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. NASA-3099

THE AEROSPACE CORPORATION
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THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA
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
OPTIONAL BASELINE LANDSAT-D

TDSC ANTENNA DISH
2 AXIS GIMBAL
Ku BAND TRANSMITTER
ANTENNA MAST
TRANSITION ADAPTER
1.M. STRUCTURE
FRUSA SOLAR ARRAY

HIGH DATA RATE DIRECT ACCESS ANTENNA
WIDE BAND MODULE
5 BAND DIRECT ACCESS ANTENNA
5 BAND M.S.S.
M.M.S.
LANDSAT-D COMPONENT BREAKAWAY SCHEMATIC

WIDE BAND MODULE

INSTRUMENT MODULE PRIMARY STRUCTURE

GLOBAL POSITIONING SYSTEM

MULTI-MISSION MODULAR SPACECRAFT

TORS ANTENNA

FLEXIBLE ROLL-UP SOLAR ARRAY

THEMATIC MAPPER

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THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA
TECHNOLOGY DEMONSTRATION SATELLITE
ATREX/AEM SPACECRAFT AND SMALL IUS MOTOR PROPULSION MODULE
STORMSAT IN LAUNCH CONFIGURATION

MICROWAVE RADOMETER ANTENNA
IMIS SPACECRAFT
AASIR

SHUTTLE BAY

SHUTTLE BAY DIMENSION
LENGTH - 18.29 m
DIAMETER - 4.57 m

TODL LENGTH 11.38 m

POTENTIAL ADDITIONAL PAYLOAD

END VIEW

Satellite Unit
Cost Estimate
$23M

THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA
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

<table>
<thead>
<tr>
<th>Day Of Occur.</th>
<th>Anomaly</th>
<th>Cause</th>
<th>Mission Impact And Corrective Action</th>
<th>Traceable To:</th>
<th>Origin</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earth sensor data not producing credible or consistent attitude fits.</td>
<td>Spurious readings appear in time ranges associated with illumination and darkening of solar panel.</td>
<td>Use sun sensor magnetometer data for attitude determination in interim. -- Sun shield added on 83-2. <strong>Major</strong></td>
<td>Hardware (SC)</td>
<td>Design</td>
<td>53-1 (73-5)</td>
</tr>
<tr>
<td>1</td>
<td>Antenna B failed to fully deploy.</td>
<td>(Class) Design change on next vehicle.</td>
<td>Use Antenna A. Mission compromised - <strong>Major</strong></td>
<td>Hardware (TTC)</td>
<td>Design or Wkmp</td>
<td>S3-3 (574-2)</td>
</tr>
<tr>
<td>1</td>
<td>Mode 6 divergent</td>
<td>Design change on next flight.</td>
<td>Plenum pumped to above normal pressure by ground. CMD - <strong>Major</strong></td>
<td>Hardware</td>
<td>Design</td>
<td>DSP Ph 1 Flt 1</td>
</tr>
<tr>
<td>2</td>
<td>High spacecraft compartment temperature.</td>
<td>Inadequate radiator area. Design change on next flight.</td>
<td>Restricted operation of selected equipment to reduce internal power dissipation. <strong>Major</strong></td>
<td>Hardware</td>
<td>Design</td>
<td>DSP Ph 1 Flt 1</td>
</tr>
<tr>
<td>3</td>
<td>High level thruster freezing.</td>
<td>Inadequate heaters and insulation on thrusters. Additional heaters added on next launch.</td>
<td>Restricted operation to those times when thruster temperature &gt; 40°F. <strong>Major</strong></td>
<td>Hardware (AP)</td>
<td>Design</td>
<td>DSP Ph 1 Flt 1</td>
</tr>
<tr>
<td>1</td>
<td>High level thruster freezing.</td>
<td>Inadequate heaters and insulation on thrusters. Insulation and heaters added on subsequent vehicle.</td>
<td>Use restricted to diurnal periods when temperature is &gt; 40°F. <strong>Major</strong></td>
<td>Hardware (AP)</td>
<td>Design</td>
<td>DSP Ph 1 Flt 1</td>
</tr>
</tbody>
</table>

**REFERENCE:** The Aerospace Corporation Report No. ATR-78(7659)-1, Volume III, Standardisation 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)**

<table>
<thead>
<tr>
<th>Day Of Occur.</th>
<th>Anomaly</th>
<th>Cause</th>
<th>Mission Impact And Corrective Action</th>
<th>Traceable To:</th>
<th>Origin</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unable to CMD.</td>
<td>Crypto box experienced difficulty in processing CMD.</td>
<td>Operational delay. Corrected by software procedures. Hardware, software, and system test changes on follow-on flights. Major</td>
<td>Hardware (TTC)</td>
<td>Design</td>
<td>DSCS-II Flight 1</td>
</tr>
<tr>
<td>1</td>
<td>Unable to CMD.</td>
<td>Crypto box experienced difficulty in processing CMD.</td>
<td>Operational delay. Corrected by software procedures. Hardware, software, and system test changes on follow-on flights. Major</td>
<td>Hardware (TTC)</td>
<td>Design</td>
<td>DSCS-II Flight 2</td>
</tr>
</tbody>
</table>
EARLY SPACECRAFT FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND Candidates for Correction with On-Orbit Checkout and Appropriate Action

MAJOR FUNCTIONAL IMPACT\(^{(1)}\)

<table>
<thead>
<tr>
<th>S/C &amp; Anomaly Number</th>
<th>Date Detected S/C Hours</th>
<th>Failed/Affected Item</th>
<th>Project</th>
<th>Discussion of Anomaly</th>
<th>Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>10/14/65 0</td>
<td>Attitude Control System Horizon Scanner</td>
<td>OGO</td>
<td>Horizon scanner locking on thermal gradients in earth's infrared image, caused depletion of gas supply, Fixed orientation of spin axis.</td>
<td>Spacecraft commanded to spin mode. Subsequent spacecraft redesigned to include new infrared filter. Bandwidth also reduced.</td>
</tr>
<tr>
<td>E-1</td>
<td>3/4/68 0</td>
<td>- Z Door Thermal Insulation</td>
<td>OGO</td>
<td>Temperature rose above expected levels (insulation degradation), excessive thermal opening.</td>
<td>Necessitated the operations' cycling of four experiments located in that region.</td>
</tr>
</tbody>
</table>


