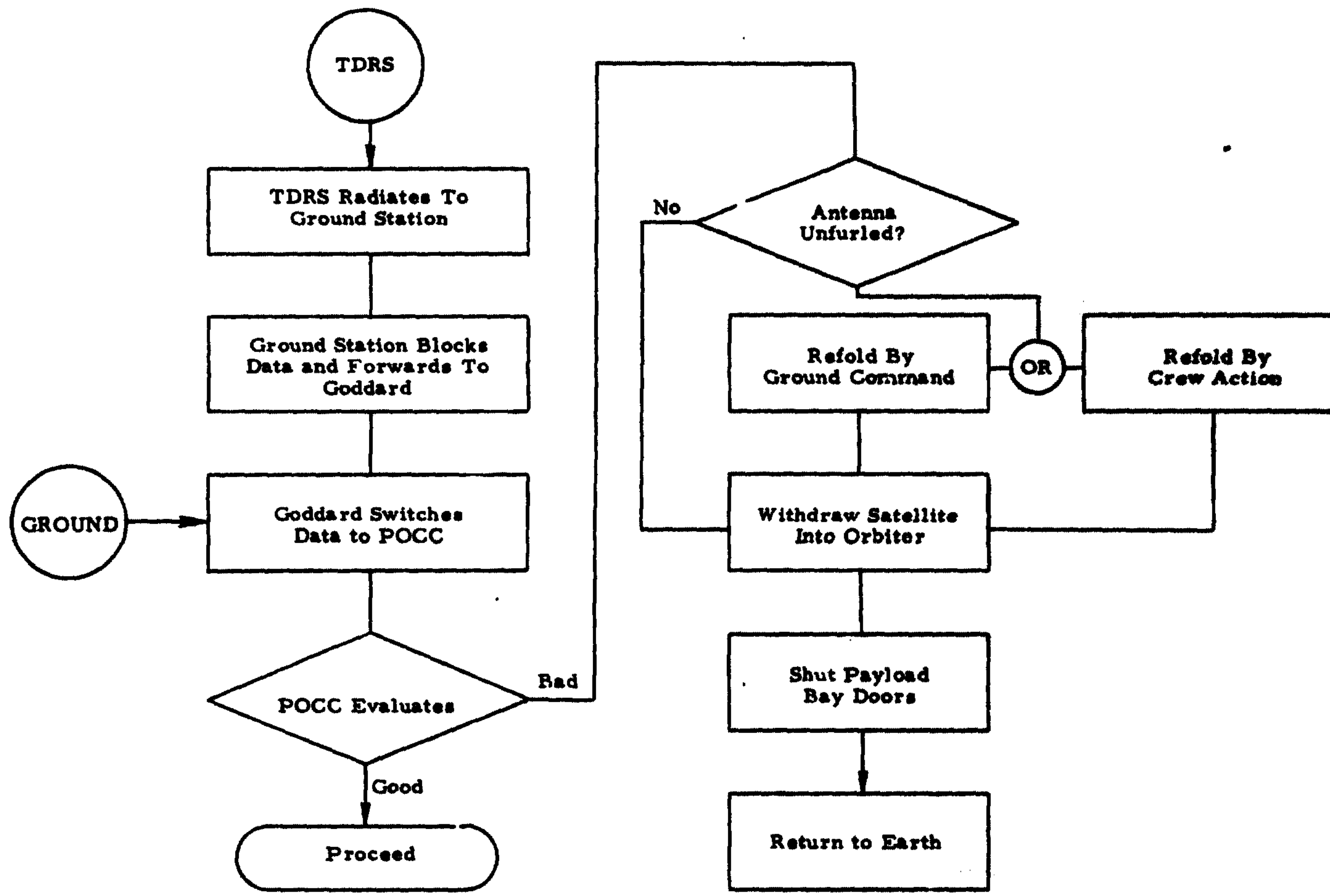
TT&C RF TESTING FOR LANDSAT OR ATREX TDRS LARGE DISH EQUIPMENT
TESTING PRIOR TO DEPLOYMENT - III



TT&C CHECKOUT OPTIONS CONSIDERED FOR LANDSAT/MMS

OPTION	ADVANTAGES	DISADVANTAGES	COMMENTS	RECOMMENDATION
1. Test Initial Configuration Only	• Quickest to run: / 5 Minutes for Manual Evaluation / 1 Minute for Software Limit Checking by POCC Computer	• Expensive Redundant Equipment Not Checked / Triple Redundant RF Systems / Dual Redundant Computer Chain With Cross Switching of Elements	• Long On-Orbit Life Capability Depends On Redundant Equipment • Failed Redundant Element Is Not Detected • Subsequent Failure In Initial Configurations May: (1) Knock Out Satellite Completely, or (2) Reduce Its Life Expectancy	Not Recommended
2. Test Three Redundant RF Configurations	• Quick to Run: / 10 Minutes for Manual Evaluation / 2 Minutes for Software Limit Checking by POCC Computer	• Does Not Check Dual Redundant Computer System or Internal Cross Switching	• RF Amplifiers Which Are Checked Here Have a Higher Failure Proability Than Computer Elements • However, Failed Computer Element in Redundant Configuration Will Not Be Detected • Subsequent Failure In Initial Configuration Element May: (1) Knock Out Satellite Completely, or (2) Reduce Its Life Expectancy	Not Recommended
3. Test All Redundant Elements	• Verification of Operability of the Entire TT&C System Using Any Configuration • Insures That Spacecraft TT&C System When Deployed Meets Design Goals	• Slower to Run: / Approximately 100 Commands Must Be Transmitted and Response Evaluated / 45 Minutes for Manual Evaluation / 20 Minutes for Software Limit Checking by POCC Computer	• This Test Insures That All Infant Mortality Items In The TT&C System Are Identified • If Failure Is Identified, Program Manager Can Weigh the Merits of Immediate Deployment With Shortened On-Orbit Life Against the Return to Earth for Repair and Later Placement On Orbit	Recommended

MMS TELEMETRY ANALYSIS

- BACKUP MONITORING POINTS EXIST IN PRESENT DESIGN WITH THE FOLLOWING RECOMMENDATIONS
  - / ADDITION OF POWER SUPPLY VOLTAGES FOR EACH BOX
  - / DETAILED MONITORING OF RF SWITCHES (3)
  - / POWER OUTPUT OF TRANSMITTERS
- BASELINE MONITORING
  - / GENERAL PERFORMANCE, ALIVENESS

ATREX PRE-DEPLOYMENT CHECKOUT

TT&C SYSTEM

ATREX TT&C

- PRIMARY SUPPORT: TDRSS
- BACKUP SUPPORT (REDUCED DATA RATE): STDN
- SINGLE THREAD SYSTEM – NO REDUNDANCY
- RECORDS SPACECRAFT TELEMETRY AND EXPERIMENT DATA VIA:
  - / 16 KBPS FOR 80% OF ORBIT
  - / 64 KBPS FOR 20% OF ORBIT
- DUMPS RECORDED DATA TO GROUND AT 50 KBPS VIA PRIMARY SYSTEM – HIGH-GAIN ANTENNA
- POSSIBLE REDUCED RATE DUMPING AT 1 KBPS VIA BACKUP SYSTEM – OMNI

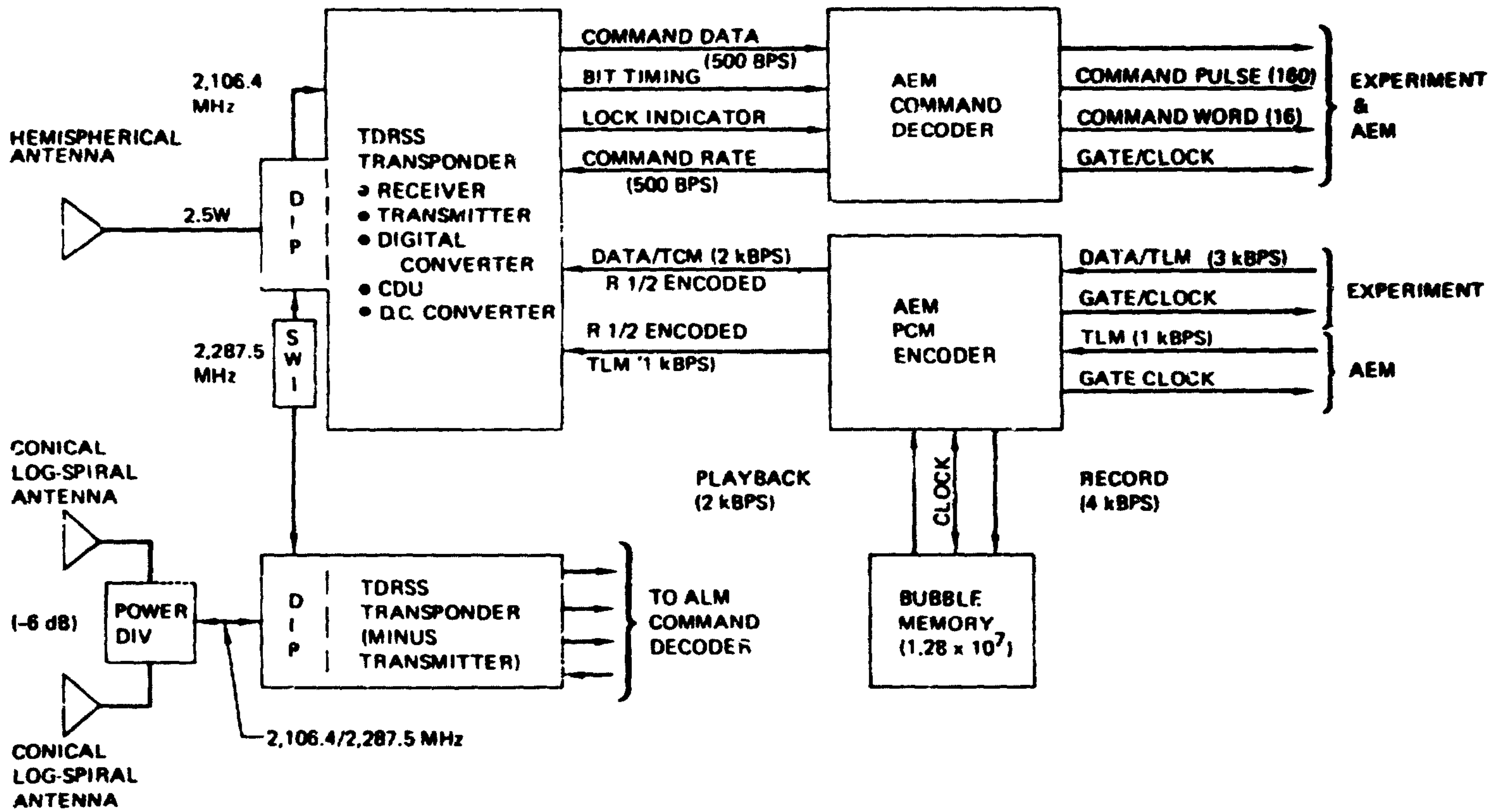
ATREX TT&C SYSTEM

- TDRSS COMPATIBLE
  - / HEMISPHERIC ANTENNA - MULTIPLE ACCESS
  - / CONICAL LOG SPIRAL ANTENNAS - SINGLE ACCESS
- TELEMETRY
  - / BIT RATE
    - REAL TIME - 16 KBPS
    - RECORDED DATA - 32 KBPS
  - / TRANSMITTED SIMULTANEOUSLY USING TDRSS
    - SINGLE ACCESS I AND Q CHANNELS
  - / FORMAT
    - 1024 BIT MINOR FRAME (128 WORDS)
    - NUMBER OF SUBCOMS UNKNOWN
  - / TELEMETRY LIST NOT AVAILABLE
    - PROBABLY INCLUDES 80% OF MONITORS NEEDED FOR BASELINE ON-ORBIT CHECKOUT