\(^{(1)}\) 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)
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**EARLY SATELLITE FAILURES SIGNIFICANTLY DEGRADING SATELLITE OPERATION AND CANDIDATES FOR CORRECTION WITH ON-ORBIT CHECKOUT AND APPROPRIATE ACTION - 1**


<table>
<thead>
<tr>
<th>Index</th>
<th>Anomaly Time (Hours)</th>
<th>Description</th>
<th>Cause</th>
<th>Mission Effect</th>
<th>Corrective Action (If Known)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>Substantial and increasing signal degradation of filter wedge spectrometer.</td>
<td>Ice deposit on cooled bimetal detector.</td>
<td>Loss of data.</td>
<td>New cooler design required for new applications.</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>One of two tape recorders provided no output in playback.</td>
<td>Attributed to launch shock.</td>
<td>Loss of experiment data and operational flexibility.</td>
<td></td>
</tr>
</tbody>
</table>

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

Reference: PRC Document PR 7 R-1453, "Reliability Data from In-Flight Spacecraft; 1958-1970"
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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"

<table>
<thead>
<tr>
<th>Index</th>
<th>Anomaly Time (Hours)</th>
<th>Anomalies</th>
<th>Cause</th>
<th>Mission Effect</th>
<th>Corrective Action (If Known)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>€</td>
<td>Degradation of neon reference for the infrared interferometer spectrometer.</td>
<td>High radiation levels early in the mission, particularly over the S0. Atlantic</td>
<td>Substantial experiment degradation.</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>€</td>
<td>Excessive spin rate subsequent to launch.</td>
<td>No despin mechanism provided.</td>
<td>Precluded receipt of useful data although spacecraft interrogated 50 times in about 6 months.</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>€</td>
<td>Failure of experimental transponder during launch</td>
<td>Unknown</td>
<td>Spacecraft completely unusable.</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>€</td>
<td>Malfunctioning Faraday Cup experiment; abnormal response to ground commands.</td>
<td>Unknown</td>
<td>Majority of anticipated data lost from this experiment.</td>
<td></td>
</tr>
</tbody>
</table>

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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"

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

(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

<table>
<thead>
<tr>
<th>Project</th>
<th>Cost Per Payload Unit</th>
<th>Potential Savings ($M) For On-Orbit Checkout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unit Saved</td>
</tr>
<tr>
<td>TDS</td>
<td>22.0</td>
<td>13.4</td>
</tr>
<tr>
<td>STORMSAT + IUS</td>
<td>27.5</td>
<td>16.8</td>
</tr>
<tr>
<td>SMS + SSUS</td>
<td>9.0</td>
<td>5.5</td>
</tr>
<tr>
<td>ATREX</td>
<td>15.9</td>
<td>9.7</td>
</tr>
<tr>
<td>ATREX + SRM</td>
<td>35.5</td>
<td>21.6</td>
</tr>
<tr>
<td>LANDSAT D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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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
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BACKGROUND FOR SUBSYSTEM TESTS RECOMMENDED FOR
ON-ORBIT CHECKOUT

TRADEOFFS

<table>
<thead>
<tr>
<th>BASELINE</th>
<th>STUDY TRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>Consider cost reduction vs benefit reduction for less thorough checkout.</td>
</tr>
</tbody>
</table>

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.

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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/MACH. 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

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests</th>
<th>Payload and Test Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measurements (1)</td>
<td>Attached To Shuttle</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>Backup</td>
</tr>
<tr>
<td>Thematic Mapper</td>
<td>Aliveness of Sensor Channels, Bands 1-4</td>
<td>Response to Calibration Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thematic Mapper</td>
<td>Aliveness of Bands 5 and 6 (Uncooled)</td>
<td>Electronic Signal Injection (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detector Bias Measurement</td>
</tr>
<tr>
<td>Thematic Mapper (4)</td>
<td>Aliveness of Bands 5 and 6 and Cooldown (5)</td>
<td>Not Applicable (6) (Backup Test Only)</td>
</tr>
<tr>
<td>Thematic Mapper (4)</td>
<td>Aliveness of Bands 1-4</td>
<td>Quick-Look Images</td>
</tr>
<tr>
<td>Thematic Mapper (4)</td>
<td>Sun Calibration</td>
<td>Response to Sun and to Built-In Calibration Light</td>
</tr>
</tbody>
</table>

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
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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

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**THERMAL CONSIDERATIONS AFFECTING TEST SEQUENCE ON ORBIT**

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

(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.
UNCLASSIFIED

GENERALIZED TOP-LEVEL CHECKOUT FLOW ASSUMING NO EARLY FAILURES

1. Payload First Out
   - Cool Down Satellite
   - Run Cool Satellite Tests
   - Deploy Satellite Initialize and Establish In Standoff Position
   - Allow Outgoing Time to Elapse
   - Heat Up Satellite to Warm Condition
   - Run Warm Satellite Tests

2. Payload Second Out
   - Cool Down Satellite
   - Proceed as with Payload First Out

(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

<table>
<thead>
<tr>
<th>Option</th>
<th>Test Objectives</th>
<th>Spaceborne Test Support Equipment</th>
<th>Location/Position Of Satellite Under Test(1)</th>
<th>Primary Test Links</th>
<th>Time Constraints</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Successful Checkout</td>
<td>Contingency</td>
</tr>
<tr>
<td>1</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>Stimulus SCSS(2)</td>
<td>Attached &amp; Elevated</td>
<td>Thru PDI Sat/TDRS</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>Stimulus OACE(5)</td>
<td>Attached &amp; Elevated</td>
<td>Thru PDI Sat/TDRS</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Limit Checks</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>Thru PDI</td>
<td>Nominal (~10 Min)</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Limit Checks(7) + Additional Tests As Possible</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>Thru PDI Sat/TDRS</td>
<td>2-3 Hours</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Limit Checks(7), Command/Response(7), Rate Matching(7), + Additional Tests As Possible</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>Thru PDI Sat/TDRS</td>
<td>4-8 Hours</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>Thru PDI Sat/TDRS</td>
<td>?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

(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.