- ATREX COMMANDING
  - / 500 BPS
  - / 16 COMMAND WORDS
  - / 160 PULSE COMMANDS
  - / COMMAND WORDS TELEMETERED TO GROUND FOR VERIFICATION

- ATREX TELEMETRY
  - / 1 KBPS OR 2 KBPS
  - / CONVOLUTIONAL ENCODING FOR ERROR CORRECTION
  - / RECORDED DATA DUMP AT 50 KBPS
  - / TELEMETRY DATA
    - 104 ANALOG WORDS
    - 20 THERMISTOR WORDS
    - 128 BILEVEL POINTS

ATREX COMMUNICATION AND DATA-HANDLING SUBSYSTEM BLOCK DIAGRAM



TT&C SUBSYSTEM TESTS – BASELINE ATREX - I

Subsystem Element	On-Orbit Tests: For:	Measurements: Primary	Measurements: Backup	Payload And Test Location: In Bay	Payload And Test Location: Standoff
• Transponder (TDRS Low Rate) Omni, Coupling, PCM Encoder, Command Decoder	• Aliveness, General Performance • Status Data Readout	• Link Established • PN Code • Compare to Normal Values • Command/Response	• Diagnostics • Alternate Commands	R[1]	
• Transponder (TDRS Normal Rate - 50 kbps), Parabola, Antenna Steering, Coupling	• Performance • Status Data Readout	• Command/Response • Compare to Normal/Expected Values	• Alternate Commands • Diagnostics	B[1,2]	
• Transponder (TDRS High Data Rate)	• Performance	• Compare to Normal/Expected Values	• Diagnostics	B[1,2]	
• Command Recorder	• Performance	• Record and Execute Recorded Commands for Antenna Steering	• Diagnostics	B[1]	

(1) Baseline is by TDRSS
(2) If antenna deployment and steering are permitted

Note: R = Required Test
B = Baseline Test

TT&C SUBSYSTEM TESTS – BASELINE ATREX - II

Subsystem Element	On-Orbit Tests			Payload And Test Location	
	For:	Measurements: Primary	Measurements: Backup	In Bay	Standoff
• Tape Recorder	• Function	• Comparison of Data Stream Recorded at Ground Station with Playback of Data Stream from Recorder	• Diagnostics	B(1)	
	• End of Tape	• Telemetry Signal	• Operate Recorder	B(1)	
• Transponder STDN	• Aliveness, General Performance	• Establish Link Command/Response	• Diagnostics	B(2)	
	• Range Signal Turn-Around and Coherent Drive	• Received Range Signal and RF Shift	• Diagnostics	B(2)	
• TT&C	• Satellite Subsystems and Mission-Peculiar Checkout	• See Appropriate Tests		R/B(3)	R/B(3)
		• Compare to Normal Values	• Diagnostics		
	• Fault Isolation Between TT&C and Other Subsystems	• Use Measurements of Related Parameters • Redundant Telemetry Channels		R/B(3)	R/B(3)

(1) Baseline is by TDRSS.
(2) Baseline is by STDN contact.
(3) Dependent on the other subsystem test.

STORMSAT TESTING, ON-ORBIT CHECKOUT

UPDATED TT&C CONSIDERATIONS

- TEST PROCEDURE COMPLICATED BY IUS CHANGES
  - / IUS NO LONGER PIPES COMMANDS THROUGH TO THE PAYLOAD
  - / IUS SENDS PAYLOAD EIGHT ON COMMANDS (16 BITS EACH) AND EIGHT OFF COMMANDS (16 BITS EACH)
  - / IUS TELEMETRY MAIN FRAME RESERVES 40 WORDS FOR PAYLOADS
- RECOMMENDED TEST SEQUENCE, STORMSAT/IUS ATTACHED TO ORBITER
  1. TEST STORMSAT USING UP TO 40 WORDS INTERLEAVED INTO 64 KBPS IUS TELEMETRY
  2. DISCONNECT (USING EVA) THE STORMSAT TT&C FROM THE IUS AND CONNECT TO THE ORBITER (POWER & COMMUNICATIONS)
  3. TEST STORMSAT SUBSYSTEMS
  4. DISCONNECT (USING EVA) STORMSAT FROM THE ORBITER AND RECONNECT TO THE IUS
  5. REPEAT TEST 1 ABOVE

ON-ORBIT CHECKOUT SUBSYSTEM LEVEL STUDIES

ELECTRICAL POWER

AEROSPACE FORM 4253

ELECTRICAL POWER SUBSYSTEM OPERATION

Subsystem Element	On-Orbit Tests: For:	Measurements: Primary	Measurements: Backup	Payload And Test Location: In Bay[1]	Payload And Test Location: Standoff	Test Priority
• Solar Array	• Solar Panels	• Visual Examination[2]	• Array Output & Temps.	All	All	2
	• Deployment Mech.	• Visual Examination	• Array Output & Temps.	---	(4)	1
	• SADA or Slip Rings	• Bus Voltage and Current		All	All	2
• Batteries	• Cell Integrity	• Nom Voltages and Currents	• Voltages & Currents Over Charge/Discharge Range	All	All	1
	• Capacity[3]			All	All	2
	• Voltage			All	All	1
• Power Conditioning And Control	• Battery Charge Rates & Voltages	• Nom Voltages and Current Under One Mode	• Nom Voltages and Currents Under All Modes	All	---	1
	• Voltage Control	• Line Voltages	• Voltage at Diff Rates	All	---	1
	• Power Quality (Regulation)	• Line Voltages	• Voltage at Diff Rates	All	---	1
	• Relay Position And Operation	• Status Verification	• Functional Equip't Check	All	---	1
	• Redundancy	• Status Verification	• Functional Equip't Check	All	---	1
	• Fuses	• Functional Equip't Check	• Continuity Check (3)	All	---	2
• Harness & Distribution	• Integrity	• Functional Equip't Check	• Continuity Check (3)	All	---	2
	• Switches & Relays	• Status Verification	• Functional Equip't Check	All	---	1
	• Fuses	• Functional Equip't Check	• Continuity Check (3)	All	---	2

(1) Payload supported by cradle or platform
(2) Limited to visible portion
(3) In case of suspected problem
(4) All payloads either transported to final orbit by the Shuttle or with retroactive solar arrays.

ON-ORBIT CHECKOUT SUBSYSTEM LEVEL STUDIES

ATTITUDE CONTROL SYSTEM (ACS)

ACS CHECKOUT OPTIONS CONSIDERED FOR STORMSAT

ACS Checkout Option	Shuttle Motion	Shuttle Data At POCC	Method Of Countering A Failure Preventing Normal Retrieval	Spaceborne Test Equipment Required	Comments[1]
Full Checkout with Full Complement of Support Equipment	Any Preplanned 3-Axis Orbiter Rotation	Voice	Before Deployment Test All ACS Components Required for Retrieval	Variable DC Stimulus, Sensor Stimulus[2], & Support Equipment	More Expensive Checkout Than Best Option
Full Checkout with Partial Complement of Support Equipment	Any Preplanned 3-Axis Shuttle Rotation	Voice	Delayed Retrieval for Rare Cases[3]	Variable DC Stimulus and Support Equipment	More Expensive Checkout and Slightly Riskier[4] Than Best Option
Full Checkout Without Support Equipment	Any Preplanned 3-Axis Shuttle Rotation	Voice	Delayed Retrieval for Rare Cases[3]	None	Slightly Riskier[4] Than Best Option
Full Checkout Without Support Equipment	Preplanned[5] Rate-Matching Rotations	Angular Position and Angular Rate Vectors and Time	Before Deployment Test All ACS Components Required for Retrieval	None	Best Option

(1) All test options require orbiter rotational maneuvering in cooperation with the ACS checkout test procedure.
(2) Artificial stimuli such as light-emitting diodes, uncover optics while Stormsat elevated as a backup.
(3) Multiple failures, optical sensors and magnetometer.
(4) Delays most of the tests of the attitude sensors until after deployment.
(5) Assumes Stormsat is retrievable.