---

UNCLASSIFIED
LANDSAT, A RETRIEVABLE SATELLITE
STUDY RESULTS FOR PRIMARY CHECKOUT OPTIONS WITH EMPHASIS ON TESTING PRIOR TO DEPLOYMENT

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

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

<table>
<thead>
<tr>
<th>Option</th>
<th>Test Objectives</th>
<th>Spaceborne Test Support Equipment</th>
<th>Location/Position Of Satellite Under Test(1)</th>
<th>Primary Test Link(2)</th>
<th>Time Constraints</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>R. F. Stimulus SCSS</td>
<td>Attached &amp; Elevated Standoff</td>
<td>Satellite/Test Equipment/PDI</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Stimulus SCSS</td>
<td>Attached &amp; Elevated Standoff</td>
<td>PDI, Payload Interrogator/PDI</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Stimulus SCSS</td>
<td>Attached &amp; Elevated Standoff</td>
<td>PDI, Sat/Gr'd Sta.</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>R.F. Stimulus OACE</td>
<td>Attached &amp; Elevated Standoff</td>
<td>Satellite/Test Equipment/PDI</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Stimulus OACE</td>
<td>Attached &amp; Elevated Standoff</td>
<td>Payload Interrogator/PDI</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Stimulus OACE</td>
<td>Attached &amp; Elevated Standoff</td>
<td>PDI, Sat/Gr'd Sta.</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>None</td>
<td>Attached &amp; Elevated Standoff</td>
<td>PDI, Payload Interrogator/PDI</td>
<td>?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

---

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

---

THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA
# ATREX, A RETRIEVABLE SATELLITE

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

<table>
<thead>
<tr>
<th>Option</th>
<th>Test Objectives</th>
<th>Risks Of Undetected Early Failures</th>
<th>Risk Of Return Of Good Satellites</th>
<th>Estimated Test Duration Increment (Hours)</th>
<th>Cost Estimate, Increment For Tests ($M)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Limit Checks(^1), Rate Matching(^2), Command/Resp. (^2), Instrument Tests (^2), Extendible Tests (^2)</td>
<td>Significant ((a), (b))</td>
<td>Minimum</td>
<td>30 Minutes</td>
<td>4 Hours(^1)</td>
<td>0.16</td>
</tr>
<tr>
<td>4</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>Acceptable ((10 \text{ to } 20%))</td>
<td>Minimum</td>
<td>8 Hours(^1)</td>
<td>18 Hours (^2)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

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

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

(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/1US, AS A NON-RETRIEVABLE PAYLOAD

**PRIMARY CHECKOUT OPTIONS**

<table>
<thead>
<tr>
<th>Option</th>
<th>Test Objectives</th>
<th>Spaceborne Test Support Equipment</th>
<th>Location/Position Of Satellite Under Test(1)</th>
<th>Primary Test Links</th>
<th>Time Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>R. F. Stimulus SCSS</td>
<td>Attached &amp; Elevated</td>
<td>Satellite/Test Equipment/PDI</td>
<td>Successful Checkout</td>
</tr>
<tr>
<td>2</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>Stimulus CSS</td>
<td>Attached &amp; Elevated</td>
<td>PDI, Sat/ Ground Sta. for RF Tests</td>
<td>Successful Checkout</td>
</tr>
<tr>
<td>3</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>h. F. Stimulus SCSS</td>
<td>Attached &amp; Elevated</td>
<td>Satellite/Test Equipment/PDI</td>
<td>Successful Checkout</td>
</tr>
<tr>
<td>4</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>Stimulus OACE</td>
<td>Attached &amp; Elevated</td>
<td>PDI, Sat/ Ground Sta. for RF Tests</td>
<td>Successful Checkout</td>
</tr>
<tr>
<td>5</td>
<td>Check Out Satellite Equipment Testable Without Test Support Equipment</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>PDI, Sat/ Ground Sta. for RF Tests</td>
<td>Successful Checkout</td>
</tr>
</tbody>
</table>

(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

<table>
<thead>
<tr>
<th>Option</th>
<th>Test Objectives</th>
<th>Risks Of Undetected Early Failures</th>
<th>Risk Of Return Of Good Satellites</th>
<th>Estimated Test Duration Increment (Hours)</th>
<th>Cost Estimate Increment For Tests ($M)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>Could Not Reach Objectives, (1)(2)(3)(4) Significant Risks</td>
<td>Minimal</td>
<td>24</td>
<td>0</td>
<td>0.80</td>
</tr>
<tr>
<td>2</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td></td>
<td>Minimal</td>
<td>24</td>
<td>0</td>
<td>0.40</td>
</tr>
<tr>
<td>3</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td></td>
<td>Minimal</td>
<td>24</td>
<td>0</td>
<td>0.88</td>
</tr>
<tr>
<td>4</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td></td>
<td>Minimal</td>
<td>24</td>
<td>0</td>
<td>0.48</td>
</tr>
<tr>
<td>5</td>
<td>Check Out Satellite Equipment Testable Without Test Support Equipment</td>
<td>Significant Risks (1)(2)(3), (4)(5), (6)</td>
<td>Minimal</td>
<td>24</td>
<td>0</td>
<td>0.10</td>
</tr>
</tbody>
</table>

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 ACS isolation valve tests.
5. Missing ACS electronics tests.
6. Missing WASSIR IR instrument electronics tests.
**SYNCHRONOUS METEOROLOGICAL SATELLITE (SMS)/GOES/SSUS**

SMS IS ASSUMED MODIFIED TO BE COMPATIBLE WITH STS

**PRIMARY CHECKOUT OPTIONS**

<table>
<thead>
<tr>
<th>Option</th>
<th>Test Objectives</th>
<th>Spaceborne Test Support Equipment</th>
<th>Location/Position Of Satellite Under Test(2)</th>
<th>Primary Test Links</th>
<th>Time Constraints</th>
<th>Successful Checkout</th>
<th>Continuity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>R.F. Stimulus OACE(1)</td>
<td>Attached &amp; Elevated Standoff</td>
<td>Thru OACE/PDI</td>
<td>?</td>
<td>Yes</td>
<td>SMS/SSUS is Retrievable(4).</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Identify 80-90% of Gross Early Failures</td>
<td>R.F. Stimulus OACE(1)</td>
<td>Attached &amp; Elevated Standoff</td>
<td>Thru PDL, Sat/Ground</td>
<td>?</td>
<td>Yes</td>
<td>SMS/SSUS is Retrievable, High Inclination Parking Orbit, Overflies Wallops Island for RF Test(6).</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Limit to Testing During Wallops Island Passes</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>R.F. Satellite to Ground</td>
<td>5 Minutes (out of 24 hr. period)</td>
<td>Yes</td>
<td>High Inclination Parking Orbit, Overflies Wallops Island for Checkout Tests(6) SMS/SSUS Not Retrievable.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Limit to Testing During Wallops Island Passes 24 Hours Apart</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>R.F. Satellite to Ground</td>
<td>Two 5 Min Periods (out of 48 hr. period)</td>
<td>Yes</td>
<td>Same as Above</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Limit to Attached Tests Without Test Equipment</td>
<td>None</td>
<td>Attached &amp; Elevated</td>
<td>Thru PDL RF Sat/ Interrog/ PDI</td>
<td>?</td>
<td>Yes</td>
<td>SMS/SSUS Not Retrievable, SMS Shaded by Orbiter</td>
<td></td>
</tr>
</tbody>
</table>