STORMSAT ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - I

- ASSUMPTION 1 - STORMSAT AND IUS NOT RETRIEVABLE -- NO TESTING IN STANDOFF POSITION
- BEST ACS TEST OPTION IDENTIFIED - PARTIAL ACS CHECKOUT WITHOUT SPABEBORNE SUPPORT EQUIPMENT
  - / MAIN FEATURES OF THE CHECKOUT
    - NO TEST EQUIPMENT REQUIRED IN ORBITER BAY
    - AlL TESTING ACCOMPLISHED IN SHUTTLE BAY IN HORIZONTAL AND 60-DEGREE ELEVATED POSITIONS
    - ELECTRICAL POWER AND TT&C SUBSYSTEMS CHECKED PRIOR TO ACS TESTING
    - ELEVATED POSITION TESTS
      - TEST IN SHUTTLE RETRIEVAL OR INERTIAL HOLD MODE
      - CHECK OUT THE ELECTRONICS AND REACTION WHEELS
      - COMPARE REDUNDANT GYRO OUTPUTS WITH PRIMARY GYRO OUTPUTS

STORMSAT ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - II

- ELEVATED POSITION TESTS (CONT'D)
  - CHECK MAGNETOMETER OUTPUTS AND CORRESPONDING TORQUER BAR CURRENTS
  - CHECK COARSE SUN SENSOR
  - SELF-TEST STAR TRACKERS (IF FEATURE AVAILABLE)
  - MAY NOT BE ABLE TO REMOVE COVERS OF STAR TRACKERS BECAUSE OF CONTAMINATION
- ASSUMPTION 2 - STORMSAT AND IUS ARE RETRIEVABLE -- STANDOFF POSITION TESTING IS USEFUL
- BEST ACS TEST OPTION IDENTIFIED -- FULL ACS CHECKOUT WITHOUT SPACEBORNE TEST EQUIPMENT
  / IN BAY
  - SAME TESTING IN BAY IN 60-DEGREE ELEVATED POSITIONS AS FOR ASSUMPTION 1
  - IN HORIZONTAL POSITION, USE ANGULAR RATE MATCHING SIMILAR TO LANDSAT TO CHECK ALIGNMENT OF IUS IRU

STORMSAT ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - III

/ IN STANDOFF POSITION

- CHECK STAR TRACKERS FOR ALIVENESS WITH STARS AS TARGETS
- RECHECK COARSE SENSOR FOR ALIVENESS
- CHECK FINE SUN SENSOR FOR ALIVENESS
- PERFORM AN END-TO-END TEST OF THE ACS AND RCS BY MANEUVERING THE PAYLOAD AS EVIDENCED BY THE TELEMETERED INSTRUMENT(S) OUTPUTS
- BACK UP EVIDENCE OF SUCCESSFUL ACS-RCS INTEGRATED TEST OBTAINED BY VISUAL OBSERVATION FROM THE ORBITER OF THE APPROXIMATE ORIENTATION AND ROTATION RATES OF THE MMS
- MONITORING OF MMS NORMAL ON-ORBIT OPERATIONS

ACS CHECKOUT OPTIONS CONSIDERED FOR TDS

ACS Checkout Option	Shuttle Motion	Shuttle Data At POCC	Method Of Countering A Failure Preventing Normal Retrieval	Spaceborne Test Equipment Required	Comments(1)
Full Checkout with Full Complement of Support Equipment	Any Preplanned 3-Axis Orbiter Rotation	Voice	Before Deployment Test All ACS Components Required for Retrieval	Variable DC Stimulus, Sensor Stimulus(2), & Support Equipment	More Expensive Checkout Than Best Option
Full Checkout with Partial Complement of Support Equipment	Any Preplanned 3-Axis Shuttle Rotation	Voice	Delayed Retrieval for Rare Cases(3)	Variable DC Stimulus and Support Equipment	More Expensive Checkout and Slightly Riskier(4) Than Best Option
Full Checkout Without Support Equipment	Any Preplanned 3-Axis Shuttle Rotation	Voice	Delayed Retrieval for Rare Cases(3)	None	Slightly Riskier(4) Than Best Option
Full Checkout Without Support Equipment	Preplanned Rate-Matching Rotations	Angular Position and Angular Rate Vectors and Time	Before Deployment Test All ACS Components Required for Retrieval	None	Best Option

(1) All test options require orbiter rotational maneuvering in cooperation with the ACS checkout test procedure.
(2) Artificial stimuli such as light-emitting diodes, uncover optics while TDS elevated as a backup.
(3) Multiple failures, optical sensors and magnetometer.
(4) Delays most of the tests of the attitude sensors until after deployment.

TDS ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - I

- BEST ACS TEST OPTION IDENTIFIED -- FULL ACS CHECKOUT WITHOUT SPACEBORNE SUPPORT EQUIPMENT
  - / MAIN FEATURES OF THE CHECKOUT
    - NO TEST EQUIPMENT REQUIRED IN ORBITER BAY
    - FAILURE DETECTION BEFORE DEPLOYMENT TO ASSURE SAFE, NORMAL SATELLITE RETRIEVAL ESSENTIAL
    - RETRIEVAL CRITERIA: DEPLOYED SPACECRAFT STABLE AT PRESCRIBED ATTITUDE WITHIN $\pm$ 1 DEGREE IN EACH AXIS AND WITH ANGULAR RATES $\leq$0.1 DEGREE PER SECOND
      - OF THE ACS EQUIPMENT, REQUIRE ONLY INERTIAL REFERENCE UNIT (IRU), ELECTRONICS (INTERFACE ASSEMBLY + REMOTE INTERFACE UNIT + DRIVE ELECTRONICS) TO BE O.K. FOR RETRIEVAL. ACS-RELATED FUNCTIONS OF COMPUTER ALSO MUST BE O.K.
    - IN-BAY TESTING PERFORMED IN THE APPROPRIATE ACS MODE(S)

TDS ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - II

/ MAIN FEATURES OF THE CHECKOUT (CONT'D)

- USE ANGULAR OR RATE MATCHING OF ATTITUDE DATA OF MMS IRUs WITH THOSE OF SHUTTLE IMUs TO DETERMINE THE MISALIGNMENT OF IRUs TO ≤20 MINUTES, 3-SIGMA (ASSUMING NO ERROR IN ORBITER ATTITUDE)
  - ORBITER PERFORMS PRE-PLANNED ROTATIONAL MANEUVERS
  - PROCESSING OF ORBITER AND MMS ATTITUDE DATA BY GROUND COMPUTER USING "RATE MATCHING" TECHNIQUE
  - VERIFICATION OF IRUs BY COMPARISON OF TELEMETERED ATTITUDE AND ATTITUDE RATE DATA OF TWO IRUs WITH SHUTTLE IMUs DURING ANGULAR RATE MATCHING ORBITER ROTATIONAL MANEUVERS
  - MISALIGNMENT COMPENSATION BY INSERTING CORRECTIONS INTO MMS COMMANDS
- VERIFICATION OF ELECTRONICS AND SELECTED MODE, ACS SOFTWARE AT THE SAME TIME BY MONITORING REACTION WHEEL TACHOMETER AND CURRENT TELEMETRY SIGNALS

TDS ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - III

/ MAIN FEATURES OF THE CHECKOUT (CONT'D)

- AFTER DEPLOYMENT, WITH TDS IN THE STANDOFF POSITION, MONITOR TELEMETRY OUTPUTS OF STAR TRACKERS, MAGNETOMETERS, AND SUN SENSORS WHILE THE MMS IS MANEUVERED AS NECESSARY TO PROVIDE PROPER TARGETS FOR THE STAR TRACKER AND FINE SUN SENSOR. THIS COULD BE ACCOMPLISHED WHILE INITIALIZING THE DEPLOYED SATELLITE.
- ALSO, IN THE STANDOFF POSITION, THE TELEMETERED TORQUER BAR CURRENTS ARE MONITORED TO SEE IF THEY ARE PROPER FOR THE MEASURED MAGNETOMETER OUTPUTS. THE RSS'D COMPONENTS OF THE EARTH'S MAGNETIC FIELD ALSO CAN BE CHECKED AGAINST THE PREDICTED B FOR THAT ALTITUDE

/ SEQUENCE OF CHECKOUT TESTS FOR TDS ACS

- PRELAUNCH REHEARSAL
  - TURN ON MMS ACS POWER AND CHECK ACS EQUIPMENT TEMPERATURES, REACTION WHEEL SPEEDS, AND POWER CONSUMPTION IN APPROPRIATE MODE
- ELEVATE PAYLOAD

TDS ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - IV

/ SEQUENCE OF CHECKOUT TESTS FOR TDS ACS (CONT'D)

- TEST PERIOD #1 (COLD)
  - TURN ON MMS ACS POWER AND CHECK ACS EQUIPMENT TEMPERATURE, REACTION WHEEL SPEEDS, AND POWER CONSUMPTION
  - COMMAND MMS TO APPROPRIATE MODE
  - COMPARE OUTPUTS OF TWO IRUs BY TELEMETRY AT THE OPERATIONAL CONTROL CENTER
  - MONITOR TELEMETRY SIGNALS TO VERIFY: IRU OUTPUTS AND REACTION WHEEL SPEEDS CORRESPOND
- LOWER AND REATTACH SATELLITE TO ORBITER
- SHUTTLE EXECUTES PRE-PLANNED MANEUVERS FOR "RATE MATCHING"
  - DURING MANEUVERS:
    - o MMS ACS IN APPROPRIATE MODE
    - o OUTPUT OF TWO IRUs COMPARED
    - o OUTPUT OF IRUs COMPARED TO OUTPUTS OF SHUTTLE IMUs
    - o SPEED AND CURRENTS OF REACTION WHEELS MONITORED
    - o ATTITUDE DATA OR IRUs AND IMUs TELEMETERED TO GROUND
    - o DIFFERENCES IN ATTITUDE CHANGES MEASURED BY IRUs AND IMUs COMPUTED AND IMUs COMPUTED AND DISPLAYED AS REQUIRED

TDS ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - V

- AFTER MANEUVERS:
  - o COMPUTED DIFFERENCES IN ATTITUDE CHANGES COMPENSATED BY:
    - COMMANDING A CHANGE IN STANDOFF ATTITUDE STORED IN MMS COMPUTERS PRIOR TO DEPLOYMENT

      OR

    - COMMAND A CORRECTION IN MMS ATTITUDE AFTER THE STANDOFF POSITION ATTAINED

- STANDOFF TESTS/TEST PERIOD #3
  - MONITORING OF THE MMS NORMAL ON-ORBIT OPERATIONS

/ TEST EQUIPMENT REQUIRED

- NONE

/ ESTIMATED TEST TIME

- TEN (10) MINUTES APPROXIMATELY FOR EACH TEST PERIOD WHILE TDS IS ATTACHED TO THE ORBITER

ACS CHECKOUT OPTIONS CONSIDERED FOR SMS

ACS Checkout Option	SMS Data To and From POCC	Spaceborne Test Equipment Required	Comments
Full Checkout With Full Complement of Support Equipment	From POCC-Selected Commands to POCC-Telemetry	Variable DC Stimulus, Sensor Stimulus(1), and Support Equipment	Much More Expensive Checkout than Best Option. More Complete Checkout than Best Option
Full Checkout With Partial Complement of Support Equipment	SMS Telemetry	Variable DC Stimulus and Support Equipment	More Expensive Than Best Option. Somewhat More Complete Checkout Than Best Option.
Full Checkout Without Support Equipment	Voice	None	Riskier(2) Than Best Option

(1) Artificial stimuli, uncover optics while SMS elevated as a backup.
(2) Delays most of the tests of the attitude sensors until after deployment.

SMS/GOES ATTITUDE CONTROL SUBSYSTEM (ACS) CHECKOUT - I

- CONSTRAINTS
  - / SPIN STABILIZED, SCHRONOUS
  - / USES SPINNING SOLID UPPER STAGE DELTA (SSUS-D)
  - / SMS NOT RETRIEVABLE, THEREFORE NO STANDOFF POSITION TESTS
  - / OOC OF SMS UNATTRACTIVE BECAUSE OF COST OF SPACEBORNE TEST EQUIPMENT RELATIVE TO TOTAL VEHICLE COST
- BEST ACS TEST OPTION IDENTIFIED
  - / MAIN FEATURES OF THE CHECKOUT
    - CHECK TEMPERATURES OF ACS COMPONENTS VIA TELEMETRY
    - CHECK RESPONSE TO COMMANDS WHERE RESPONSE CAN BE OBSERVED ON TELEMETRY SIGNALS
    - SINCE SPACEBORNE TEST EQUIPMENT IS PROHIBITED, THERE IS NO FEASIBLE WAY TO CHECK THE ACS EQUIPMENT ON ORBIT IN THE BAY

SMS/GOES ATTITUDE CONTROL SUBSYSTEM (ACS) CHECKOUT - II

/ SEQUENCE OF CHECKOUT TESTS

- PRE-LAUNCH REHEARSAL
  - TURN ON SPACECRAFT ACS POWER IN APPROPRIATE MODE, CHECK ACS EQUIPMENT TEMPERATURES
  - CHECK RESPONSE TO COMMANDS
  - RETURN TO APPROPRIATE MODE FOR BOOST
- TEST PERIOD #1 (COLD)
  - CHECK TEMPERATURES OF ACS COMPONENTS
  - CHECK RESPONSE TO COMMANDS
- TEST PERIOD # 2 (HOT)
  - REPEAT TEST PERIOD #1 TESTS
  - RETURN TO APPROPRIATE MODE FOR DEPLOYMENT

/ TEST EQUIPMENT REQUIRED

- NONE

/ ESTIMATED TEST TIME

- LESS THAN 1/2 HOUR DEPENDING ON NUMBER OF COMMANDS

PARTIAL CHECKOUT OF SMS

- PARTIAL CHECKOUT
  - / PARTIAL CHECKOUT HERE MEANS NO STANDOFF POSITION TESTS AND SPACEBORNE TEST EQUIPMENT NOT USED. THIS IS THE BEST ACS TEST OPTION
- ADVANTAGES
  - / LEAST COST OF ON-ORBIT CHECKOUT OPTIONS
  - / CHECKS RESPONSE OF SOME COMMANDS
  - / NO REQUIREMENT FOR SPACEBORNE TEST EQUIPMENT; HENCE MINIMUM COST
  - / CHECKS TEMPERATURES OF ACS COMPONENTS
- DISADVANTAGES
  - / NO CHECKOUT OF ACS COMPONENTS FUNCTIONALLY (EXCEPT FOR RESPONSE OF SOME COMMANDS) NOR PERFORMANCE-WISE; HENCE MINIMUM DETECTION OF FAULTS
- RECOMMENDATION
  - / RECOMMEND THAT THIS MINIMUM CHECKOUT BE PERFORMED BECAUSE ALTHOUGH IT IS NOT VERY DISCERNING, ITS COST WITH RESPECT TO MONEY AND TIME IS THE LOWEST OF TEST OPTIONS

ACS CHECKOUT OPTIONS CONSIDERED FOR LANDSAT

ACS Checkout Option	Shuttle Motion	Shuttle Data At POCC	Method Of Countering A Failure Preventing Normal Retrieval	Spaceborne Test Equipment Required	Comments[1]
Full Checkout with Full Complement of Support Equipment	Any Preplanned 3-Axis Orbiter Rotation	Voice	Before Deployment Test All ACS Components Required for Retrieval	Variable DC Stimulus, Sensor Stimulus[2], & Support Equipment	More Expensive Checkout Than Best Option
Full Checkout with Partial Complement of Support Equipment	Any Preplanned 3-Axis Shuttle Rotation	Voice	Delayed Retrieval for Rare Cases[3]	Variable DC Stimulus and Support Equipment	More Expensive Checkout and Slightly Riskier[4] Than Best Option
Full Checkout Without Support Equipment	Any Preplanned 3-Axis Shuttle Rotation	Voice	Delayed Retrieval for Rare Cases[3]	None	Slightly Riskier[4] Than Best Option
Full Checkout Without Support Equipment	Preplanned Rate-Matching Rotations	Angular Vector and Time	Before Deployment Test All ACS Components Required for Retrieval	None	Best Option

(1) All test options require orbiter rotational maneuvering in cooperation with the ACS checkout test procedure.
(2) Artificial stimuli such as light-emitting diodes, uncover optics while Landsat elevated as a backup.
(3) Multiple failures, optical sensors and magnetometer.
(4) Delays most of the tests of the attitude sensors until after deployment.

EXAMPLE CASES OF ACS INFANT MORTALITY LEADING TO MMS SATELLITE (LANDSAT, TDS, STORMSAT) RETURN FOR REPAIRS

(FAILURES ARE DETECTED BY ONE MEASUREMENT AND CONFIRMED BY ANOTHER)

- FAILURE TO UNCOVER OPTICS OF STAR TRACKERS
- STAR TRACKERS INOPERATIVE
- COARSE OR FINE SUN SENSORS INOPERATIVE
- FAILURE OF SAME AXIS IN TWO GYROS
- FAILURE OF TWO REACTION WHEELS
- FAILURE TO TRANSFER SHUTTLE IMU AND/OR MMS IRU ATTITUDE AND ATTITUDE RATE DATA
- ABNORMAL ACS COMPONENT TEMPERATURES
- COMPUTERS INOPERATIVE
- ACS REMOTE INTERFACE UNIT INOPERATIVE
- INTERFACE AND/OR DRIVE ELECTRONICS INOPERATIVE
- MAGNETOMETER INOPERATIVE
- MAGNETIC TORQUERS INOPERATIVE

LANDSAT D ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - I

- BEST ACS TEST OPTION IDENTIFIED -- FULL ACS CHECKOUT WITHOUT SPACE-BORNE SUPPORT EQUIPMENT
- MAIN FEATURES OF THE CHECKOUT
  - NO TEST EQUIPMENT REQUIRED IN ORBITER BAY
  - FAILURE DETECTION BEFORE DEPLOYMENT TO ASSURE SAFE, NORMAL SATELLITE RETRIEVAL ESSENTIAL
  - RETRIEVAL CRITERIA: DEPLOYED SPACECRAFT STABLE AT PRESCRIBED ATTITUDE WITHIN $\pm$ 1 DEGREE IN EACH AXIS AND WITH ANGULAR RATES $\leq$0.1 DEGREE PER SECOND
    - OF THE ACS EQUIPMENT, REQUIRE ONLY INERTIAL REFERENCE UNIT (IRU), ELECTRONICS (INTERFACE ASSEMBLY + REMOTE INTERFACE UNIT + DRIVE ELECTRONICS), AND REACTION WHEELS TO BE O.K. FOR RETRIEVAL. ACS-RELATED FUNCTIONS OF COMPUTER ALSO MUST BE O.K.
  - IN-BAY TESTING PERFORMED IN THE APPROPRIATE ACS MODE(S)

LANDSAT D ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - II

- MAIN FEATURES OF THE CHECKOUT (CONT'D)
  - / USE ANGULAR OR RATE MATCHING OF ATTITUDE DATA OF MMS IRUs WITH THOSE OF SHUTTLE IMUs TO DETERMINE THE MISALIGNMENT OF IRUs TO ≤20 MINUTES, 3-SIGMA (ASSUMING NO ERROR IN ORBITER ATTITUDE)
    - ORBITER PERFORMS PRE-PLANNED ROTATIONAL MANEUVERS
    - PROCESSING OF ORBITER AND MMS ATTITUDE DATA BY GROUND COMPUTER USING "RATE MATCHING" TECHNIQUE
    - VERIFICATION OF IRUs BY COMPARISON OF TELEMETERED ATTITUDE AND ATTITUDE RATE DATA OF TWO IRUs WITH SHUTTLE IMUs DURING ANGULAR RATE MATCHING ORBITER ROTATIONAL MANEUVERS
    - MISALIGNMENT COMPENSATION BY INSERTING CORRECTIONS INTO MMS COMMANDS
  - / VERIFICATION OF ELECTRONICS AND SELECTED MODE, ACS SOFTWARE AT THE SAME TIME BY MONITORING REACTION WHEEL TACHOMETER AND CURRENT TELEMETRY SIGNALS

LANDSAT D ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - III

/ AFTER DEPLOYMENT, WITH LANDSAT IN THE STANDOFF POSITION, MONITOR TELEMETRY OUTPUTS OF STAR TRACKERS, MAGNETOMETERS, AND SUN SENSORS WHILE THE MMS IS MANEUVERED AS NECESSARY TO PROVIDE PROPER TARGETS FOR THE STAR TRACKER AND FINE SUN SENSOR. THIS COULD BE ACCOMPLISHED WHILE INITIALIZING THE DEPLOYED SATELLITE

/ ALSO IN THE STANDOFF POSITION, THE TELEMETERED TORQUER BAR CURRENTS ARE MONITORED TO SEE IF THEY ARE PROPER FOR THE MEASURED MAGNETOMETER OUTPUTS. THE RSS'D COMPONENTS OF THE EARTH'S MAGNETIC FIELD CAN ALSO BE CHECKED AGAINST THE PREDICTED B FOR THAT ALTITUDE

- SEQUENCE OF CHECKOUT TESTS FOR LANDSAT ACS

  / PRE-LAUNCH REHEARSAL

  - TURN ON MMS ACS POWER AND CHECK ACS EQUIPMENT TEMPERATURES, REACTION WHEEL SPEEDS, AND POWER CONSUMPTION IN APPROPRIATE MODE

  / ELEVATE PAYLOAD (AFTER FLIGHT TO ORBIT AND PAYLOAD BAY DOORS OPEN)

LANDSAT D ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - IV

/ TEST SATELLITE (COLD)

- TURN ON MMS ACS POWER AND CHECK ACS EQUIPMENT TEMPERATURE, REACTION WHEEL SPEEDS, AND POWER CONSUMPTION
- COMMAND MMS INTO APPROPRIATE MODE
- COMPARE OUTPUTS OF TWO IRUs BY TELEMETRY AT THE OPERATIONAL CONTROL CENTER
- MONITOR TELEMETRY SIGNALS TO VERIFY: IRU OUTPUTS AND REACTION WHEEL SPEEDS CORRESPOND

/ LOWER AND RELATCH SATELLITE TO ORBITER

/ SHUTTLE EXECUTES PRE-PLANNED MANEUVERS FOR "RATE MATCHING"