(1) Including transforcer 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**

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

**Notes:**
(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.

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39
### SUMMARY OF PAYLOAD RETRIEVABILITY AND PAYLOAD TEST LOCATION CASES

<table>
<thead>
<tr>
<th>Payload</th>
<th>Summary Results In Table No.</th>
<th>Checkout Studied For</th>
<th>Employing Checkout Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Retrieval Payload</td>
<td>Non-Retrievable Payload</td>
<td>Prior To Deployment</td>
</tr>
<tr>
<td>Stormsat/IUS</td>
<td>7-7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7-4</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7-5</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Technology Demonstration Satellite</td>
<td>7-6</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7-7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SMS/GOES/SSUS</td>
<td>7-8</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7-8</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Landsat D</td>
<td>7-9</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7-10</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ATREX</td>
<td>7-12</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7-13</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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 (1), (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), (2), and (3).
(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

POCC

Or

Orbiter Communications System

TDRS Satellite Link

SATELLITE

Command System

Note: ① is satellite/orbiter (payload interrogator) link.
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TELEMETRY (DOWN-LINK) SYSTEM FOR ON-ORBIT CHECKOUT
LANDSAT D STANDING OFF FROM ORBITER

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

①

Or

POCC

②

TDRS
Satellite
Link

①

Orbiter
Communications
System

①

Telemetry
System

SATELLITE

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

ATREX SATELLITE ATTACHED OR ORBITER OR STANDING OFF FROM THE ORBITER

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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

+ INSTRUMENTATION MODULE
## LANDSAT TT&C CHARACTERISTICS

### MMS COMMUNICATIONS AND DATA HANDLING SUBSYSTEM

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

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
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MMS SYSTEM BLOCK DIAGRAM
SIMPLIFIED BLOCK DIAGRAM OF THE TT&C SUBSYSTEM
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C&DH SUBSYSTEM BLOCK DIAGRAM (SHOWING MODULE INTERFACE)
LANDSAT D MISSION-PECULIAR COMMUNICATION
TT&C RF TESTING FOR LANDSAT OR ATREX TDRS LARGE DISH EQUIPMENT
TESTING PRIOR TO DEPLOYMENT - I

START

Is OSTD Compatible & ERP Sufficient to Communicate With Ground? No RF Test

No

Yes

Wait for Dedicated Ground Station To Be Visible

Test Through Dedicated Ground Station

Ground Station Blocks Data and Transmits to OPCR

GROUND

Open Payload Bay Doors

TT&C Antenna Unfolding Required or Desired? Yes

TT&C Antenna Unfolding Required or Desired? No

Can it Be Refolded After Unfolding By Ground Command? Yes

Can it Be Refolded by Crew? Yes

Can it Be Refolded by Crew? No

TT&C Compatible With Orbiter Payload Interrogator? Yes

TT&C Compatible With Orbiter Payload Interrogator? No

Raise Payload Or Antenna So Antenna Clears Orbiter

Unfold Antenna

Maneuver Orbiter So That Payload Antenna Acquires TDRS

Radiate Payload Telemetry to Orbiter Payload Interrogator

Radiate Payload Telemetry to TDRS

TDRE

START

ORBITER

GROUND

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

ORBITER

Use Orbiter TDRS Link?

No

Yes

Payload Interrogator Routes Data to Orbiter Data System

Orbiter Data System Blocks Data and Sends to Orbiter S-Band FM Downlink System

Orbiter Radiates S-Band FM Link

STDN Site Receivers

STDN Site Routes to Goddard

GROUND

Payload Interrogator Routes Data to Orbiter Data System

Orbiter Data System Blocks Data and Routes to Orbiter Communication System

Orbiter Communication System Multiplexes Payload Telemetry Data With Other Downlink Data and Transmits to TDRS

TDRS

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

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TDRS

TDRS Radiates To Ground Station

Ground Station Blocks Data and Forwards To Goddard

Goddard Switches Data to POCC

GODDARD

POCC Evaluates

Good

Proceed

Bad

Antenna Unfurled?

No

Refold By Ground Command

OR

Refold By Crew Action

Yes

Withdraw Satellite Into Orbiter

Shut Payload Bay Doors

Return to Earth

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### TT&C CHECKOUT OPTIONS CONSIDERED FOR LANDSAT/MMS

<table>
<thead>
<tr>
<th>OPTION</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
<th>COMMENTS</th>
<th>RECOMMENDATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Test Three Redundant RF Configurations</td>
<td>- Quick to Run; / 10 Minutes for Manual Evaluation / 2 Minutes for Software Limit Checking by POCC Computer</td>
<td>- Does Not Check Dual Redundant Computer System or Internal Cross Switching</td>
<td>- RF Amplifiers Which Are Checked Here Have a Higher Failure Probability 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</td>
<td>Not Recommended</td>
</tr>
<tr>
<td>3. Test All Redundant Elements</td>
<td>- Verification of Operability of the Entire TT&amp;C System Using A New Configuration / Ensures That Spacecraft TT&amp;C System When Deployed Meets Design Goals</td>
<td>- Slower to Run; / Approximately 100 Commands Must Be Transmitted and Responses Evaluated / 45 Minutes for Manual Evaluation / 20 Minutes for Software Limit Checking by POCC Computer</td>
<td>- This Test Ensures That All Inadequate Mortality Items In The TT&amp;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</td>
<td>Recommended</td>
</tr>
</tbody>
</table>
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 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

HEMISPHERICAL ANTENNA

2.106.4 MHz

2.287.5 MHz

CONICAL LOG-SPIRAL ANTENNA (1-6 dB)