- DURING MANEUVERS:
  - MMS ACS IN APPROPRIATE MODE
  - OUTPUT OF TWO IRUs COMPARED
  - OUTPUT OF IRUs COMPARED TO OUTPUTS OF SHUTTLE IMUs
  - SPEED AND CURRENTS OF REACTION WHEELS MONITORED
  - ATTITUDE DATA OF IRUs AND IMUs TELEMETERED TO GROUND
  - DIFFERENCES IN ATTITUDE CHANGES MEASURED BY IRUs AND IMUs COMPUTED AND DISPLAYED AS REQUIRED

LANDSAT D ATTITUDE CONTROL SYSTEM (ACS) CHECKOUT - V

- AFTER MANEUVERS:
  - COMPUTED DIFFERENCES IN ATTITUDE CHANGES COMPENSATED BY:
    - o COMMANDING A CHANGE IN STANDOFF ATTITUDE STORED IN MMS COMPUTERS PRIOR TO DEPLOYMENT

      OR

    - o COMMANDING A CORRECTION IN MMS ATTITUDE AFTER THE STANDOFF POSITION ATTAINED
- / STANDOFF TESTS/TEST PERIOD
  - MONITORING OF THE MMS NORMAL ON-ORBIT OPERATIONS
- TEST EQUIPMENT REQUIRED
  - / NONE
- ESTIMATED TEST TIME
  - / TEN (10) MINUTES APPROXIMATELY FOR EACH TEST PERIOD WHILE LANDSAT IS ATTACHED TO THE ORBITER

ACS CHECKOUT OPTIONS CONSIDERED FOR ATREX

ACS Checkout Option	Shuttle Motion	Shuttle Data At POCC	Method Of Countering A Failure Preventing Normal Retrieval	Spaceborne Test Equipment Required	Comments[1]
Full Checkout Without Support Equipment	Any Preplanned 3-Axis Shuttle Rotation	Voice	Delayed Retrieval for Rare Cases[2]	None	Slightly Riskier[3] Than Best Option
Full Checkout Without Support Equipment	Preplanned Rate-Matching Rotations	Angular Position and Angular Rate Vectors and Time	Before Deployment Test All ACS Components Required for Retrieval	None	Best Option

(1) All test options require orbiter rotational maneuvering in cooperation with the ACS checkout test procedure.

(2) Multiple failures, optical sensors, and magnetometer.

(3) Delays most of the tests of the attitude sensors until after deployment.

ATREX ATTITUDE CONTROL SUBSYSTEM (ACS) CHECKOUT - I

- ASSUMPTIONS
  - PER GSFC PRELIMINARY SYSTEMS DESIGN GROUP, NO TESTING WITH SIMULATED SIGNALS EXTERNAL TO THE SATELLITE PERMITTED; HENCE TESTING IS WITHOUT EXTERNAL TEST EQUIPMENT
  - ATREX ASSUMED TO BE RETRIEVABLE
- BEST ACS TEST OPTION -- FULL ACS CHECKOUT WITHOUT SPACEBORNE SUPPORT EQUIPMENT
  - MAIN FEATURES OF THE CHECKOUT
    - FAILURE DETECTION BEFORE DEPLOYMENT ESSENTIAL TO ASSURE SAFE, NORMAL SATELLITE RETRIEVAL
      - NORMAL RETRIEVAL CRITERIA: DEPLOYED SPACECRAFT STABLE AT PRESCRIBED ATTITUDE WITHIN $\pm$ 1 DEGREE IN EACH AXIS WITH ANGULAR RATES $\leq$ 0.1 DEG/SEC
      - THE ONLY ACS EQUIPMENT REQUIRED FOR RETRIEVAL IS THE GYRO PACKAGE, THE CONTROL PROCESSOR AND INTERFACE UNIT (CPIU), AND THE REACTION WHEELS
    - CPIU SELF-CHECKED

ATREX ATTITUDE CONTROL SUBSYSTEM (ACS) CHECKOUT - II

MAIN FEATURES OF THE CHECKOUT (CONTINUED)

- ALIGNMENT OF THE GYRO PACKAGE AND CHECKOUT OF THE GYRO PACKAGE -- CPIU + SOFTWARE (PARTIAL) + REACTION WHEELS BY ANGULAR RATE MATCHING SIMILAR TO LANDSAT
- AFTER DEPLOYMENT, WITH ATREX IN THE STANDOFF POSITION, THE TELEMETERED OUTPUTS OF THE STAR TRACKER ARE MONITORED
- ALSO IN THE STANDOFF POSITION, ALL THE ATREX ACS TELEMETERED SIGNALS ARE MONITORED FOR NORMAL ACS ON-ORBIT OPERATION
- IN THE STANDOFF POSITION, THE TELEMETERED ELECTROMAGNET CURRENTS ARE MONITORED TO SEE IF THEY ARE PROPER FOR THE MEASURED MAGNETOMETER OUTPUTS. ALSO THE RSS'D COMPONENTS OF THE EARTH'S MEASURED MAGNETIC FIELD CAN BE CHECKED AGAINST THE PREDICTED B FOR THAT ALTITUDE

/ SEQUENCE

- PRELAUNCH REHEARSAL
  - SELF-CHECK CPIU
  - PARTIAL CHECK OF IRU BY COMPARISON BETWEEN REDUNDANT AXIS
  - SELF-CHECK STAR TRACKER[1]

(1) If Capability Exists

ATREX ATTITUDE CONTROL SUBSYSTEM (ACS) CHECKOUT - III

SEQUENCE - PRELAUNCH REHEARSAL (CONTINUED)

- SIMULATE SHUTTLE ANGULAR RATE MATCHING MANEUVERS BY TORQUING SHUTTLE IMUs AND THE ATREX GYROS. THIS CHECKS OUT THE GYROS, THE CPIU (PARTIALLY), SOFTWARE (PARTIALLY), AND REACTION WHEELS

- TEST PERIOD #2 (HOT)
  - REPEAT THE FOLLOWING:
    - a) PARTIAL RECHECK OF IRU COMPARED TO REDUNDANT AXIS SIGNAL
    - b) SELF-CHECK CPIU
    - c) SELF-CHECK MAGNETOMETER(1)
    - d) CHECK REACTION WHEEL SPEEDS AND CURRENTS PROPER FOR EXISTING IRU OUTPUTS
- MONITOR TRANSFER OF ORBITER STATE VECTOR DATA TO ATREX USING RATE MATCHING TECHNIQUES
- DURING ORBITER MANEUVERS
  - OUTPUT OF IRU REDUNDANT AXIS COMPARED WITH APPROPRIATE IRU OUTPUT

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(1) If Capability Exists

ATREX ATTITUDE CONTROL SUBSYSTEM (ACS) CHECKOUT - IV

SEQUENCE - PRELAUNCH REHEARSAL (CONTINUED)

- TEST PERIOD #3 (COLD)
  - SELECT ON-ORBIT ACS OPERATING MODE
  - RECHECK IRU WITH REDUNDANT AXIS CHANNEL
  - SELF-CHECK CPIU
  - SELF-CHECK STAR TRACKER
  - CHECK REACTION WHEEL SPEEDS AND CURRENTS PROPER FOR THE EXISTING IRU OUTPUTS

/ ESTIMATED TEST TIME

- APPROXIMATELY 10 MINUTES FOR EACH TEST PERIOD

TESTS MISSED IF ATREX NOT RETRIEVABLE

- ASSUMPTION - ATREX IS NOT RETRIEVABLE; THEREFORE ON-ORBIT CHECKOUT MUST BE COMPLETED BEFORE DEPLOYMENT. SHUTTLE DOES NOT HAVE A TILT TABLE NOR AN RMS.

- IN SUMMARY, THE TESTS MISSED IF ATREX IS NOT RETRIEVABLE ARE THOSE CONDUCTED ON THE RMS AND IN THE STANDOFF POSITION. THESE TESTS ARE:
  - / CHECK OF THE MAGNETOMETER AND ELECTROMAGNETS
  - / CHECK OF THE STAR TRACKERS

- RECOMMENDATION ON PARTIAL CHECKOUT:
  - / THE CHECKOUT IF THE ATREX IS NOT RETRIEVABLE IS CONSIDERED TO BE WORTHWHILE EVEN THOUGH IT IS ONLY PARTIAL. IT DOES CHECK THE GYRO PACKAGE, THE CPIU, AND THE REACTION WHEELS. THE VALUE OF THE PARTIAL CHECK IS ENHANCED CONSIDERABLY IF THE STAR TRACKERS HAVE A SELF-TEST FEATURE. ALSO, IT COSTS ONLY THE COMPLICATION OF REQUIRING TWO SHUTTLE MANEUVERS. NO TEST EQUIPMENT IS NEEDED.

EXAMPLE CASES OF ACS INFANT MORTALITY LEADING TO ATREX SATELLITE RETURN FOR REPAIRS

(FAILURES ARE DETECTED BY ONE MEASUREMENT AND CONFIRMED BY ANOTHER)

- ABNORMAL ACS COMPONENT TEMPERATURES
- FAILURE OF A NON-REDUNDANT GYRO AXIS
- FAILURE OF CPIU
- FAILURE OF A REACTION WHEEL
- FAILURE OF BOTH STAR TRACKERS
- FAILURE OF ELECTROMAGNETS
- FAILURE OF MAGNETOMETER
- FAILURE TO TRANSFER ATTITUDE DATA FROM ORBITER

SATELLITE REQUIREMENTS IMPOSED BY ACS ON-ORBIT CHECKOUT

- OPEN AND CLOSED CYCLE FOR OPTICS COVERS GOOD FOR SEVERAL CYCLES (INSTEAD OF ONE)

- PRESCRIBED ORBITER MANEUVERS REQUIRED FOR RATE MATCHING

- BUILT-IN TEST EQUIPMENT

  / RECOMMEND SELF CHECK OF STAR TRACKERS WITH REDUNDANT INTERNAL ARTIFICIAL LIGHT SOURCES FOR NON-RETRIEVABLE PAYLOAD SPACECRAFT

ANGULAR RATE MATCHING

FOR ALIGNMENT OF SATELLITE IRU

ALIGNMENT TRANSFER BY ANGULAR RATE MATCHING FOR LANDSAT - I

- PURPOSE IS TO ALIGN LANDSAT IRU ACCURATELY ENOUGH TO SUPPORT SATELLITE RETRIEVAL

- FIRST COARSELY ESTABLISH (PRIOR TO LAUNCH OR ON ORBIT):

    1. ORBITER VEHICLE REFERENCE TO ORBITER IMU REFERENCE ALIGNMENT

    2. LANDSAT (MMS) VEHICLE REFERENCE TO ORBITER VEHICLE REFERENCE ALIGNMENT

    3. LANDSAT (MMS) INERTIAL REFERENCE UNIT TO LANDSAT (MMS) VEHICLE REFERENCE ALIGNMENT

ALIGNMENT TRANSFER BY ANGULAR RATE MATCHING FOR LANDSAT - II

- SECOND UPDATE THE KNOWLEDGE OF THE LANDSAT (MMS/IRU) ATTITUDE REFERENCE SUFFICIENT THAT IT COULD BE USED TO CONTROL THE LANDSAT FOR POSSIBLE RETRIEVAL SHORTLY AFTER DEPLOYMENT BY THE ORBITER

  1. ROTATE THE ORBITER, WITH LANDSAT RIGIDLY ATTACHED(1)

  2. COMPARE THE ROTATION VECTORS DURING CERTAIN INTERVALS AS MEASURED BY THE ORBITER IMU AND LANDSAT (MMS) IRU

  3. COMPUTE CORRECTIONS APPLICABLE TO THE LANDSAT IRU BY USE OF COVARIANCE ANALYSIS PROGRAM

- NOTE THAT ATTITUDE DATA AND TIMING DATA ARE TELEMETERED TO THE GROUND FOR THE ORBITER AND FOR LANDSAT

  / PROCESSING WOULD BE ACCOMPLISHED BY GROUND COMPUTER AT THE POCC

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(1) ROTATIONAL RATES ON THE ORDER OF 0.5 DEGREE PER SECOND, ROTATION IN ABOUT TWO BODY AXES

MMS PRE-DEPLOYMENT INERTIAL REFERENCE UNIT CHECKOUT

ORBITER PERTINENT TELEMETRY CHARACTERISTICS

- ATTITUDE DATA
  - 3 IMUs
    - X, Y, Z GYRO READOUTS FROM EACH, TWO 8-BIT WORDS BOTH 22.5 DEGREES AND 360 DEGREES FULL-SCALE READINGS, TEN SAMPLES PER SECOND PER GYRO
    - E. G., IMU-1 THETA X (ID # VH2080B, V71H2100B)
- TIME DATA
  - TWO SOURCES; DAY, HOURS, MINUTE, SECOND, MILLISECOND READOUTS (GMT); FIVE SAMPLES PER SECOND PER SOURCE

MMS PRE-DEPLOYMENT INERTIAL REFERENCE UNIT CHECKOUT

PERTINENT TELEMETRY CHARACTERISTICS OF MMS

- TIME DATA
  - / THREE WORDS, 1 SECOND LEAST SIGNIFICANT BIT
    - 8 LEAST SIGNIFICANT BITS - WORD 63 OF MINOR FRAME
    - 16 MOST SIGNIFICANT BITS - ONCE PER SUBCOM. CYCLE
- ATTITUDE DATA
  - / X, Y, Z GYRO READOUTS
    - ONE WORD EACH
    - ONCE PER SUBCOM CYCLE
- REPORTING FREQUENCY

TELEMETRY BIT RATE (KBPS)	READOUT FREQUENCY	
	ATTITUDE (SEC)	TIME (RDG./SEC)
2	Every 65.536	2
16	Every 8.192	15
64	Every 2.048	60

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ON-ORBIT CHECKOUT SUBSYSTEM LEVEL STUDIES

THERMAL CONTROL

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THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE
ATREX SATELLITE, EMPHASIS ON SHORTENED TEST DURATION PRIOR TO SATELLITE DEPLOYMENT

Operation	Conditions	Rationale	Thermal Tests And Components Checked	Thermal Instrumentation
1. Cargo Bay Doors Opened	Parking Orbit(1)	Drive Satellite Heaters On and Prepare for Cool Satellite Tests	Heater/Thermostat Activation, Check Thermostats for Dither, Check Louver Travel (Closing), Check for Cold Spots	Thermocouples, Heater On-Off Indicators, Potentiometers(2)
2. Set Attitude of Orbiter for Satellite to Cool Down	———			
3. Satellite Cooling Down	Satellites in Shadow of Orbiter			
4. Power Up Satellite and Test (Initially Cool)	Satellite Heaters On (Initially)	Check Satellite Equipment, Cold Start & Operation	———	———
5. Perform Rate Matching Test	Dark Side	ACS Test	———	———
6. Deploy Satellite	———	———	———	———
7. Operate Satellite	Standoff(3)	Set Env. Conds. for Warm Tests, Drive Louvers Open, Heaters Off	Heater Shutdown, Louver Travel (Opening)	Thermocouples, Potentiometers(2) Heater On-Off Indication
8. Satellite Warming Up	Standoff(3)			
9. Test Warm Satellite	Standoff(3)	Warm Satellite Thermal Checks	Check for Hot Spots	Thermocouples

(1) No sun on payloads in the bay.
(2) On louvers.
(3) Position ATREX so that solar heating on louver radiation is within design tolerances.

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THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE
ATREX SATELLITE, EMPHASIS ON TESTING PRIOR TO SATELLITE DEPLOYMENT

Operation	Conditions	Rationale	Thermal Tests And Components Checked	Thermal Instrumentation
1. Cargo Bay Doors Opened	Parking Orbit[1]	Drive Louvers Closed, Heaters On	Louver Travel (Closing) Heater/Thermostat Activation	Potentiometers,[2] Thermocouples, Heater Off Indicators
2. Set Attitude of Orbiter for Satellite to Cool Down	——			
3. Satellite Cooling Down	Satellite in Shadow of Orbiter			
4. Power Up Satellite and Test (Initially Cool)	Satellite Heaters On (Initially)	Test Subsystems	——	——
5. Satellite Warming Up	——	Drive Louvers Open and Heaters Off, Test Subsystems	Louver Travel (Opening) and Heater Shutdown and Dither	Potentiometers,[2] Thermocouples, Heater On-Off Indicators
6. Test Warm Satellite	——			
7. Deploy Satellite	——	——	——	——
8. Continue Warm Tests	Standoff	Warm Satellite Thermal Checks	Check for Hot Spots	Thermocouples

(1) No Sun on Payloads in the Bay (2) On Louvers

THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE
TDS, EMPHASIS ON SHORTENED TEST DURATION PRIOR TO DEPLOYMENT

Operation	Conditions	Rationale	Thermal Tests And Components Checked	Thermal Instrumentation
1. Cargo Bay Doors Opened	Parking Orbit(1)	Set Environmental Heat Loads for Cool Conditions, Drive Heaters On and Prepare for Cool Satellite Tests	Heater/Thermostat Activation, Check Thermostats for Dither, Check Louver Travel (Closing)	Thermocouples, Heater On-Off Indicators, Potentiometer(2)
2. Set Attitude of Orbiter for Satellite to Cool	Parking Orbit(1)			
3. Rotate Satellite to Elevated Position in Bay	Dark Side, Satellite Powered Dn.			
4. Satellite Cooling Down	Satellite in Shadow or Orbiter		Check for Cold Spots	
5. Power Up Satellite(3) and Test (Cool)	Satellite Cool, Heaters On (Initially)(1)	Check Satellite Equipment Cold Start and Operation(3)	——	——
6. Rotate Satellite to Lowered Position and Latch	Satellite Still Attached to Orbiter in Parking Orbit(1)	ACS Test		
7. Perform Rate Matching Test	Dark Side(1)			
8. Deploy & Operate Sat.	Standoff(4)	Set Env. Conds. for Warm Tests, Drive Louvers Open, Heaters Off	Heater Shutdown, Louver Travel (Opening)	Heater-Off Indicators, Thermocouples, Potentiometers(2)
9. Satellite Warming Up	Standoff(4)			
10. Test (Warm)	Standoff(4)	Warm Satellite Thermal Checks	Check for Hot Spots	Thermocouples

(1) No sun on other payloads in bay.
(2) On louvers.
(3) Except for equipment subject to arcing or glow.
(4) Position TDS so that the sun on the louvered radiator is within design tolerances.

THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE
TDS, EMPHASIS ON TESTING PRIOR TO SATELLITE DEPLOYMENT

Operation	Condition	Rationale	Thermal Tests And Components Checked	Thermal Instrumentation
1. Cargo Bay Doors Opened	Parking Orbit[1]	Set Environmental Heat Loads for Warm Tests Drive Louvers Open and Heaters Off	Louver Travel (Opening) Heater/Thermostat Shutdown	Potentiometers[2] Thermocouples Heater Off Indicators
2. Rotate Satellite to Elevated Position in Cargo Bay	Parking Orbit[1]			
3. Set Attitude of Orbiter for TDS to Warm Up	Sun[3] on TDS[1]			
4. Equipment Power Up and Warm Up Satellite	Sun[3] on TDS[1]			
5. Continue Satellite Operation and Checkout Tests	Satellite Warm Louvers Open	Test Subsystems (4)	Check for Hot Spots	Thermocouples
6. Change Attitude of Orbiter for TDS to Cool Down	Parking Orbit[1]	Set Environmental Heat Loads for Cool Case, Drive Louvers Closed, Heaters On	Heater/Thermostat Activation, Check Thermostats for Dither, Check Louver Travel (Closing)	Thermocouples Heater On-Off Indicators Potentiometers[2]
7. Equipment Power Down and Cool Off Satellite	Satellites in Shadow of Orbiter			
8. Power Up and Operate Satellite for Checkout Tests	Satellite Cool, Heaters On (Initially)[1]	Test Subsystems	Check Satellite Equip. Cold Start Capability & Equip Operation, Heater Operation, Check for Cold Spots	Thermocouples

(1) No Sun on Other Payloads in the Bay
(2) On Louvers
(3) On Light Side as Required for TDS to Warm Up
(4) Except for Equipment Subject to Arcing and Glow

THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE
LANDSAT D, EMPHASIS ON SHORTENED TEST DURATION PRIOR TO DEPLOYMENT

Operation	Conditions	Rationale	Thermal Tests And Components Checked	Thermal Instrumentation
1. Cargo Bay Doors Opened	Parking Orbit(1)	Set Environmental Heat Loads for Cool Conditions, Drive Heaters On and Prepare for Cool Satellite Tests	Heater/Thermostat Activation, Check Thermostats for Dither, Check Louver Travel (Closing) Check for Cold Spots	Thermocouples, Heater On-Off Indicators, Potentiometer(2)
2. Set Attitude of Orbiter for Satellite to Cool	Parking Orbit(1)			
3. Rotate Satellite to Elevated Position in Bay	Dark Side, Satellite Powered On.			
4. Satellite Cooling Down	Satellite in Shadow or Orbiter			
5. Power Up Satellite(3) and Test (Cool)	Satellite Cool, Heaters On (Initially)(1)	Check Satellite Equipment Cold Start and Operation(3)	———	———
6. Rotate Satellite to Lowered Position and Latch	Satellite Still Attached to Orbiter in Parking Orbit(1)	ACS Test		
7. Perform Rate Matching Test	Dark Side(1)			
8. Deploy & Operate Sat.	Standoff	Set Env. Conds. for Warm Tests, Drive Louvers Open, Heaters Off	Heater Shutdown, Louver Travel (Opening)	Heater-Off Indicators, Thermocouples, Potentiometers(2)
9. Satellite Warming Up	Standoff			
10. Test (Warm)	Standoff	Warm Satellite Thermal Checks	Check for Hot Spots	Thermocouples