2.106.4/2,287.5 MHz

CONICAL LOG-SPIRAL ANTENNA

HEMISPHERICAL ANTENNA

TDRSS TRANSPONDER
- RECEIVER
- TRANSMITTER
- DIGITAL CONVERTER
- CDU
- D.C. CONVERTER

COMMAND DATA
- BIT TIMING (500 BPS)
- LOCK INDICATOR
- COMMAND RATE (500 BPS)

AEM COMMAND DECODER

COMMAND PULSE (100)

COMMAND WORD (16)

GATE/CLOCK

DATA/TLM (3 kBPS)

R 1/2 ENCODED

R 1/2 ENCODED

TLM (1 kBPS)

AEM PCM ENCODER

EXPERIMENT

AEM

EXPERIMENT

AEM

DATA/TLM (2 kBPS)

PLAYBACK (2 kBPS)

RECORD (4 kBPS)

TO ALM COMMAND DECODER

BUBBLE MEMORY (1.28 x 10^7)

POWER DIV

CONICAL LOG-SPIRAL ANTENNA

2.5 W

TRANSMITTER

TRANSPONDER TO ALM COMMAND [MINUS TRANSMITTER]
## TT&C SUBSYSTEM TESTS - BASELINE ATREX - 1

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>For:</th>
<th>Measurements</th>
<th>Payload And Test Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Primary</td>
<td>Backup</td>
</tr>
<tr>
<td>Transponder</td>
<td>Avail, General Performance</td>
<td>Link Established</td>
<td>Diagnostics</td>
</tr>
<tr>
<td>(TDSS Low Rate)</td>
<td></td>
<td>PN Code</td>
<td></td>
</tr>
<tr>
<td>Omni, Coupling,</td>
<td></td>
<td>Compare to Normal Values</td>
<td></td>
</tr>
<tr>
<td>PCM Encoder,</td>
<td></td>
<td>Command/Response</td>
<td>Alternate Commands</td>
</tr>
<tr>
<td>Command Decoder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transponder</td>
<td>Performance</td>
<td>Command/Response</td>
<td>Alternate Commands</td>
</tr>
<tr>
<td>(TDSS Normal Rate - 50 kbps)</td>
<td>Status Data Readout</td>
<td>Compare to Normal/Expected Values</td>
<td>Diagnostics</td>
</tr>
<tr>
<td>Parabola, Antenna Steering, Coupling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transponder</td>
<td>Performance</td>
<td>Compare to Normal/Expected Values</td>
<td>Diagnostics</td>
</tr>
<tr>
<td>(TDSS High Data Rate)</td>
<td>Status Data Readout</td>
<td>Record and Execute Recorded Commands for Antenna Steering</td>
<td>Diagnostics</td>
</tr>
<tr>
<td>Command Recorder</td>
<td>Performance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Note: R = Required Test  B = Baseline Test
## TT&C SUBSYSTEM TESTS - BASELINE ATREX - II

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests</th>
<th>Payload And Test Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measurements</td>
<td>In Bay</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>Backup</td>
</tr>
<tr>
<td>Tape Recorder</td>
<td>Function</td>
<td>Comparison of Data Stream Recorded at Ground Station with Playback of Data Stream from Recorder</td>
</tr>
<tr>
<td></td>
<td>End of Tape</td>
<td>Telemetry Signal</td>
</tr>
<tr>
<td></td>
<td>Aliveness, General Performance</td>
<td>Establish Link Command/Response</td>
</tr>
<tr>
<td></td>
<td>Range Signal Turn-Around and Coherent Drive</td>
<td>Received Range Signal and RF Shift</td>
</tr>
<tr>
<td>Transponder STDN</td>
<td>Satellite Subsystems and Mission-Peculiar Checkout</td>
<td>See Appropriate Tests</td>
</tr>
<tr>
<td></td>
<td>Fault Isolation Between TT&amp;C and Other Subsystems</td>
<td>Compare to Normal Values</td>
</tr>
<tr>
<td>TT&amp;C</td>
<td>Use Measurements of Related Parameters</td>
<td>Redundant Telemetry Channels</td>
</tr>
</tbody>
</table>

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
# ELECTRICAL POWER SUBSYSTEM OPERATION

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>For:</th>
<th>Measurements</th>
<th>Payload And Test Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solar Array</strong></td>
<td></td>
<td></td>
<td>In Bay&lt;sup&gt;(1)&lt;/sup&gt; Standoff</td>
</tr>
<tr>
<td></td>
<td>Solar Panels</td>
<td>Visual Examination</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Deployment Mech.</td>
<td>Visual Examination</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>SADA or Slip Rings</td>
<td>Bus Voltage and Current</td>
<td>All</td>
</tr>
<tr>
<td><strong>Batteries</strong></td>
<td></td>
<td></td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Cell Integrity</td>
<td>Nom Voltages and Currents</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Capacity&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>Nom Voltages and Currents</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Voltage</td>
<td>Nom Voltages and Currents</td>
<td>All</td>
</tr>
<tr>
<td><strong>Power Conditioning And Control</strong></td>
<td></td>
<td></td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Battery Charge Rates &amp; Voltages</td>
<td>Nom Voltages and Currents Under All Modes</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Voltage Control</td>
<td>Line Voltages</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Power Quality (Regulation)</td>
<td>Line Voltages</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Relay Position And Operation</td>
<td>Status Verification</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Redundancy</td>
<td>Status Verification</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Fuses</td>
<td>Functional Equip't Check</td>
<td>All</td>
</tr>
<tr>
<td><strong>Harness &amp; Distribution</strong></td>
<td></td>
<td></td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Integrity</td>
<td>Continuity Check (3)</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Switches &amp; Relays</td>
<td>Functional Equip't Check</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Fuses</td>
<td>Functional Equip't Check</td>
<td>All</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> Payload supported by cradle or platform  
<sup>(2)</sup> Limited to visible portion  
<sup>(3)</sup> In case of suspected problem  
<sup>(4)</sup> 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

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

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 - 1

ASSUMPTION 1 – STORMSAT AND IUS NOT RETRIEVABLE -- NO TESTING IN STANDOFF POSITION

BEST ACS TEST OPTION IDENTIFIED – PARTIAL ACS CHECKOUT WITHOUT SPACEDRONE 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

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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 - II:

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

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

(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.

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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 ± 1 DEGREE IN EACH AXIS AND WITH ANGULAR RATES ≤ 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)
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
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)

1. 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

2. LOWER AND REATTACH SATELLITE TO ORBITER

3. 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 OR IRUs AND IMUs TELEMETERED TO GROUND
     - 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:
  - 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

<table>
<thead>
<tr>
<th>ACS Checkout Option</th>
<th>SMS Data To and From POCC</th>
<th>Spaceborne Test Equipment Required</th>
<th>Comments</th>
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<tr>
<td>Full Checkout With Full Complement of Support Equipment</td>
<td>From POCC-Selected Commands to POCC-Telemetry</td>
<td>Variable DC Stimulus, Sensor Stimulus(1), and Support Equipment</td>
<td>Much More Expensive Checkout than Best Option. More Complete Checkout than Best Option</td>
</tr>
<tr>
<td>Full Checkout Without Support Equipment</td>
<td>Voice</td>
<td>None</td>
<td>Riskier(2) Than Best Option</td>
</tr>
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(1) Artificial stimuli, uncover optics while SMS elevated as a backup.
(2) Delays most of the tests of the attitude sensors until after deployment.
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SMS/GOES ATTITUDE CONTROL SUBSYSTEM (ACS) CHECKOUT - 1

- CONSTRAINTS
  - SPIN STABILIZED, Synchronized
  - 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
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

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<td>Variable DC Stimulus, Sensor Stimulus(2), &amp; Support Equipment</td>
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(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 - 1

- 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 +1 DEGREE IN EACH AXIS AND WITH ANGULAR RATES ≤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)
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:
  - COMMANDING A CHANGE IN STANDOFF ATTITUDE STORED IN MMS COMPUTERS PRIOR TO DEPLOYMENT

OR

- 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  
|------------------------------|-------------------------------|----------------------|------------------------------------------------------------|-----------------------------------|-----------
| 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 ± 1 DEGREE IN EACH AXIS WITH ANGULAR RATES ≤ 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

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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

(1) If Capability Exists
SEQUENCE - PRELAUNCH REHEARSAL (CONTINUED)

- TEST PERIOD #3 (COLD)
  - SELECT ON-ORBIT ACS OPERATING MODE
  - RECHECK IRU WITH REDUNDANT AXIS CHANNEL
  - SELF-CHECK CPU
  - 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 1RU
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/1RU) 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

2. Compare the rotation vectors during certain intervals as measured by the Orbiter IMU and LANDSAT (MMS) 1RU.

3. Compute corrections applicable to the LANDSAT 1RU 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 POC.

---

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**

<table>
<thead>
<tr>
<th>TELEMETRY BIT RATE (KBPS)</th>
<th>ATTITUDE (SEC)</th>
<th>TIME (RDG./SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Every 65.536</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>Every 8.192</td>
<td>15</td>
</tr>
<tr>
<td>64</td>
<td>Every 2.048</td>
<td>60</td>
</tr>
</tbody>
</table>
ON-ORBIT CHECKOUT SUBSYSTEM LEVEL STUDIES

THERMAL CONTROL
## THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE

**ATREX SATELLITE, EMPHASIS ON SHORTENED TEST DURATION PRIOR TO SATELLITE DEPLOYMENT**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Conditions</th>
<th>Rationale</th>
<th>Thermal Tests and Components Checked</th>
<th>Thermal Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cargo Bay Doors Opened</td>
<td>Parking Orbit&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>Drive Satellite Heaters On and Prepare for Cool Satellite Tests</td>
<td>Heater/Thermosstat Activation, Check Thermostats for Dither, Check Louver Travel (Closing), Check for Cold Spots</td>
<td>Thermocouples, Heater On-Off Indicators, Potentiometers&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>2. Set Attitude of Orbiter for Satellite to Cool Down</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Perform Rate Matching Test</td>
<td>Dark Side</td>
<td>ACS Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Deploy Satellite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Operate Satellite</td>
<td>Standoff&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>Set Env. Conds. for Warm Tests, Drive Louvers Open, Heaters Off</td>
<td>Heater Shutdown, Louver Travel (Opening)</td>
<td>Thermocouples, Potentiometers&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>8. Satellite Warming Up</td>
<td>Standoff&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td></td>
<td></td>
<td>Heater On-Off Indication</td>
</tr>
<tr>
<td>9. Test Warm Satellite</td>
<td>Standoff&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>Warm Satellite Thermal Checks</td>
<td>Check for Hot Spots</td>
<td>Thermocouples</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> No sun on payloads in the bay.

<sup>(2)</sup> On louvers.

<sup>(3)</sup> Position ATREX so that solar heating on louver radiation is within design tolerances.

UNCLASSIFIED
## THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE

**ATREX SATELLITE, EMPHASIS ON TESTING PRIOR TO SATELLITE DEPLOYMENT**

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

(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

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

(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 louvers radiator is within design tolerances.
<table>
<thead>
<tr>
<th>Operation</th>
<th>Condition</th>
<th>Rationale</th>
<th>Thermal Tests And Components Checked</th>
<th>Thermal Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cargo Bay Doors Opened</td>
<td>Parking Orbit (^{(1)})</td>
<td>Set Environmental Heat Loads for Warm Tests</td>
<td>Louver Travel (Opening)</td>
<td>Potentiometers (^{(2)})</td>
</tr>
<tr>
<td>2. Rotate Satellite to Elevated Position in Cargo Bay</td>
<td>Parking Orbit (^{(1)})</td>
<td>Drive Louvers Open and Heaters Off</td>
<td>Heater/Thermosstat Shutdown</td>
<td>Thermocouples</td>
</tr>
<tr>
<td>3. Set Attitude of Orbiter for TDS to Warm Up</td>
<td>Sun (^{(3)}) on TDS (^{(1)})</td>
<td>Check for Hot Spots</td>
<td></td>
<td>Heater Off Indicators</td>
</tr>
<tr>
<td>5. Continue Satellite Operation and Checkout Tests</td>
<td>Satellite Warm Louvers Open</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Change Attitude of Orbiter for TDS to Cool Down</td>
<td>Parking Orbit (^{(1)})</td>
<td>Set Environmental Heat Loads for Cool Case, Drive Louvers Closed, Heaters On</td>
<td>Heater/Thermosstat Activation, Check Thermosstats for Dither, Check Louver Travel (Closing)</td>
<td>Thermocouples</td>
</tr>
<tr>
<td>8. Power Up and Operate Satellite for Checkout Tests</td>
<td>Satellite Cool, Heaters On (Initially) (^{(1)})</td>
<td>Test Subsystems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(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**