(1) No Sun on Other Payloads in Bay (2) On Louvers (3) Except for Equipment Subject to Arcing or Glow

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THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE
LANDSAT D, EMPHASIS ON TESTING PRIOR TO SATELLITE DEPLOYMENT

Operation	Condition	Rationale	Thermal Tests And Components Checked	Thermal Instrumentation
1. Cargo Bay Doors Opened	Parking Orbit(1)	Set Environmental Heat Loads for Warm Tests Drive Louvers Open and Heaters Off	Louver Travel (Opening) Heater/Thermostat Shutdown	Potentiometers(2) Thermocouples Heater Off Indicators
2. Rotate Satellite to Elevated Position in Cargo Bay	Parking Orbit(1)			
3. Set Attitude of Orbiter for Landsat to Warm Up	Sun(3) on Landsat(1)			
4. Equipment Power Up and Warm Up Satellite	Sun(3) on Landsat(1)			
5. Continue Satellite Operation and Checkout Tests	Satellite Warm Louvers Open	Test Subsystems (4)	Check for Hot Spots	Thermocouples
6. Change Attitude of Orbiter for Landsat to Cool Down	Parking Orbit(1)	Set Environmental Heat Loads for Cool Case, Drive Louvers Closed, Heaters On	Heater/Thermostat Activation, Check Thermostats for Dither, Check Louver Travel (Closing)	Thermocouples Heater On-Off Indicators Potentiometers(2)
7. Equipment Power Down and Cool Off Satellite	Satellites in Shadow of Orbiter			
8. Power Up and Operate Satellite for Checkout Tests	Satellite Cool, Heaters On (Initially)(1)	Test Subsystems	Check Satellite Equip. Cold Start Capability & Equip Operation, Heater Operation, Check for Cold Spots	Thermocouples

(1) No Sun on Other Payloads in the Bay
(2) On Louvers
(3) On Light Side as Required for Landsat to Warm Up
(4) Except for Equipment Subject to Arcing and Glow

LANDSAT D/MMS THERMAL CONTROL OPTIONS NOT ADOPTED

- CHECKOUT OF ON-ORBIT REPROGRAMMABILITY OF MMS STRUCTURAL HEATER
  - / PURPOSE: ASSURE THAT MMS STRUCTURAL HEATER SET POINT AND DEAD BAND CAN BE REPROGRAMMED ON ORBIT. REPROGRAMMING DECREASES HEATER POWER USAGE WHILE MAINTAINING STRUCTURAL ALIGNMENT
  - / REASON FOR DISCARDING:
    - THIS CAPABILITY IS ONLY REQUIRED FOR POWER CRITICAL MISSIONS
    - TEST IS RISKY SINCE AFTER CHECKOUT, SET POINT AND DEAD BAND MUST BE RETURNED TO ORIGINAL VALUES
- CHECKOUT IN HORIZONTAL POSITION IN CARGO BAY
  - / PURPOSE: DOES NOT REQUIRE TILTING OF SATELLITE TO VERTICAL POSITION BEFORE TEST INITIATION
  - / REASON FOR DISCARDING:
    - VERTICAL ARRANGEMENT ALLOWS EACH MODULE OF THE MMS TO RADIATE HEAT SYMMETRICALLY TO CARGO BAY AND SPACE
    - IF ORBITER ATTITUDE PROVIDES PROPER SHADING, VERTICAL ARRANGEMENT OFFERS POTENTIALLY MORE RAPID COOLDOWN OR MORE EQUIPMENT CAN BE OPERATED DURING COOLDOWN

ON-ORBIT CHECKOUT SUBSYSTEM LEVEL STUDIES

REACTION CONTROL AND PROPULSION

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REACTION CONTROL SYSTEM CONFIGURATIONS

Satellite	N_2H_4 Thrusters	Diaphragm Tanks	Valves	Heaters	Thermostats
MMS	Yes	Yes	Latching	Yes	?
IUS	Yes	Yes	Pyrotechnic	Yes	No
ATREX	Yes	Yes	Latching	Yes	?
SMS/GOES	Yes	No	Latching	Yes	No
Stormsat	(Uses MMS)	—	—	—	—
TDS	(Uses MMS)	—	—	—	—
Landsat	(Uses MMS)	—	—	—	—

- CONCLUSIONS:
  - / ALL SPACECRAFT PROPULSION SUBSYSTEMS ARE THE BLOWDOWN HYDRAZINE TYPE WITH VARIOUS HEATER CIRCUITS
  - / ALL SUBSYSTEMS WILL BE LAUNCHED WITH PROPELLANT ABOVE THE ISOLATION VALVES AND SHOULD HAVE 150 PSIA NITROGEN PRESSURE IN THE MANIFOLD BELOW
  - / ON-ORBIT CHECKOUT CAN BE STANDARDIZED FOR ALL PROPULSION SUBSYSTEMS

REACTION CONTROL SYSTEM TEST SEQUENCE

Task	Test Activity, Test Period, And Elapsed Time	Equipment
Leakage of Tanks, Propellant Manifold and All Valves	Sampling of All Pressures As Soon As Possible During TT&C Checkout Period No. 1 (2 Minutes) Intermittent Pressure Sampling Once During Each Subsequent Period. Last Sample No Less Than 24 Hours After First. Period #3 Sample During Thruster Valve Functioning.	Narrow Range Pressure Transducers, 1 psi Resolution Telemetry, No Special Support Equipment
All Heater and Thermostat Functions	Cold and Hot Periods #2 and #3, Continuous Monitoring of All Temperatures	Temperature Transducers, No Special Support Equipment
Thruster Valve Function	As Late In Period #3 As Possible, After Isolation Valve Function In Standby (1 Minute Per Valve)	Narrow Range Pressure Transducers, 1 psi Resolution Telemetry, No Special Support Equipm't
Isolation Valve Function	In Standby Only, (30 Seconds Per Valve) After 24-Hour Leak Check Period	Narrow Range Pressure Transducers, 1 psi Resolution Telemetry, No Special Support Equipm't

REACTION CONTROL SYSTEM - ALTERNATIVE CHECKOUT OPTIONS

TASK	STATUS	COMMENTS
Thruster Valve Function:		
Position Switch	Recommended for Development	Mechanical connection to armature positively indicates functioning; multiple high-frequency actuation up to 1000 cycles presents difficult design problem; must be adaptable to many different valves. Backup for manifold pressure loss due to valve chatter during boost.
Current/Voltage Measurements	Rejected	Requires spacecraft electronics; information would not completely define movement of armature
Nozzle Flow Indicator	Rejected	Balloons or flags would create space debris; all nozzles must be observable.
System Leakage:		
Helium Sniffer	Rejected	Mechanization of a remote sniffer probe is difficult, system is typically buried by structure and insulation and wire harness can occur; built-in sniffing system too complicated; "gathering" of leakage would require a completely bagged spacecraft.
Heater Circuit Continuity:		
Thermostat Coolant	Rejected	Built-in or remotely actuated liquid N_2 or Freon is complicated; use of orbiter shadow is effective for all thermal control systems.

ATREX SOLID ROCKET MOTOR SYSTEM TEST SEQUENCE

TASK	PERIOD	ELAPSED TIME
Propellant Grain Temperature	Continual Sampling All Periods	One Minute Per Sample
Thrust Vector Control Actuator Function	Cold Period in Bay, Also in Standby	One Minute Per Actuator
Safe and Arm Switch Function	When Required for Ignition in Standby	30 Seconds

PARTIAL ON-ORBIT CHECKOUT OF SOLID ROCKET MOTOR SYSTEM

- TWO OF THREE TESTS CONDUCTED IN STANDOFF ARE INITIALLY ACCOMPLISHED IN BAY
- NO SPECIAL ORBITER EQUIPMENT NECESSARY
- BAY TESTING IS ALWAYS RECOMMENDED

SPACECRAFT REQUIREMENTS IMPOSED BY ON-ORBIT CHECKOUT OF REACTION CONTROL SYSTEM

- DEVELOPMENT AND ADDITION OF NARROW RANGE, HIGH SENSITIVITY PRESSURE TRANSDUCERS
  - / MAY REQUIRE USE OF SEVERAL RANGES AT SOME LOCATIONS
- ADDITION OF REDUNDANT PRESSURE TRANSDUCERS
- ADDITION OF REDUNDANT THRUSTER TEMPERATURE TRANSDUCERS
- IMPROVED PRESSURE TELEMETRY RESOLUTION TO 1 PSI FOR LEAK DETECTION
- POTENTIAL DEVELOPMENT AND ADDITION OF THRUSTER VALVE POSITION SWITCHES
  - / 1000 CYCLE LIFE TO ALLOW FOR ACCEPTANCE TESTING AND CHECKOUT
- THRUSTER VALVE VIBRATION QUALIFICATION WITH 150 PSID ACROSS POPPET
  - / MONITOR POPPET CHATTER AND NITROGEN LEAKAGE RATE
- NITROGEN SPHERE AND PYROTECHNIC VALVE PLUMBED TO PROPELLANT MANIFOLD
  - / SYSTEM LEAKAGE AND THRUSTER VALVE CHECKS
  - / 2.5 IN^3 SPHERE AT 3000 PSIA FOR IUS; 1.5 LB INCLUDING PYRO VALVE
    - REPRESENTS MAXIMUM MANIFOLD VOLUME. 45 IN^3

ON-ORBIT CHECKOUT SUBSYSTEM LEVEL STUDIES

INSTRUMENTS

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STORMSAT INSTRUMENT SUBSYSTEM CHECKOUT CANDIDATE TESTS

Subsystem Element	On-Orbit Tests			Test Locations	
	For:	Indications			
		Primary	Backup	In-Bay	Standoff
• ASSIR					
IR(1)	• Sensor Electronics Aliveness(2)	• Response to Injected Signal	• Diagnostics Verifying Signal Injection	X	
Visible	• Visible Sensor, Sensor Electronics Aliveness(2)	• Visible Light Range Target Stimulated Signal Recognition	• Diagnostics Verifying Target Signal Aliveness	X	
• Atmospheric Microwave Sounder	• Sensor, Sensor Electronics, Gimbal, Scanning System Aliveness	• Space to Earth Viewing Signal Difference	-----	X(3)	X

(1) IR sensor check requires cryogenic cool-down (cooler to be supported in payload bay); may not be practical due to contamination.