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

(1) No Sun on Other Payloads in Bay  (2) On Louvers  (3) Except for Equipment Subject to Arcing or Glow
## THERMAL CONTROL CHECKOUT TESTS AND SEQUENCE

**LANDSAT D, EMPHASIS ON TESTING PRIOR TO SATELLITE DEPLOYMENT**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Condition</th>
<th>Rationale</th>
<th>Thermal Tests And Components Checked</th>
<th>Thermal Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cargo Bay Doors Opened</td>
<td>Parking Orbit (1)</td>
<td>Set Environmental Heat Loads for Warm Tests</td>
<td>Louver Travel (Opening)</td>
<td>Potentiometers (2)</td>
</tr>
<tr>
<td>2. Rotate Satellite to Elevated Position in Cargo Bay</td>
<td>Parking Orbit (1)</td>
<td>Drive Louvers Open and Heaters Off</td>
<td>Heater/Thermostat Shutdown</td>
<td>Thermocouples</td>
</tr>
<tr>
<td>3. Set Attitude of Orbiter for Landsat to Warm Up</td>
<td>Sun (3) on Landsat</td>
<td></td>
<td></td>
<td>Heater Off Indicators</td>
</tr>
<tr>
<td>4. Equipment Power Up and Warm Up Satellite</td>
<td>Sun (3) on Landsat (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Continue Satellite Operation and Checkout Tests</td>
<td>Satellite Warm</td>
<td>Test Subsystems (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Change Attitude of Orbiter for Landsat to Cool Down</td>
<td>Parking Orbit (1)</td>
<td>Set Environmental Heat Loads for Cool Case, Drive Louvers Closed, Heaters On</td>
<td>Heater/Thermostat Activation, Check Thermostats for Dither, Check Louver Travel (Closing)</td>
<td>Thermocouples</td>
</tr>
</tbody>
</table>

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
### 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

<table>
<thead>
<tr>
<th>Task</th>
<th>Test Activity, Test Period, And Elapsed Time</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage of Tanks, Propellant Manifold and All Valves</td>
<td>Sampling of All Pressures As Soon As Possible During TT&amp;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.</td>
<td>Narrow Range Pressure Transducers, 1 psi Resolution Telemetry, No Special Support Equipment</td>
</tr>
<tr>
<td>All Heater and Thermostat Functions</td>
<td>Cold and Hot Periods #2 and #3, Continuous Monitoring of All Temperatures</td>
<td>Temperature Transducers, No Special Support Equipment</td>
</tr>
<tr>
<td>Thruster Valve Function</td>
<td>As Late In Period #3 As Possible, After Isolation Valve Function In Standby (1 Minute Per Valve)</td>
<td>Narrow Range Pressure Transducers, 1 psi Resolution Telemetry, No Special Support Equipment</td>
</tr>
<tr>
<td>Isolation Valve Function</td>
<td>In Standby Only, (30 Seconds Per Valve) After 24-Hour Leak Check Period</td>
<td>Narrow Range Pressure Transducers, 1 psi Resolution Telemetry, No Special Support Equipment</td>
</tr>
</tbody>
</table>
## UNCLASSIFIED

### REACTION CONTROL SYSTEM - ALTERNATIVE CHECKOUT OPTIONS

<table>
<thead>
<tr>
<th>TASK</th>
<th>STATUS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thruster Valve Function:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position Switch</td>
<td>Recommended for Development</td>
<td>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.</td>
</tr>
<tr>
<td>Current/Voltage Measurements</td>
<td>Rejected</td>
<td>Requires spacecraft electronics; information would not completely define movement of armature</td>
</tr>
<tr>
<td>Nozzle Flow Indicator</td>
<td>Rejected</td>
<td>Balloons or flags would create space debris; all nozzles must be observable.</td>
</tr>
<tr>
<td><strong>System Leakage:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helium Sniffer</td>
<td>Rejected</td>
<td>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.</td>
</tr>
<tr>
<td><strong>Heater Circuit Continuity:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermostat Coolant</td>
<td>Rejected</td>
<td>Built-in or remotely actuated liquid $N_2$ or Freon is complicated; use of orbiter shadow is effective for all thermal control systems.</td>
</tr>
</tbody>
</table>
### ATREX SOLID ROCKET MOTOR SYSTEM TEST SEQUENCE

<table>
<thead>
<tr>
<th>TASK</th>
<th>PERIOD</th>
<th>ELAPSED TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant Grain Temperature</td>
<td>Continual Sampling All Periods</td>
<td>One Minute Per Sample</td>
</tr>
<tr>
<td>Thrust Vector Control Actuator Function</td>
<td>Cold Period in Bay, Also in Standby</td>
<td>One Minute Per Actuator</td>
</tr>
<tr>
<td>Safe and Arm Switch Function</td>
<td>When Required for Ignition In Standby</td>
<td>30 Seconds</td>
</tr>
</tbody>
</table>
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
## STORMSAT INSTRUMENT SUBSYSTEM CHECKOUT CANDIDATE TESTS

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests</th>
<th>Test Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indications</td>
<td>In-Bay</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>Backup</td>
</tr>
<tr>
<td>ASSIR IR</td>
<td>Sensor Electronics Aliveness</td>
<td>Response to Injected Signal</td>
</tr>
<tr>
<td>Visible</td>
<td>Visible Sensor, Sensor Electronics Aliveness</td>
<td>Visible Light Range Target Stimulated Signal Recognition</td>
</tr>
<tr>
<td>Atmospheric Microwave Sounder</td>
<td>Sensor, Sensor Electronics, Gimbal, Scanning Stem Aliveness</td>
<td>Space to Earth Viewing Signal Difference</td>
</tr>
</tbody>
</table>

(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**

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests</th>
<th>Test Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In-Bay</td>
</tr>
<tr>
<td>VISSR IR(^{(1)})</td>
<td>Sensor Electronics Aliveness</td>
<td>Response to Injected Signal</td>
</tr>
<tr>
<td>Visible</td>
<td>Sensor and Sensor Electronics Aliveness</td>
<td>Visible Light Range Target Stimulated Signal Recognition</td>
</tr>
<tr>
<td>Environmental Monitoring Instruments(^{(2)})</td>
<td>Sensor Electronics Aliveness</td>
<td>Response to Injected Signal</td>
</tr>
</tbody>
</table>