(2) Gimbal and scanning system aliveness tests may not be practical since the mechanisms would have to be uncaged, tested, and recaged.

(3) Feasibility dependent on orientation of sounder in payload bay.

SMS INSTRUMENT SUBSYSTEM CHECKOUT CANDIDATE TESTS

Subsystem Element	On-Orbit Tests			Test Location	
	For:	Indications			
		Primary	Backup	In-Bay	Standby
• VISSR IR(1)	• Sensor Electronics Aliveness	• Response to Injected Signal	• Diagnostics Verifying Signal Injection	X	
Visible	• Sensor and Sensor Electronics Aliveness	• Visible Light Range Target Stimulated Signal Recognition	• Diagnostics Verifying Target Signal Aliveness	X	
• Environmental Monitoring Instruments(2)	• Sensor Electronics Aliveness	• Response to Injected Signal	• Diagnostics Verifying Signal Injection	X	

(1) IR Sensor Check Requires Cryogenic Cool-Down, Instrument Cooler Expected to be Inaccessible In Payload Bay

(2) Sensor Tests Require Low-Level Radioactive Source, Not Recommended

TDS INSTRUMENT SUBSYSTEM CHECKOUT CANDIDATE TESTS

Subsystem Element	On-Orbit Tests			Test Location	
	For:	Indications		In-Bay	Standoff
		Primary	Backup		
• Air Quality Instrument VTPR[1] THIR[1] MAPS[2] CIMATS[2] SER(SAGE)[2] HALOE[2] LACATE[2]	• Sensor, Sensor Electronics, Scanning Systems, and Optical Alignment; Focus (End-to-End)	• Earth Radiance Stimulated Signals Coming Through	-----	X[3]	X[4]
• Hydrology Instrument L-Band Radar	• Array, Radar Electronics, and Array Pointing System	• Earth Reflected Signals Coming Through	-----	X[3]	X[5]

(1) Uncooled IR sensor

(2) Visible light sensor

(3) If TDS in vertical position on FSS platform, down pointing and limb pointing required

(4) Deployed solar arrays are used for power in standoff position. If the spacecraft operating mode excludes deploying solar arrays and maintaining satellite attitude, an alternate set of candidate tests would be recommended. Instrument targets would be set up in the payload bay as they normally are in thermo-vac tests.

(5) If needed (see 4 above), an alternate set of candidate tests is recommended using ground test equipment (e.g., echo box).

ON-ORBIT CHECKOUT OF INSTRUMENTS - LANDSAT D MULTISPECTRAL SCANNER (MSS)

Subsystem Element	On-Orbit Tests: For:	Measurements[1]: Primary	Measurements[1]: Backup	Payload and Test Location: Attached To Shuttle	Payload and Test Location: Standoff	Test Priority
MSS	Aliveness of Sensor Channels, Bands 1-4 and Multiplexer	Response to Built-In Calibration Light	Response to Redundant Built-In Calibration Light	X		(1)
MSS	Aliveness of Band 5 (Uncooled)	Electronic Signal Injection[2] Detector Bias Measurement	Detector Noise Measurement[3]	X		(1)
MSS[4]	Aliveness of Band 5 and Cooldown[5]	Not Applicable[6] (Backup Test Only)	Detector Signal Full Cooldown Temperature		X	–
MSS[4]	Aliveness of Bands 1-4	Quick-Look Images[7]	Analog (Video) Signals		X	(2)
MSS[4]	Sun Calibration (Bands 1-4 Only)	Response to Sun and to Built-In Calibration Light	Repeat Test on Another Orbit		X	(2)

(1) Data examined at Operational Control Center or experimenter's facility.
(2) If available from built-in test equipment.
(3) Feasibility needs study.
(4) Not recommended during checkout if MSS is a serviceable module on orbit and a spare is available.
(5) Requires up to 5 days wait for outgassing to subside and then approximately 1 day for cooldown.
(6) Recommended as a backup test, only used if detector noise measurement test is either not feasible or fails.
(7) Check proper focus of optics.

(1) = Required
(2) = Desirable

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ON-ORBIT CHECKOUT OF INSTRUMENTS - LANDSAT D THEMATIC MAPPER

Subsystem Element	On-Orbit Tests			Payload and Test Location		Test Priority
	For:	Measurements[1] Primary	Measurements[1] Backup	Attached To Shuttle	Standoff	
Thematic Mapper	Aliveness of Sensor Channels, Bands 1-4	Response to Calibration Light	Response to Redundant Calibration Light	X		1
Thematic Mapper	Aliveness of Bands 5 and 6 (Uncooled)	Electronic Signal Injection[2] Detector Bias Measurement	Detector Noise Measurement[3]	X		1
Thematic Mapper[4]	Aliveness of Bands 5 and 6 and Cooldown[5]	Not Applicable[6] (Backup Test Only)	Detector Signal Full Cooldown Temperature		X	-
Thematic Mapper[4]	Aliveness of Bands 1-4	Quick-Look Images	Analog (Video) Signals		X	2
Thematic Mapper[5]	Sun Calibration	Response to Sun and to Built-In Calibration Light	Repeat Test on Another Orbit		X	2

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ATREX INSTRUMENT SUBSYSTEM CANDIDATE TESTS - I

Subsystem Element	On-Orbit Tests			Payload & Test Location		Test Priority	Time
	For	Measurements					
		Primary	Back-up	In Bay	Standoff		
All-Sky Monitor	Sensors, electronics, data-handling system (aliveness)	Response to celestial x-ray sources and detector "internal" background.	Currents, voltages, command status.	X		1	5
	Same as above	Response to celestial x-ray sources.	Currents, voltages, command status, spacecraft altitude.		X	2	5-60
Large Area Proportional Counter Array	Sensors, electronics, data-handling system aliveness, background rejection system function.	Response to detector "internal" background. Detector counting rates, anti-coincidence rates	Currents, voltages, command status.	X		1	5
	Sensor, electronics, data-handling system aliveness.	Response to detector's internal calibration sources.	Currents, voltages, command status.		X	2	50
	Sensor, electronics, data-handling system aliveness.	Response to strong celestial X-ray source.	Currents, voltages, command status, spacecraft altitude.		X	2	35

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ATREX INSTRUMENT SUBSYSTEM CANDIDATE TESTS - II

Subsystem Element	On-Orbit Tests			Payload & Test Location		Test Priority	Time
	For	Measurements					
		Primary	Back-up	In Bay	Standoff		
Spectrometer-Vectrometer Array	Sensor, electronics, data-handling system aliveness, spectrometer detector performance	Vectrometer detector individual response to diffuse celestial gamma-ray background, spectrometer detector summed response to same.	Currents, voltages, command status.	X		1	1
	Sensor, electronics, data-handling system aliveness. Spectrometer detector performance. Calibration system.	Spectrometer spectrum from internal calibration sources. Individual module spectra.*	Currents, voltages, command status.	X		1	≤30
	Detector aliveness	Vectrometer detector individual response to diffuse celestial gamma-ray background.	Currents, voltages, command status.		X	2	1

*The required data may not be available in the telemetry stream, in which case the test could not be used.

ATREX INSTRUMENT SUBSYSTEM CANDIDATE TESTS - III

Subsystem Element	On-Orbit Tests			Payload & Test Location		Test Priority	Time
	For	Measurements: Primary	Measurements: Back-up	In Bay	Stand-off		
Multiple Slot Camera	Sensor, electronics, data-handling system aliveness, position sensing.	Detector response to internal calibration source.	Currents, voltages, command status.	X		1	≤30
	Detector position sensing ability.	Response to electronic position sensing calibration	Currents, voltages, command status.	X		1	<30
	Sensor, electronics, data-handling system aliveness.	Detector response to internal calibration source.	Currents, voltages, command status.		X	2	≤30

AEROSPACE FORM 4253

SATELLITE REQUIREMENTS IMPOSED BY ON-ORBIT CHECKOUT - I

- SOME ADDITIONAL TELEMETRY TEST POINTS[1]
- GLOW AND ARCING PROTECTION FOR HIGH VOLTAGE EQUIPMENT
  - ALTERNATIVE IS TO ACCEPT DELAY FOR OUTGASSING
- LOW ALTITUDE RETRIEVABLE SATELLITES
  - OPEN AND CLOSE CYCLE FOR OPTICS COVERS GOOD FOR AT LEAST TWO CYCLES (INSTEAD OF ONE) (LANDSAT, STORMSAT, TDS)
  - EXTEND AND RETRACT CYCLE FOR ANTENNAS AND SOLAR ARRAYS GOOD FOR AT LEAST TWO CYCLES (INSTEAD OF ONE) OR DESIGNED TO WITHSTAND TRANSFER PROPULSION LOADS IN THE EXTENDED POSITION (ATREX, LANDSAT)

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(1) CANDIDATES - TT&C SUBSYSTEM SUPPLEMENTARY TELEMETRY POINTS, OUTPUTS OF EACH SENSOR, INPUTS TO EACH ACTUATOR, OUTPUTS FROM RCS TO PROPULSION MODULE, CRITICAL SIGNALS BETWEEN (TO AND FROM) THE RIU AND THE ACS INTERFACE ASSEMBLY AND THE ACS DRIVE ELECTRONICS, THE TEMPERATURES OF TEMPERATURE -- CRITICAL COMPONENTS, MISSION EQUIPMENT ELECTRONICS FOR UPPER STAGE SATELLITES, POTENTIOMETERS FOR LOUVER POSITION MONITORING, ADDITIONAL THERMOCOUPLES

SATELLITE REQUIREMENTS IMPOSED BY ON-ORBIT CHECKOUT - II

- BUILT-IN TEST EQUIPMENT
  - / CANDIDATES INCLUDE SELF CHECK OF STAR TRACKERS WITH REDUNDANT INTERNAL ARTIFICIAL LIGHT SOURCES FOR NON-RETRIEVABLE SATELLITES
- SATELLITE ORIENTATION AS INSTALLED IN PAYLOAD BAY
  - / WIDEBAND DATA LINK ANTENNA ERECTION (ATREX)
- SPECIAL RCS EQUIPMENT FOR LEAK DETECTION AND VALVE POSITION INDICATIONS