(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

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests For:</th>
<th>Indications</th>
<th>Test Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Primary</td>
<td>Backup</td>
</tr>
<tr>
<td>Air Quality Instrument</td>
<td></td>
<td>Sensor, Sensor Electronics, Scanning Systems, and Optical Alignment; Focus (End-to-End)</td>
<td>Earth Radiance Stimulated Signal Coming Through</td>
</tr>
<tr>
<td>Hydrology Instrument</td>
<td></td>
<td>Array, Radar Electronics, and Array Pointing System</td>
<td>Earth Reflected Signals Coming Through</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests</th>
<th>Measurements (1)</th>
<th>Payload and Test Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For:</td>
<td>Primary</td>
<td>Backup</td>
</tr>
<tr>
<td>MSS</td>
<td>Aliveness of Sensor Channels, Bands 1-4 and Multiplexer</td>
<td>Response to Built-In Calibration Light</td>
<td>Response to Redundant Built-In Calibration Light</td>
</tr>
<tr>
<td>MSS</td>
<td>Aliveness of Band 5 (Uncooled)</td>
<td>Electronic Signal Injection(2)</td>
<td>Detector Noise Measurement(3)</td>
</tr>
<tr>
<td>MSS(4)</td>
<td>Aliveness of Band 5 and Cooldown(5)</td>
<td>Not Applicable(6) (Backup Test Only)</td>
<td>Detector Signal</td>
</tr>
<tr>
<td>MSS(4)</td>
<td>Aliveness of Bands 1-6</td>
<td>Quick-Look Images(7)</td>
<td>Analog (Video) Signals</td>
</tr>
<tr>
<td>MSS(4)</td>
<td>Sun Calibration (Bands 1-4 Only)</td>
<td>Response to Sun and to Built-In Calibration Light</td>
<td>Repeat Test on Another Orbit</td>
</tr>
</tbody>
</table>

---

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.

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129
## On-Orbit Checkout of Instruments - Landsat D Thematic Mapper

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>Measurements (1)</th>
<th>Payload and Test Location</th>
<th>Test Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For:</td>
<td>Primary</td>
<td>Backup</td>
</tr>
<tr>
<td>Thematic Mapper</td>
<td>Aliveness of Sensor Channels, Bands 1-4</td>
<td>Response to Calibration Light</td>
<td>Response to Redundant Calibration Light</td>
</tr>
<tr>
<td>Thematic Mapper</td>
<td>Aliveness of Bands 5 and 6 (Uncooled)</td>
<td>Electronic Signal Injection(2)</td>
<td>Detector Noise Measurement(3)</td>
</tr>
<tr>
<td>Thematic Mapper(4)</td>
<td>Aliveness of Bands 5 and 6 and Cooldown(5)</td>
<td>Not Applicable(6) (Backup Test Only)</td>
<td>Detector Signal Full Cooldown Temperature</td>
</tr>
<tr>
<td>Thematic Mapper(4)</td>
<td>Aliveness of Bands 1-4</td>
<td>Quick-Look Images</td>
<td>Analog (Video) Signals</td>
</tr>
<tr>
<td>Thematic Mapper(5)</td>
<td>Sun Calibration</td>
<td>Response to Sun and to Built-In Calibration Light</td>
<td>Repeat Test on Another Orbit</td>
</tr>
</tbody>
</table>

(1) For Primary and Backup: Attached To Shuttle and Standoff are not applicable for primary measurements. Test Priority is assigned based on criticality.

**Notes:**
- (2) Electronic Signal Injection
- (3) Detector Noise Measurement
- (4) Additional details for Thematic Mapper
- (5) Cooldown
- (6) Not Applicable: Backup Test Only
### ATREX INSTRUMENT SUBSYSTEM CANDIDATE TESTS - 1

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests</th>
<th>Payload &amp; Test Location</th>
<th>Test Priority</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All-Sky Monitor</strong></td>
<td>For</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsystem Element: Sensors, electronics, data-handling system (aliveness)</td>
<td>Primary Response to celestial X-ray sources and detector &quot;internal&quot; background</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Same as above</td>
<td>Back-up Response to celestial X-ray sources</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Subsystem Element: Sensors, electronics, data-handling system aliveness, background rejection system function</td>
<td>Response to detector &quot;internal&quot; background, Detector counting rates, anti-coincidence rates</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td><strong>Large Area Proportion-Al Counter Array</strong></td>
<td>Sensor, electronics, data-handling system aliveness,</td>
<td>Response to detector's internal calibration sources</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>For</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsystem Element: Sensor, electronics, data-handling system aliveness,</td>
<td>Response to strong celestial X-ray source</td>
<td>X</td>
<td>2</td>
</tr>
</tbody>
</table>

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# ATREX INSTRUMENT SUBSYSTEM CANDIDATE TESTS - II

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>On-Orbit Tests</th>
<th>Measurements</th>
<th>Payload &amp; Test Location</th>
<th>Test Priority</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrometer-Vectrometer Array</td>
<td>For</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor, electronics, data-handling system aliveness, spectrometer detector performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vectrometer detector individual response to diffuse celestial gamma-ray background, spectrometer detector summed response to same.</td>
<td>Currents, voltages, command status.</td>
<td>X</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sensor, electronics, data-handling system aliveness, Spectrometer detector performance, Calibration system, Detector aliveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrometer spectrum from internal calibration sources, Individual module spectra.</td>
<td>Currents, voltages, command status.</td>
<td>X</td>
<td>1</td>
<td>≤30</td>
<td></td>
</tr>
<tr>
<td>Vectrometer detector individual response to diffuse celestial gamma-ray background.</td>
<td>Currents, voltages, command status.</td>
<td>X</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Subsystem Element</th>
<th>Measurements</th>
<th>Payload &amp; Test Location</th>
<th>Test Priority</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On-Orbit Tests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>For</td>
<td>Primary</td>
<td>Back-up</td>
<td>In Bay</td>
</tr>
<tr>
<td>Multiple Slot Camera</td>
<td>Sensor, electronics, data-handling system aliveness, position sensing.</td>
<td>Detector response to internal calibration source</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Detector position sensing ability.</td>
<td>Response to electronic position sensing calibration</td>
<td>X</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sensor, electronics, data-handling system aliveness.</td>
<td>Detector response to internal calibration source</td>
<td>X</td>
<td>2</td>
</tr>
</tbody>
</table>
SATELLITE REQUIREMENTS IMPOSED BY ON-ORBIT CHECKOUT - 1

- 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)

(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